UNITED STATES PATENT AND TRADEMARK OFFICE

_____

BEFORE THE PATENT TRIAL AND APPEAL BOARD

_____

AT&T SERVICES INC., T-MOBILE USA, INC., CELLCO PARTNERSHIP D/B/A VERIZON WIRELESS, ERICSSON INC., AND NOKIA OF AMERICA CORPORATION,

Petitioners

v.

ASUS TECHNOLOGY LICENSING INC. AND CELERITY IP, LLC.

Patent Owner.

Case IPR2024-01121

DECLARATION OF DR. ALEX HAIMOVICH, PH.D.

IN SUPPORT OF PETITION FOR INTER PARTES REVIEW OF

U.S. PATENT NO. 10,148,402

Petitioners' Exhibit 1003, p. 2
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table of Contents

I. Background and Qualifications.....1

II. Assignment and Materials 5

III. Standards Applied 6

IV. Technological Background.....9

A. The LTE standard.....9

B. OFDM, Control Signaling, and Reference Signals.....10

C. MIMO.....12

D. Introduction of Aperiodic CSI-RS Transmission at 3GPP 19

E. 5G Development and Beamforming Contributions 23

F. Introduction of Varying CSI-RS Length at 3GPP 24

V. The ’402 Patent 31

A. Listing of the Challenged Claims and Claim Language 38

VI. Patentability Analysis.....40

A. Level of Ordinary Skill in the Art.....40

Petitioners' Exhibit 1003, p. 3
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

B. Claim Construction 41

VII. Descriptions of the Prior Art References 41

A. International Application Number PCT/US2016/033019 (WIPO Publication Number 2017/142573A1) to Sungho Moon, et al. ("Moon") 41

B. R1-1609515 Titled "On network beam switching and refinement (BM P-2)," 3GPP TSG RAN WG1 #86bis, Intel ("R1-1609515") 46

VIII. Claims 1–4 and 12–15 are Unpatentable 51

A. Ground #1: Claims 1–4 and 12–15 are Anticipated Under 35 U.S.C. § 102(a) by Moon 51

1. Claim 1 51

2. Claim 2 70

3. Claim 3 71

4. Claim 4 74

5. Claim 12 74

Petitioners' Exhibit 1003, p. 4
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6. Claim 13 76

7. Claim 14 76

8. Claim 15 76

B. Ground #2: Claims 1–4 and 12–15 are Obvious Under 35 U.S.C. § 103(a) by Moon 77

1. A POSITA Would Have Modified Moon 77

2. Independent Claims 80

3. Dependent Claims 81

C. Ground #3: Claims 3 and 14 are Obvious Under 35 U.S.C. § 103(a) by Moon over R1-1609515 81

1. A POSITA Would Have Combined Moon with R1-1609515 82

2. Moon modified by R1-1609515 Renders Claims 3 and 14 Obvious 89

IX. Conclusion 91

Petitioners' Exhibit 1003, p. 5
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

I, Dr. Alexander Haimovich, do hereby declare and state as follows:

I. Background and Qualifications

1. I received my Ph.D. degree from the University of Pennsylvania in 1989 in Systems Engineering. Prior to that, I graduated from Drexel University with a Master's degree in Electrical Engineering in 1983, and I obtained a B.Sc. degree in Electrical Engineering from the Israel Institute of Technology in 1977. From 1983 until 1987, I worked as an engineer for the American Electronics Laboratories (AEL), a company in Lansdale, Pennsylvania that produced electronic warfare equipment for the Department of Defense. From 1987 until 1989, I taught communication courses at the New Jersey Institute of Technology (NJIT). Upon receiving the Ph.D. degree, I rejoined AEL for a short period, followed by joining a company that consulted for the U.S. Navy. In 1992, I came to NJIT as an associate professor.

2. At NJIT, over the years, I have taught practically all undergraduate and graduate communication courses offered by the Electrical and Computer Engineering Department (10 different courses from undergraduate to PhD level). I also initiated several new courses in communications/signal processing/radar in general, and in wireless communications, in particular. In the mid-1990's I designed and introduced a new graduate course in wireless communications ("Introduction to

Petitioners' Exhibit 1003, p. 6
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Wireless and Personal Communications Systems"), and later I created a new undergraduate course in wireless communications ("Wireless Communications Systems"). These courses are the key wireless courses being taught at NJIT. From time to time, I have also initiated and taught special topic courses on advanced topics in wireless communications.

3. I have developed an extensive research program, with several graduate students engaged in wireless research at any given time. I have supervised more than 20 PhD dissertations and numerous Masters theses. I currently supervise the work of several PhD students. My work has been disseminated extensively in over 230 publications, and I have been invited to present my research nationally and internationally.

4. From 2003-2005, I served as Director of the New Jersey Center for Wireless Telecommunication (NJCWT). The mission of the NJCWT was to function as a consortium of the four main research universities in the State of New Jersey, namely, NJIT, Princeton University, Rutgers University, and Stevens Institute of Technology, to interact and perform technology transfer with industry in the state. Separate from NJCWT, my research work has been extensively funded by federal agencies, such as the National Science Foundation, U.S. Air Force, U.S. Navy, U.S. Army, as well as by grants and contracts from industrial sponsors.

Petitioners' Exhibit 1003, p. 7
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5. I taught short courses on Orthogonal Frequency Division Multiplexing ("OFDM") and Multiple-Input Multiple-Output ("MIMO") wireless technologies in Europe. The courses were attended by participants from European wireless companies. I have developed an online course on OFDM that has been offered for a time through Institute of Electrical and Electronics Engineers (IEEE). IEEE is a non-profit organization, and it is the world's leading professional association for the advancement of Electrical Engineering Technology.

6. I have served in numerous professional leadership positions including chairing sessions at conferences. From 1997-2007, I was an associate editor of a top journal in communications ("IEEE Communications Letters").

7. I am a Fellow of the IEEE and hold the Ying Wu endowed Chair position at the New Jersey Institute of Technology.

8. Since 2013, I have served as the Director of the Center for Wireless Information Processing at NJIT. The Center supports research in the fields of wireless communications and signal processing.

9. Additional details about my employment history, fields of expertise, awards, publications, and other activities are further included in my curriculum vitae, Ex-1004.

Petitioners' Exhibit 1003, p. 8
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10. The ’402 Patent relates to wireless communication systems such as LTE and 5G, and particularly to the transmission of downlink control information involved in beamforming. As a result of my education, academic experience, and industrial experience, I am familiar with the technology related to the ’402 Patent and with the state of that technology at the time the ’402 Patent was filed. I recognize the technology of the ’402 Patent as being well within the sphere of my experience and expertise, and I understand the technology described in the ’402 Patent fully. Based on my education and experience, I believe I am qualified to submit expert analyses in this proceeding and specifically to submit this declaration.

11. I am being compensated for services provided in this matter at my customary rate, plus travel expenses. My compensation is not conditioned on the conclusions I reach as a result of my analysis or on the outcome of this matter. Similarly, my compensation is not dependent upon and in no way affects the substance of my statements in this declaration.

12. I have no financial interest in Petitioners AT&T Services Inc., T-Mobile USA, Inc., Cellco Partnership d/b/a Verizon Wireless, Ericsson Inc., and Nokia of America Corporation (collectively, “Petitioners”) or any of their subsidiaries. I also do not have any financial interest in Patent Owner ASUS Technology Licensing Inc. nor Patent Owner Celerity IP, LLC. I do not have any

Petitioners' Exhibit 1003, p. 9
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

financial interest in the ’402 Patent and have not had any contact with any of the named inventors of the ’402 Patent (Ko-Chiang Lin and Richard Lee-Chee Kuo).

II. Assignment and Materials

13. I submit this declaration in support of Petitioner’s petition for *inter partes* review of U.S. Patent No. 10,148,402 (“the ’402 Patent”).

14. I am not an employee of Petitioners or any affiliates or subsidiaries thereof.

15. I am being compensated at my usual consulting rate of $650 per hour for my time spent working on issues in this matter. My compensation does not depend upon the outcome of this matter or the opinions I express.

16. I have been asked to provide certain opinions relating to the patentability of the ’402 Patent. Specifically, I have been asked to provide my opinion regarding (i) the level of ordinary skill in the art to which the ’402 Patent pertains; and (ii) whether claims 1-4 and 12-15 would have been anticipated or rendered obvious over certain prior art references.

17. In forming my opinions I have reviewed the ’402 Patent, its prosecution history, and all applications to which it claims priority.

18. I have also reviewed International Application Number PCT/US2016/033019 (WIPO Publication Number 2016/142573A1) to Sungho

Petitioners' Exhibit 1003, p. 10
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Moon, Bishwarup Mondal, Yushu Zhang, and Jong-Kae Fwu ("Moon") and TDoc R1-1609515 ("R1-1609515").

19. I also reviewed sections and releases of the 4G LTE and 5G Standards as cited herein, all cited contributions to the 4G LTE and 5G standard-setting meetings, and "4G, LTE-Advanced Pro and the Road to 5G" by Erik Dahlman, Stefan Parkvall, and Johan Skold.

20. I also reviewed any document cited herein.

III. Standards Applied

21. I understand that a claim in an issued patent is unpatentable as anticipated if the recited invention is described in a single prior-art reference that discloses each limitation, either expressly or inherently.

22. I further understand that a claim in an issued patent is unpatentable as obvious if the differences between the claimed subject matter and the prior art are such that the subject matter as a whole would have been obvious to a person having ordinary skill in the relevant art at the time the alleged invention was made.

23. I further understand that the following factors are to be evaluated to determine whether the claimed subject matter is obvious: (1) the scope and content of the prior art; (2) the difference or differences, if any, between each claim of the

Petitioners' Exhibit 1003, p. 11
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

patent and the prior art; and (3) the level of ordinary skill in the art at the time the time the alleged invention was made.

24. Unlike anticipation, obviousness does not require that every element of the claim be in a single prior art reference. Instead, I understand that obviousness may be shown by considering more than one item of prior art and by considering the knowledge of a person having ordinary skill in the art, so long as there is motivation or sufficient reasoning to combine these references and knowledge.

25. I understand that this motivation may be based on various rationales, including, but not limited to:

a. Combining prior art elements according to known methods to yield predictable results;

b. Simple substitution of one known element for another to obtain predictable results;

c. Use of known techniques to improve similar devices (methods, or products) in the same way;

d. Applying a known technique to a known device (method, or product) ready for improvement to yield predictable results

e. "Obvious to try" – choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success;

Petitioners' Exhibit 1003, p. 12
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

f. Known work in one field of endeavor may prompt variations of it for use in either the same field or a different one based on design incentives or other market forces if the variations are predictable to one of ordinary skill in the art; and

g. Some teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill to modify the prior art reference or to combine prior art reference teachings to arrive at the claimed invention.

26. I have been informed and I understand that the following so-called objective indicia of non-obviousness, also known as "secondary considerations," are to be considered when assessing obviousness: (1) commercial success; (2) long-felt but unresolved need; (3) copying of the invention by others in the field; (4) initial expressions of disbelief by experts in the field; (5) failure of others to solve the problem that the inventor solved; (6) unexpected results; and (7) industry praise. I also understand that evidence of objective indicia of non-obviousness must be commensurate in scope with and have a nexus to the claimed subject matter.

27. I understand that when considering obviousness, one must not refer to teachings in the specification of the patent itself. One can, however, refer to portions of the specification admitted to be prior art.

Petitioners' Exhibit 1003, p. 13
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

IV. Technological Background

28. A person of ordinary skill in the art in the pre-January 2017 timeframe would have been familiar with the background information I describe below.

A. The LTE standard

29. The ’402 Patent relates to wireless communication networks, in particular Long-Term Evolution (LTE) standardized by the “3rd Generation Partnership Project” (3GPP). The first release of the LTE standard is known as release 8. Each release introduces new features. For example, as discussed in more detail below, release 8 included beamforming via transmission modes 4 and 7. That release was frozen in December 2008. *See* Appendix 1 at 7 (https://www.3gpp.org/ftp/Information/WORK_PLAN/Description_Releases/(Rel-08_description_20140924)). Then, release 9 introduced transmission mode 8 non-codebook-based precoding supporting up to two layers, which means supporting forming two simultaneous beams. That release was frozen in March 2010. *See* https://www.3gpp.org/specifications-technologies/releases/release-9. The latest version of the LTE standard frozen before the ’402 Patent’s priority date was release 13. Release 13 was frozen in March 2016. *See* https://www.3gpp.org/specifications-technologies/releases/release-13. Release 13

Petitioners' Exhibit 1003, p. 14
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

introduced CSI class B reporting, for which, CSI reference signals are beamformed, and the reporting is per-beam.

B. OFDM, Control Signaling, and Reference Signals

30. The reference signals that are the topic of the challenged claims (claims 1-4 and 12-15 of the '402 Patent) are transmitted in the downlink — the direction of transmission from a base station to a mobile terminal. In LTE, a mobile terminal is referred to as user equipment (UE). The LTE downlink transmission scheme is based on Orthogonal Frequency-Division Multiplexing (OFDM).

31. In LTE, an OFDM symbol comprises a large number of modulation symbols (e.g., BPSK, QPSK, M-QAM) transmitted in parallel on tightly packed subcarriers. Each modulation symbol modulates a subcarrier over the time interval of the OFDM symbol. OFDM is implemented using IFFT/FFT processing. In LTE, the IFFT/FFT size is 2048. The time duration of an OFDM symbol T_{OFDM} comprises the IFFT/FFT integration time T_u and the cyclic prefix time T_{cp}. A cyclic prefix is a selected last part of the OFDM symbol that is copied and inserted at the beginning of the symbol. As known in the art, the cyclic prefix enables OFDM to handle time dispersion in the channel.

32. LTE transmissions are organized into radio frames of 10 ms. Each frame consists of ten 1 ms subframes. For normal cyclic prefix, one subframe

Petitioners' Exhibit 1003, p. 15
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

contains 14 OFDM symbols, split into two slots. Downlink subcarriers are grouped into resource blocks, where each resource block consists of 12 consecutive subcarriers in the frequency domain and, for normal cyclic prefix, 7 OFDM symbols in the time domain (see figure). One OFDM subcarrier by one OFDM symbol interval on the time-frequency grid is referred to as a resource element.

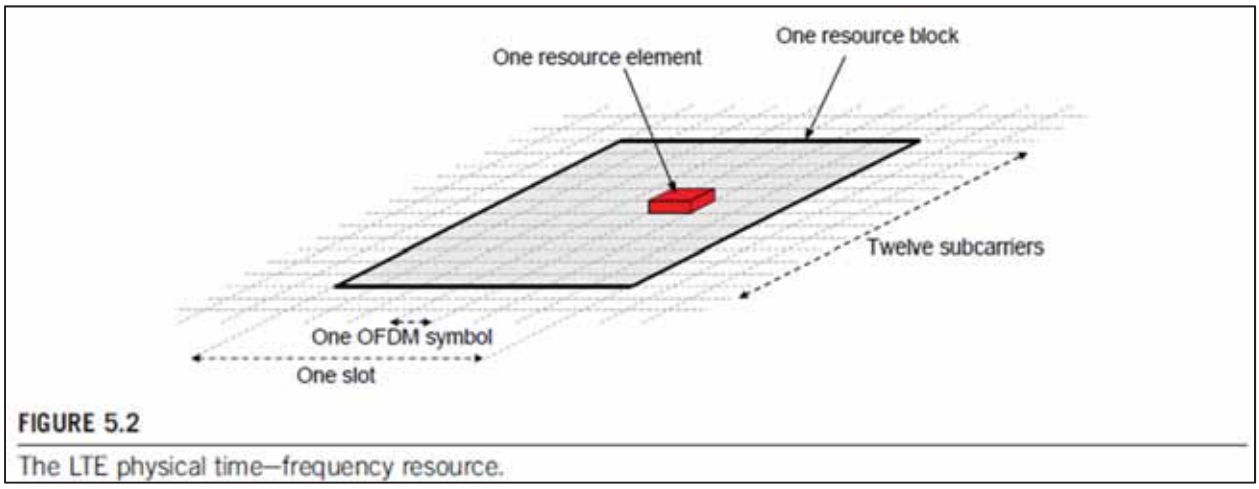


FIGURE 5.2

The LTE physical time–frequency resource.

Ex-1008 (Dahlman 2016) at 78.

33. The first few OFDM symbols in the subframe typically carry *control signaling* that enables the UE to decode the downlink data transmission. The control signaling for a single UE is organized in a channel referred to as the Physical Downlink Control Channel (PDCCH).

34. In addition to control signaling and data, a subframe also contains reference symbols. Reference symbols are modulation symbols known to both the base station and the UE. A UE may use reference symbols transmitted by the base

Petitioners' Exhibit 1003, p. 16
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

station to estimate channel state information (CSI) in the downlink. CSI is used by the UE for processing the received signals. CSI is also fed back to the base station for setting parameters for subsequent downlink transmissions. CSI is further discussed below. An illustration of control symbols and reference symbols alongside data symbols is shown in the figure below.

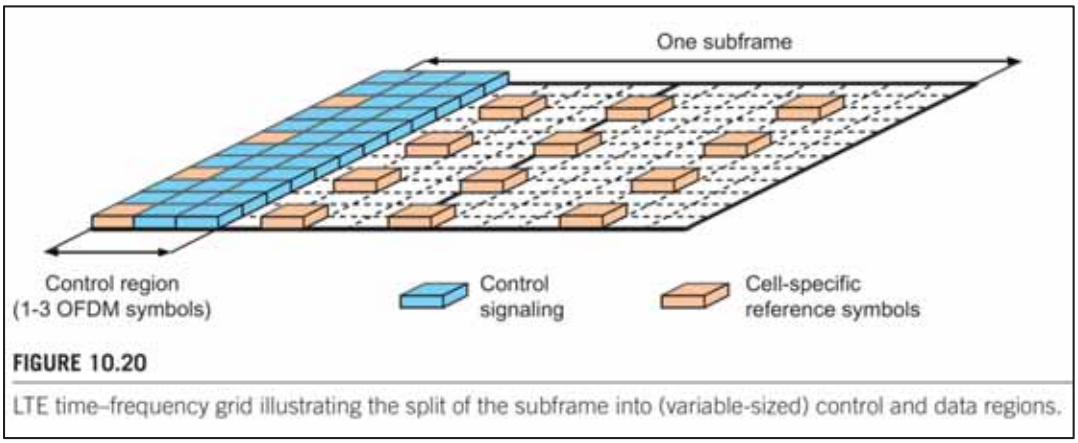


FIGURE 10.20

LTE time–frequency grid illustrating the split of the subframe into (variable-sized) control and data regions.

Ex-1008 (Dahlman 2016) at 131, Figure 6.20.

C. MIMO

35. The use of multiple antennas at both the transmitter and the receiver is referred to as MIMO (Multiple-Input Multiple-Output). There are different types of multi-antenna techniques including beamforming. An illustration of a 2×2 MIMO configuration is shown in the figure.

Petitioners' Exhibit 1003, p. 17
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

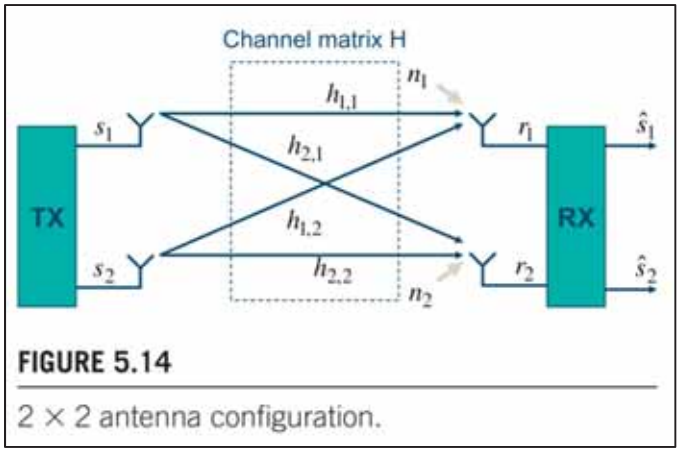


FIGURE 5.14

2 × 2 antenna configuration.

Appendix 2, Dahlman et al., 4G LTE/LTE-Advanced for Mobile Broadband, 2011 at 73, Figure 5.14.

36. A 2×2 MIMO configuration may support two separate data streams (depending on the values of the channel coefficients (h_{11}, h_{12}, h_{21}, h_{22})). A channel that supports two data streams is said to support *two layers*.

37. MIMO is typically implemented with antenna arrays. A typical antenna array may have antenna elements laid out in two dimensions. The figure below shows typical layouts of antenna array panels for 8, 12, and 16 antenna ports.

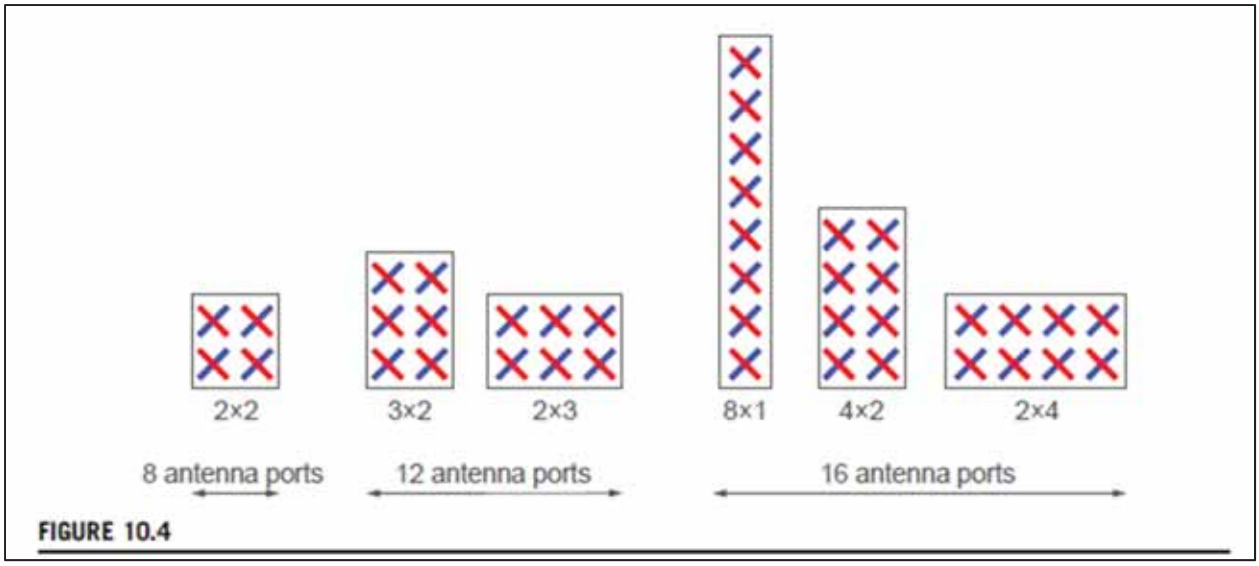


FIGURE 10.4

Ex-1008 (Dahlman 2016) at 281, Figure 10.4.

38. Beamforming at the transmitter is a single layer form of MIMO with multiple antennas at the transmitter. To form a beam, all antenna elements transmit the same symbol, but the carrier phase is controlled separately at each element. By adjusting the phase at each antenna element it is possible to make all signals add constructively, thus to create beams, in different directions. A beam may be steered in different directions by applying different phase shifts. An exemplary one-dimensional array is shown in the figure below.

Petitioners' Exhibit 1003, p. 19
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

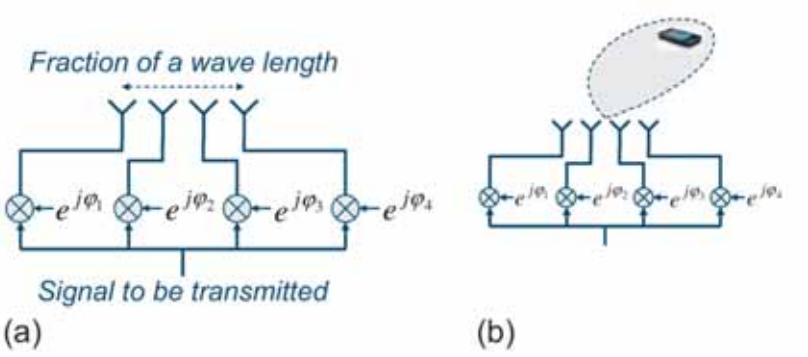
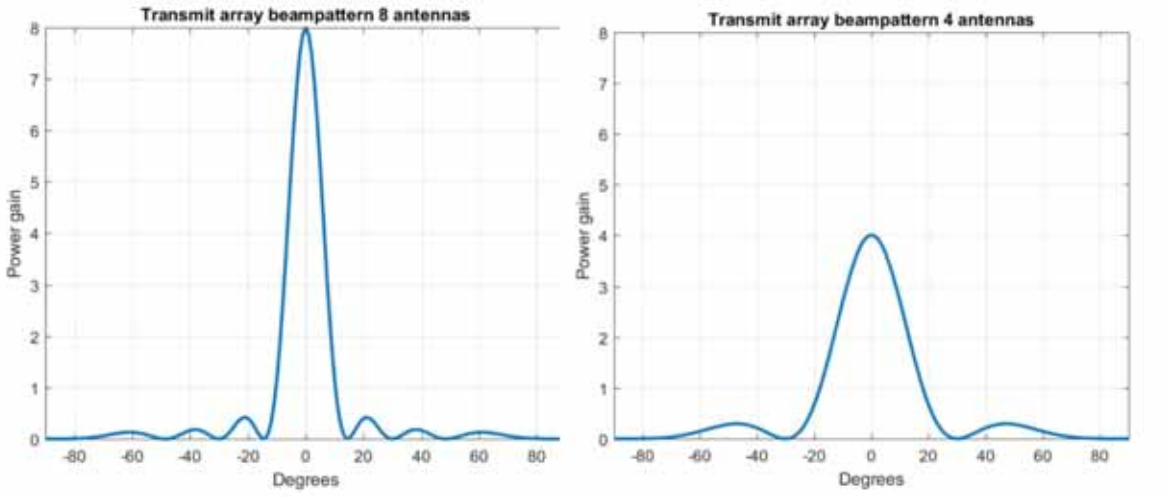


FIGURE 5.11

Classical beam-forming with high mutual antennas correlation: (a) antenna configuration; (b) beam-structure.

Appendix 2 (Dahlman 2011) at 69, Figure 5.11.

39. Increasing the number of antenna elements decreases the beamwidth and increases the antenna gain in the direction of the beam. In the examples shown in the side-by-side figures, beampatterns obtained using Matlab are shown for an 8-element array (left) and a 4-element array (right), respectively.



Petitioners' Exhibit 1003, p. 20
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

40. Scheduling refers to the allocation of radio resources available to the system to make their utilization as efficient as possible. Wireless communications is subject to significant variations in channel conditions, which greatly affect the quality of communications. For this reason, scheduling is channel-dependent. The set of channel parameters that capture the current channel conditions is referred to as *channel state information* (CSI). Downlink transmissions are scheduled based on the CSI available at the base station. In LTE, the CSI is estimated at a UE based on reference signals. Reference signals are known to the UE, and thus can be used to estimate the CSI. *CSI reports* are uplink transmissions sent from the UE to the base station that provide the base station with information on current channel conditions. The UE is able to calculate CSI by comparing the signal that it actually receives to the signal that it expected to receive base on the known reference signal.

41. When there are multiple transmit-antenna elements, each antenna may transmit a different reference signal. When the channels from multiple transmit antennas to the UE are similar, the same reference signal may be transmitted by all the antennas. In the latter case, the UE estimates the combined effect of channels from multiple antennas. Since the CSI may relate to the combined effect of multiple transmissions, LTE uses the concept of an *antenna port*. An antenna port is a logical construction associated with the transmission of a reference signal. Thus, an antenna

Petitioners' Exhibit 1003, p. 21
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

port may be formed by multiple physical antennas, but it corresponds to a single reference signal.

42. Using this antenna port concept, Release 10 of LTE introduced an enhanced reference-signal structure referred to as *channel state information reference signals* (*CSI-RS*). In release 10, CSI-RS provide support for transmissions of up to eight layers. That means that CSI-RS are transmitted over up to 8 antenna ports. In release 10 through release 13, a CSI-RS resource consists of two time-consecutive reference symbols per resource-block pair, as illustrated in the figure below. Two CSI-RS resources utilizing the same CSI-RS symbols may be separated by applying two orthogonal cover codes (OCC-2).

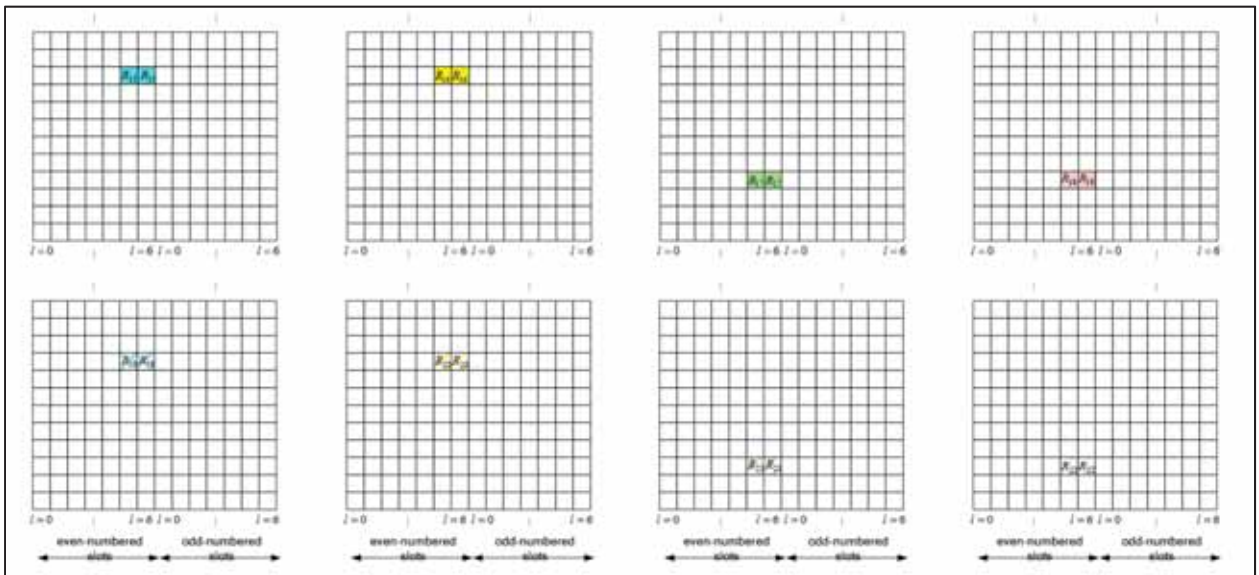


Figure 6.10.5.2-1: Mapping of CSI reference signals (CSI configuration 0, normal cyclic prefix).

Appendix 3, 3GPP TS 36.211 v10.7.0 Release 10, at 89, Figure 6.10.5.2-1.

43. LTE Release 13 introduced CSI reporting Class B to support beamforming using CSI-RS. In the example below, a 4×8 array panel transmits 4 CSI-RS resources. Each CSI-RS resources consists of two resource elements spanning two OFDM symbols. The CSI-RS are multiplexed both in the frequency and time domains. Each CSI-RS resource is transmitted over a different antenna port, and it corresponds to a different beam. The UE measures each of the CSI-RS resources and reports back CSI.

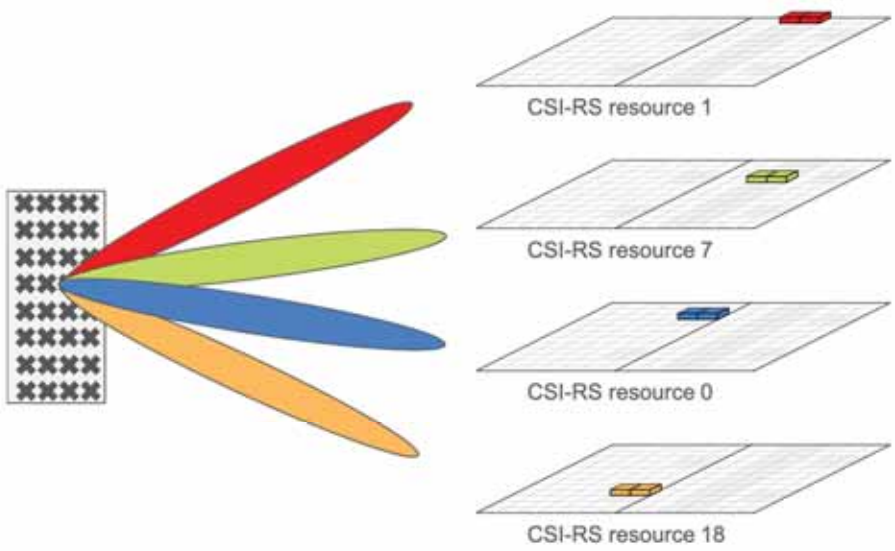


FIGURE 10.5
Example of CSI-RS resources for beam measurements.

Ex-1008 (Dahlman 2016) at 282.

Petitioners' Exhibit 1003, p. 23
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

D. Introduction of Aperiodic CSI-RS Transmission at 3GPP

44. The interface between a base station and a UE entails the exchange of data and signaling messages. The transfer of data and signaling uses hardware and software protocols. The protocols are grouped into layers, each of which handles one aspect of transmission and reception process. The collection of layers is referred to as a protocol stack, with the upper layers handling system level tasks, and lower-level layers handling the physical transmission and reception of signals. The protocol stack has two planes. The user plane handles data, while the control plane handles signaling messages. Focusing on the control plane, the higher layer of the protocol stack is the radio resource control (RRC) protocol. At the bottom of control plane protocol stack the Downlink Control Information (DCI) is carried over the Physical Downlink Control Channel (PDCCH).

45. In LTE, RRC is used to configure periodic CSI-RS reports. The periodicity of the CSI-RS transmissions and of the associated reports is 5-80 ms. *See* Ex-1008 at 112. "In the time domain, CSI-RS can be configured for transmission with different periodicity, ranging from a period of 5ms (twice every frame) to 80 ms (every eighth frame)." Ex-1008 at 112. Setting up periodic reports is efficient from the point of view of minimizing signaling, since one signaling message results in many reports. But periodic reporting does not react as quickly to dynamic channel

Petitioners' Exhibit 1003, p. 24
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

conditions, for example the rapid decrease in gain of a narrow beam associated with a moving terminal at high frequencies. As discussed below, Moon, and others proposed dynamic triggering of CSI-RS using DCI messages transmitted over PDCCH. Dynamic triggering results in aperiodic CSI reports at a time associated with the time of triggering.

46. 3GPP participants began discussing the need for aperiodic or dynamic CSI-RS transmission during the development of LTE release 14 in early 2016. As noted in R1-162686 (Ex-1013), from the 3GPP TSG RAN WG1 #84bis meeting in Busan, Korea in April 2016, "semi-static and periodic CSI-RS resource allocation" causes an "increase in overhead," which becomes problematic when UE-specific beamformed CSI-RS are used for a sufficiently large number of UEs. "To circumvent this drawback, CSI-RS resource allocation can be performed dynamically. That is, CSI-RS is transmitted by the eNB and measured by the UE only when needed, i.e., aperiodically." Ex-1013 (R1-162686) at 1.

47. By the end of the 3GPP TSG RAN WG1 Meeting #85 in Nanjing, China, from May 23, 2016 through May 27, 2016, the participants had agreed on "aperiodic CSI-RS transmission instance is indicated by UL-related DCI transmitted on a control channel with a CSI request field." Ex-1012 (R1-166056 - Final Report of 3GPP TSG RAN WG1 #85 v1.0.0 (Nanjing, China 23rd – 27th May 2016)) at 49.

Petitioners' Exhibit 1003, p. 25
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

In other words, by the end of May 2016, 3GPP participants agreed that the presence/absence of aperiodic CSI-RS is signaled by the UL grant transmitted on a control channel (such as the PDCCH), with a request for the UE to provide CSI feedback. 3GPP participants devoted an entire section of the RAN WG1 #85 meeting to "Beamformed CSI-RS," focused on developing "[m]ore efficient resource utilization for UE-specific BF CSI-RS, including aperiodic CSI-RS." Ex-1014 at 48 (Section 6.2.3.1.2). As part of that development, at the RAN WG1 #85 meeting, 3GPP participants submitted numerous T-Docs discussing the use of aperiodic CSI-RS in LTE release 14, includin:

- R1-164523, Beamformed CSI-RS enhancements including aperiodic CSI-RS, by LG Electronics
- R1-164773, On aperiodic CSI-RS design, by Samsung
- R1-164845, PDSCH rate matching enhancement for aperiodic NZP and ZP CSI-RS, by Huawei and HiSilicon
- R1-165406, Dynamic CSI-RS Design and Overhead Reduction, by Ericsson
- R1-164217, On aperiodic CSI-RS transmission, by CATT
- R1-165200, Aperiodic CSI-RS with Semi-static Resource Reservation, by NTT Docomo

Petitioners' Exhibit 1003, p. 26
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

See Ex-1014 at 48–49. POSITAs in the field of the '402 Patent would have been aware of these submissions by the time of the '402 Patent's priority date in January 2017.

48. 3GPP participants continued to expand on that topic at the remaining RAN WG1 meetings in 2016. Before and during the 3GPP TSG RAN WG1 Meeting #86 in Goteborg, Sweden, from August 22 through August 26, 2016, 3GPP participants submitted numerous T-Docs discussing the use of "aperiodic" or "dynamic" CSI-RS:

- R1-166442 – "Support for aperiodic CSI-RS," submitted by CATT
- R1-166728 – "Additional details on aperiodic CSI-RS," submitted by Samsung
- R1-167653 – "On Rate-matching of A-CSI-RS," submitted by Interdigital
- R1-168046 – "WF on Aperiodic CSI-RS for Rel.14," submitted by Samsung, Nokia, Alcatel-Lucent Shanghai Bell, KT Corporation, Ericsson, LG Electronics, Interdigital, Qualcomm, AT&T, CHTTL, Xinwei, Straightpath, and ITL.
- R1-166340 – "Aperiodic CSI-RS and Overhead Reduction," submitted by Nokia, Alcatel-Lucent, and Shanghai Bell

Petitioners' Exhibit 1003, p. 27
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- R1-167138 – "Rate matching enhancements for aperiodic CSI-RS in different transmission mode," submitted by Huawei and HiSilicon
- R1-167347 – "Discussion on Aperiodic CSI-RS," submitted by NTT Docomo
- R1-167637 – "UE specific Beamforming with Aperiodic CSI-RS Transmission," submitted by Ericsson
- R1-167651 – "Remaining Issues on A-CSI-RS," by InterDigital

Appendix 4 (R1-1608562 – Final Report of 3GPP TSG RAN WG1 #86), at 43-45.

E. 5G Development and Beamforming Contributions

49. 3GPP began the process of developing 5G in 2015. *See* https://www.ericsson.com/en/blog/2015/9/5g-now-started-in-3gpp. The earliest version of the 5G standard, release 15, was frozen in June 2018. *See* https://www.3gpp.org/technologies/5g-system-overview.

50. This development process took place alongside the development for release 14 for LTE. For instance, at the same 3GPP RAN WG1 meeting #85 discussed above, participants worked toward incorporating aperiodic CSI-RS into NR release 15.

51. It was understood at the time of NR's (New Radio) development that higher frequency bands, e.g., mm wave, should be used by NR. Beamforming was identified as a way to compensate the increased path loss of higher frequency bands.

Petitioners' Exhibit 1003, p. 28
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The figure below illustrates the lower gain of sector beam coverage at high frequency and the narrow beamwidth of high gain beams at high frequency. Narrow beams entail quicker drops in beam gains, and thus require rapid ability to change beams. That affects the reporting of reference signals, as discussed below.

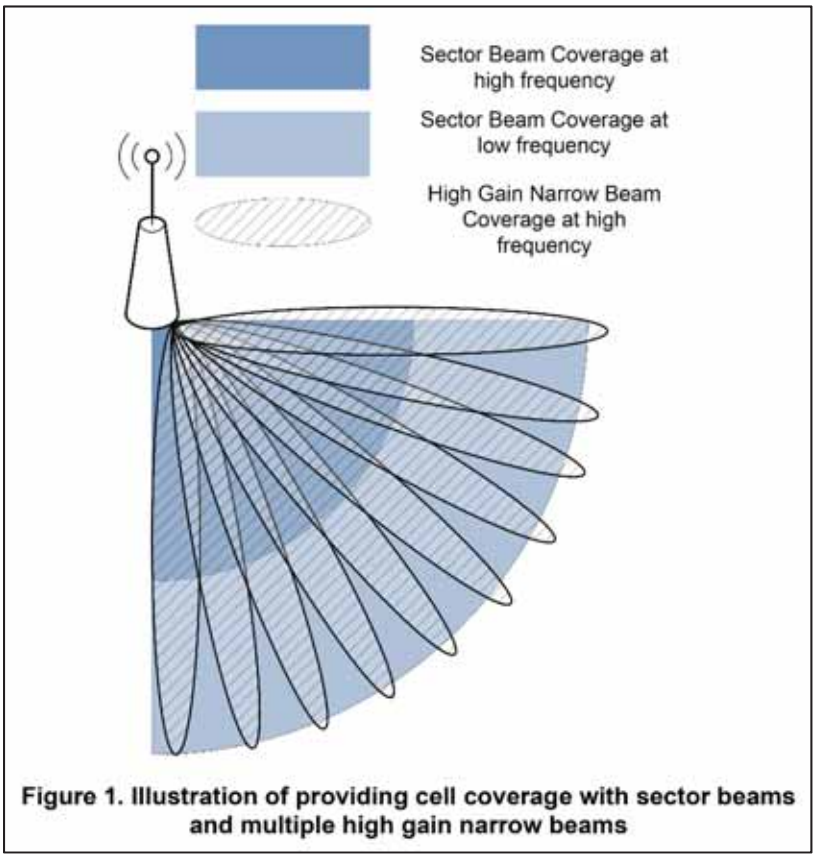


Figure 1. Illustration of providing cell coverage with sector beams and multiple high gain narrow beams

Appendix 5 (R2-162366).

F. Introduction of Varying CSI-RS Length at 3GPP

52. In light of the additional antenna ports available on release-14-compliant devices, 3GPP members agreed that CSI-RS would no longer be limited to spanning two consecutive resource elements on two OFDM symbols. Ex-1012 at

Petitioners' Exhibit 1003, p. 29
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

2 (“Agreements at RAND1#86bis . . . At least for 32-port CSI-RS, at least one CDM-8 pattern exists which uses REs from more than 2 OFDM symbols.”). As such, control signaling would need to indicate to the UE the length of the CSI-RS for any specific measurement occasion.

53. As initial point, a POSITA understands that in order to receive and process reference signals for beam measurement, such as CSI-RS, the control signal associated with the reference signal has to include information on the mapping of the reference signal to resource elements. Since reference signals resource elements are included alongside resource elements that carry data or control signals, the signal mapping provides the UE with information on which resource elements carry reference signals. In some cases, how many symbols are used to carry the reference signal is explicitly included in the control signal, in other cases, the number of symbols is implicit in the signal mapping.

54. For example, Moon teaches the number of reference symbols explicitly. “For dynamic triggering of xCSI-RS, the DCI (downlink control information) for the triggering can include any of a variety of xCSI-RS configurations, such as the example configurations shown in Table 1”:

Petitioners' Exhibit 1003, p. 30
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 1: CSI-RS Trigger Indication

3 bit CSI-RS Configuration	Indication
0	No xCSI-RS
1	One xCSI-RS symbol
2	Two xCSI-RS symbols from the same Tx beam (Same beam ID)
3	Two xCSI-RS symbols from different Tx beam (Different beam ID)
4	Two xCSI-RS symbols with zero powers in both symbols
5	Two xCSI-RS symbols with zero power in the second xCSI-RS symbol
6	Two xCSI-RS symbols with zero power in the first xCSI-RS symbol
7	Maintain the previous configuration

Ex-1005 at [0040], Table 1, (emphasis added to messages that include explicit number of CSI-RS).

55. A POSITA knows that in LTE, information on the number of symbols used to carry reference signals is implicit (not explicit) in the signal mapping. For example, in LTE release 13, the base station transmits to the UE downlink control information (DCI) format 0, which includes up to 3 bits of CSI request (Appendix 11 (3GPP TS 36.212 v13.1.0) at 95, clause 5.3.3). The CSI request points to a set of CSI processes, for example as taught by 3GPP TS 36.213, Table 7.2.1-1D. Each row in the table, points to a set of CSI processes. A CSI process is defined by one CSI-

Petitioners' Exhibit 1003, p. 31
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

RS configuration and one CSI-IM configuration. (Ex. 1008 at 276). CSI-RS configurations are defined, for example, in 3GPP TS 36.211, v13.1.0, Table 6.10.5.2-1. In Release 13, all CSI-RS configurations are time-multiplexed over 2 resource elements.

56. As discussed previously, in Releases 10 through 13, CSI-RS resources are supported by two OFDM symbols each. This approach enables support for 16 CSI-RS ports through the use of OCC-4 spreading, as it is done in Release 13. However, the goal for release 14 was to increase the number of CSI-RS to 32. At RAN1 #85, it was understood that 32 CSI-RS require the use of OCC-8 spreading. At RAN1 #86 Aug. 22 – 26, 2016, various CSI-RS mappings were proposed to support OCC-8 spreading. For example, Intel proposed a scheme that uses 4 OFDM symbols (see Appendix 6, 3GPP R1-166519). In Figure 1a, the OCC spreading is applied across 4 OFDM symbols and 2 adjacent subcarriers, while in Figure 1b, across 8 OFDM symbols.

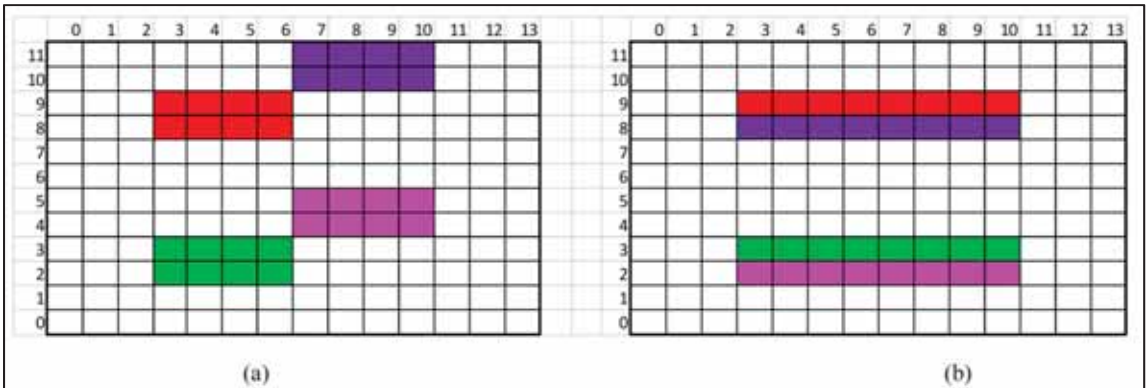


Figure 1: Examples of OCC-8 mapping across 2 or 4 CSI-RS resources

Petitioners' Exhibit 1003, p. 32
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Appendix 6 (R1-166519).

57. Figure 2 below shows another example of multiplexing 8 ports using OCC-8, where the OCC spreading is applied across 4 OFDM symbols and 2 adjacent subcarriers. One color corresponds to the 8 multiplexed CSI-RS antenna ports using OCC-8 codes.

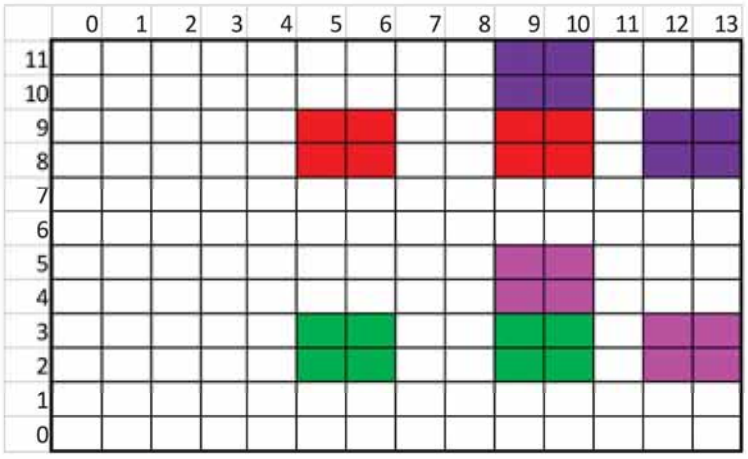


Figure 2: Example of OCC-8 mapping across 2 sub-carriers and 4 OFDM symbols, that is compatible with the Rel-13 CSI-RS resource elements.

Appendix 6 (R1-166519).

58. CATT proposal at RAN1 #86 also discloses CSI-RS spread over 4 OFDM symbols for OCC-8. In this technical documents, and others, OCC-8 is referred to CDM-8. The CDM-8 CSI-RS mapping pattern is shown in Figure 2. One CDM RE set (labeled by the same letter) is constructed by the combination of 4 time multiplexed resource elements (OFDM symbol 5,6 of slot 0 and slot 1) and 4 time and frequency multiplexed resource elements (OFDM symbol 2,3 of slot 1).

Petitioners' Exhibit 1003, p. 33
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

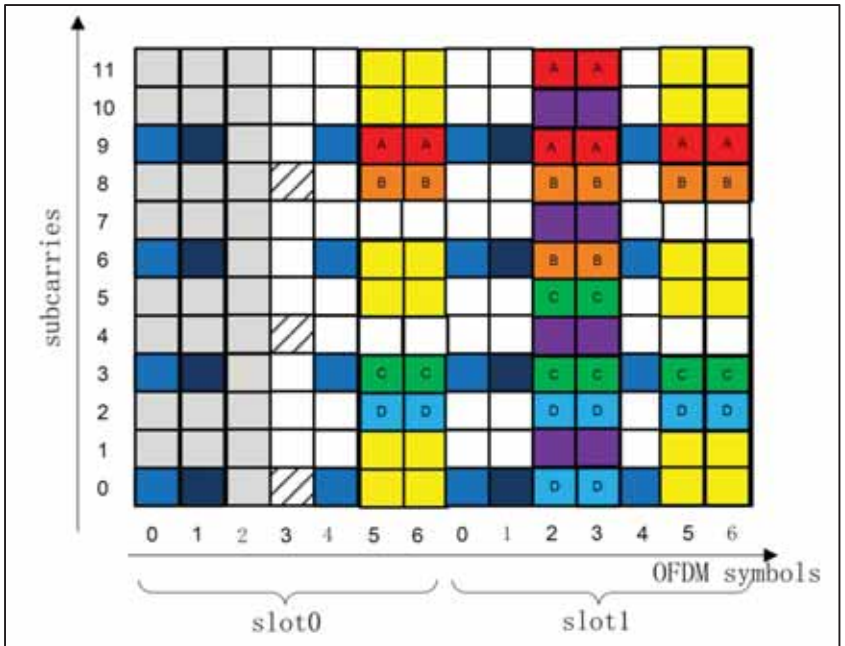


Figure 2: CDM-8 RE set construction

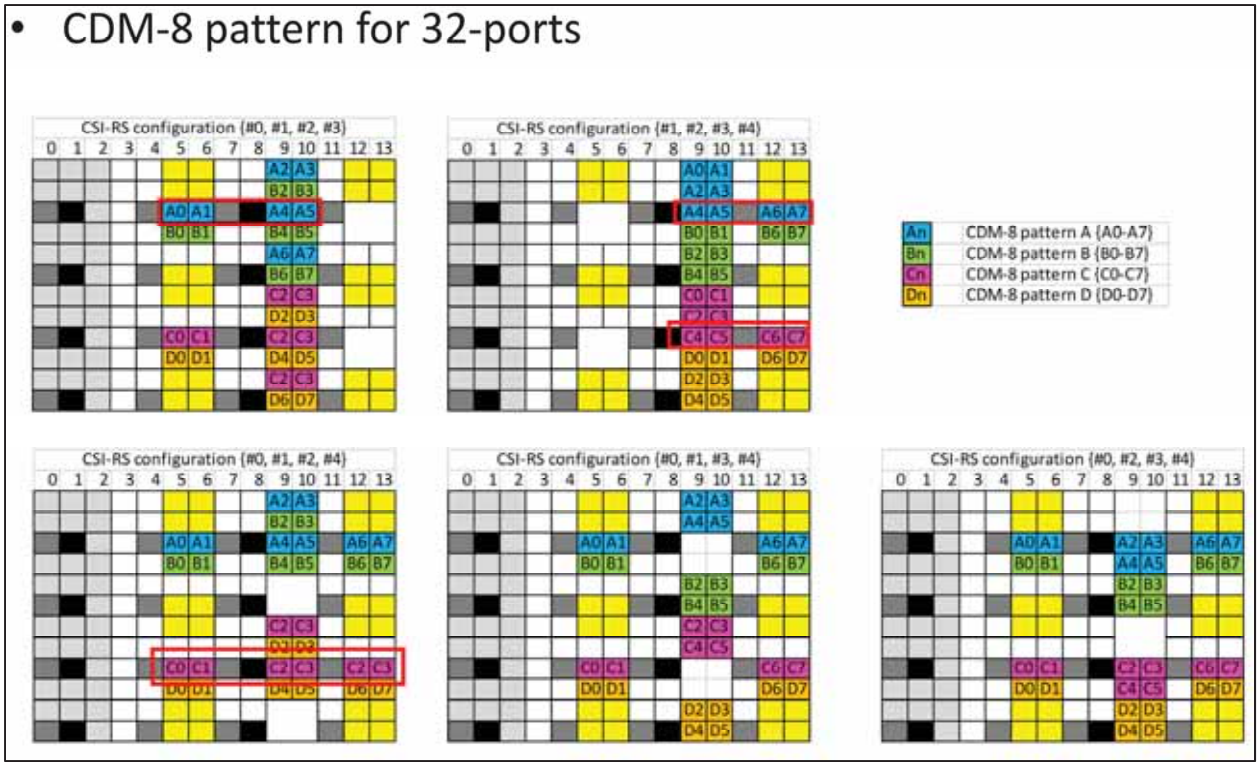
Appendix 7 (R1-166439).

59. Agreements at RAN1 #86bis include CSI-RS designs that use resource elements from more than 2 OFDM symbols. For example:

- Agreements at RAN1#86bis
  - FFS on additional CDM-4 pattern(s) at least for 28- and 32-port to support full power utilization within a single PRB.
  - CDM-8 design for {24, 32} ports:
    - At least for 32-port CSI-RS, at least one CDM-8 pattern exists which uses REs from more than 2 OFDM symbols

Ex-1012 (R1-1613206) (annotated).

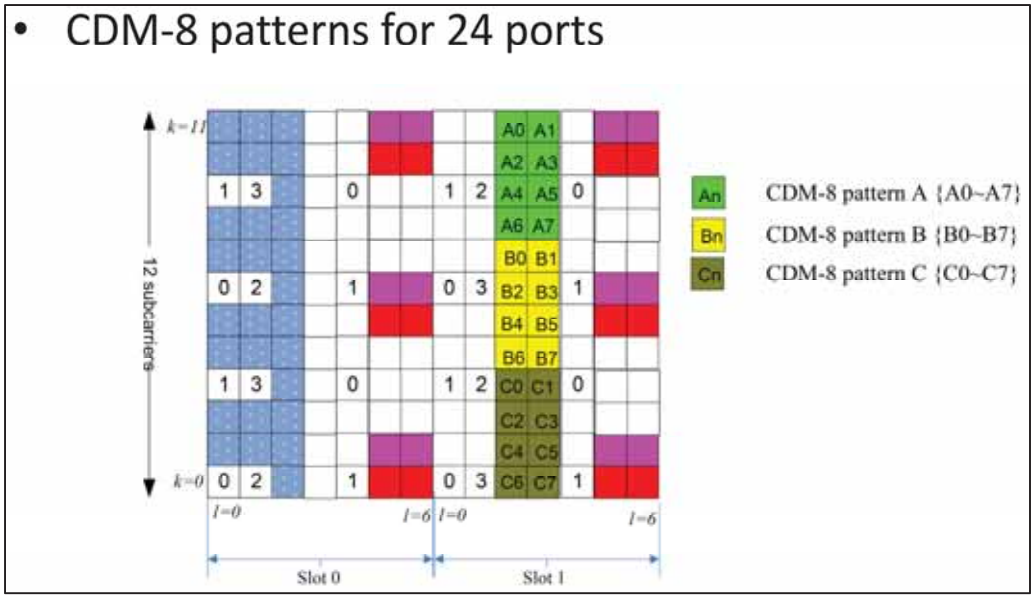
Petitioners' Exhibit 1003, p. 34
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121



Ex-1012 (R1-1613206) (annotated).

60. At RAN1 #87, a way forward was agreed on the design of CSI-RS based on 2, 4 or 6 OFDM symbols for 32 ports and 2 ODFM symbols for 24 ports, as illustrated in the examples shown here:

Petitioners' Exhibit 1003, p. 35
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121



Ex-1012 (R1-1613206).

V. The ’402 Patent

61. The ’402 Patent (Ex-1001) is directed to a method and apparatus for beam management in a wireless communication system. Ex-1001 at 1:15-18. In particular, the patent claims a control signal sent from a base station to user equipment (a UE), in which the control signal is associated with a reference signal for beam measurement. The challenged claims are reproduced in Section V(A), below.

62. Figure 1 “shows a multiple access wireless communication system according to one embodiment of the invention”:

Petitioners' Exhibit 1003, p. 36
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

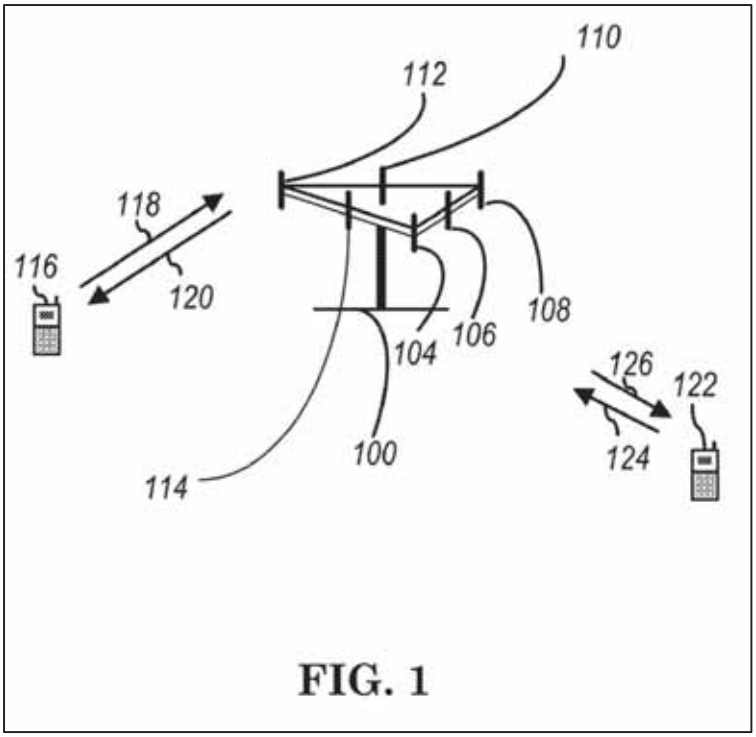


FIG. 1

Id. at Figure 1, 2:43-44. According to the Patent, "[a]n access network 100 (AN) includes multiple antenna groups, one including 104 and 106, another including 108 and 110, and an additional including 112 and 114." *Id*. at 2:44-47. "Access terminal 116 (AT) is in communication with antennas 112 and 114, where antennas 112 and 114 transmit information to access terminal 116 over forward link 120 and receive information from access terminal 116 over reverse link 118." *Id*. at 2:50-54.

63. The '402 Patent explains that "[i]n communication over forward links 120 and 126, the transmitting antennas of access network 100 may utilize beamforming in order to improve the signal-to-noise ratio of forward links for the different access terminals 116 and 122." *Id*. at 3:1-4. The '402 Patent describes a

Petitioners' Exhibit 1003, p. 37
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

benefit of beamforming that was well known in the art before its priority date: "an access network using beamforming to transmit to access terminals scattered randomly through its coverage causes less interference to access terminals in neighboring cells than an access network transmitting through a single antenna to all its access terminals." *Id*. at 3:5-9.

64. Under the '402 Patent's terminology, "[a]n access network (AN) may be a fixed station or base station used for communicating with the terminals and may also be referred to as an access point, a Node B, a base station, an enhanced base station, an evolved Node B (eNB), or some other terminology." *Id*. at3:10-14. "An access terminal (AT) may also be called user equipment (UE), a wireless communication device, terminal, access terminal or some other terminology." *Id*. at 3:14-17.

65. "Fig. 2 is a simplified block diagram of an embodiment of a transmitter system 210 (also known as the access network) and a receiver system 250 (also known as access terminal (AT) or user equipment (UE)) in a MIMO system 200":

Petitioners' Exhibit 1003, p. 38
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

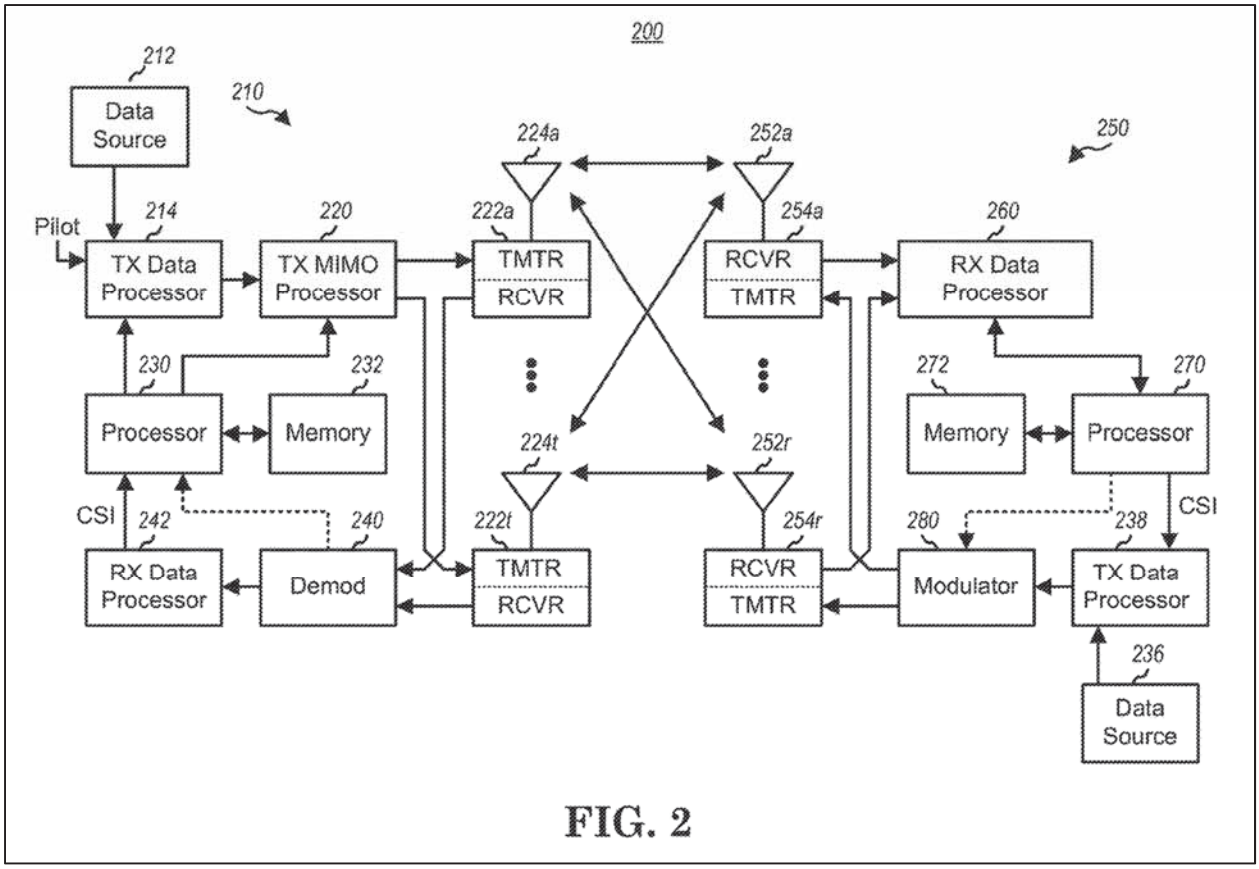


FIG. 2

Id. at Figure 2, 3:18-21. The ’402 Patent goes on to describe well-known methods of transmitting and receiving data in a wireless communication system. *Id*. at 3:22-4:26.

66. The ’402 Patent specification also summarizes the 3GPP work of others regarding beamforming in NR. *Id*. at 4:60-6:20 (describing 3GPP contributions from 3GPP RAN WG2 Meeting #93bis, in April 2016). For example, as acknowledged by the ’402 Patent, in R2-162762 (Appendix 8), Ericsson described how the “reliability of a system purely relying on beamforming and operating in higher frequencies might be challenging, since the coverage might be more sensitive to both

time and space variations." Ex-1001 at 6:5-8. "As a consequence of that the SINR of the narrow link can drop much quicker than in the case of LTE." *Id*. at 6:8-10. R2-162762 explains that "NR also needs to support massive beamforming as an essential feature to overcome the propagation challenges in higher frequencies." Appendix 8 at 4.

67. As explained by the '402 Patent, one way to track the current beam(s) available for communication between a base station and a UE "could be to perform measurement from the UE side. A base station may transmit reference signal on all base station beams or some of the base station beams in certain time occasion(s)." Ex-1001 at 6:43-48. In response, "[a]fter measuring the reference signal, the UE may detect whether there is any beam change or update, e.g., an existing beam disappears or a new beam comes out." *Id*. at 6:48-50. The UE may then report this beam measurement result to the base station "to inform base station the new status of beam(s)." *Id*. at 6:50-52. "The reference signal for beam measurement may be sent periodically, aperiodically, or semi-persistently." *Id*. at 6:53-54.

68. The '402 Patent describes the difference between these three categories of reference signals. "For periodic beam reference signal, the base station may configure a proper periodicity for measurement occasion(s) when UE would perform measurement." *Id*. at 6:54-57. "On the other hand, an aperiodic beam reference

Petitioners' Exhibit 1003, p. 40
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

signal is transmitted when there is an associated triggering signal." *Id*. at 6:63-64. When the UE "detects the associated triggering signal (e.g., a control signal, a control channel, an uplink grant, or a downlink assignment), the UE would realize there would be beam reference signal in an associated timing occasion, e.g., the rest of the symbol(s) in the same slot or the symbol(s) in the following slot." *Id*. at 6:65-7:3. "Semi-persistent reference signal could be something in between (e.g., first being configured, start periodic transmission if there is an associated signal, and could modify or pause the transmission if another associated signal is detected." *Id*. at 7:24-28.

69. According to the '402 Patent, the need for an aperiodic beam reference signal can be determined by either the UE or the base station. "It is possible for UE to request the beam reference signal (e.g., an aperiodic beam reference signal) if UE detects there is a beam quality change, UE mobility, UE rotation or any other case when beam refinement or adjustment is required." *Id*. at 7:29-32. "Of course, as discussed above, an aperiodic beam reference signal can be sent by the base station without request from the UE, if the base station detects that a beam refinement or adjustment is required." *Id*. at 7:34-37.

70. The '402 Patent describes that "a UE may detect beam refinement/adjustment is required for some beam(s) or some TRP(s) among the

Petitioners' Exhibit 1003, p. 41
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

beams within the base station set of the UE while beam refinement/adjustment is not require[d] for other beam(s) or other TRP(s) among the beams within the base station beam set of the UE." *Id*. at 7:44-49. When that occurs, "simply requesting beam reference signal for beam adjustment/refinement is inefficient as the base station has no idea beam direction of which beam(s) or of which TRP(s) is changed/unchanged." *Id*. at 7:52-55. The '402 Patent says this would lead to inefficiencies by requiring the base station to "send the beam reference signal for refining/adjusting all the beams within the beam set of the UE, even if some of them does not require any adjustment." *Id*. at 7:56-59. And "one base station beam might need[] several transmission occasions to carry the beam reference signal (with a narrower beam or several different beam directions), performing refinement or adjustment for all beams in the beam set of the UE would require more resources to carry a beam reference signal (e.g., many symbols or slots)." *Id*. at 7:59-65. In addition, "as the number of occasions associated with one triggering signal is expected to be limited, performing refinement or adjustment for all beams in the beam set of the UE may also result in more triggering of beam reference signal, which increases the control overhead as well." *Id*. at 7:65-8:3.

71. The '402 Patent proposes two "general concept[s]" to solve these problems. "A first general concept of this invention is that when a UE requests beam

Petitioners' Exhibit 1003, p. 42
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

refinement or adjustment, the UE would indicate which beam(s) or beam(s) from which TRP(s) would require beam refinement/adjustment associated with the request." *Id*. at 8:13-17. "An example of requesting beam refinement or adjustment would be to request beam reference signal." *Id*. at 8:17-18. The "general second concept" of the '402 Patent's purported invention "is that when a base station triggers beam refinement or adjustment for a UE, the base station would indicate that beam refinement or adjustment is performed on which beam(s) or beam(s) from which TRP(s) associated with the trigger." *Id*. at 8:19-23. "An example of triggering beam refinement or adjustment for a UE would be to send an aperiodic trigger for beam reference signal to the UE." *Id*. at 8:23-26.

A. Listing of the Challenged Claims and Claim Language

72. The challenged claims are reproduced below:

Claim	Claim Language
1	A method of a base station, comprising: the base station transmits to a UE a control signal associated with a reference signal for beam measurement, wherein the control signal triggers aperiodical transmission of the reference signal for beam measurement, and wherein the control signal includes a beam-related information for transmitting the reference signal for beam measurement and indicates how many symbols are used to carry the reference signal for beam measurement; and

Petitioners' Exhibit 1003, p. 43
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Claim	Claim Language
	the base station transmits the reference signal for beam measurement to the UE.
2	The method of claim 1, wherein the beam-related information indicates at least a beam on which the reference signal for beam measurement is transmitted.
3	The method of claim 1, wherein the beam-related information indicates a first beam, and wherein the reference signal for beam measurement is transmitted on at least a refined beam of the first beam.
4	The method of claim 1, wherein the control signal is transmitted via a control channel.
12	A base station, comprising: a control circuit; a processor installed in the control circuit; and a memory installed in the control circuit and operatively coupled to the processor; wherein the processor is configured to execute a program code stored in the memory to: transmit to a UE a control signal associated with a reference signal for beam measurement, wherein the control signal triggers aperiodical transmission of the reference signal for beam measurement, and wherein the control signal includes a beam-

Petitioners' Exhibit 1003, p. 44
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Claim	Claim Language
	related information for transmitting the reference signal for beam measurement and indicates how many symbols are used to carry the reference signal for beam measurement; and transmit the reference signal for beam measurement to the UE.
13	The base station of claim 12, wherein the beam-related information indicates at least a beam on which the reference signal for beam measurement is transmitted.
14	The base station of claim 12, wherein the beam-related information indicates a first beam, and wherein the reference signal for beam measurement is transmitted on at least a refined beam of the first beam.
15	The base station of claim 12, wherein the control signal is transmitted via a control channel.

VI. Patentability Analysis

A. Level of Ordinary Skill in the Art

73. In my opinion, with regard to the ’402 Patent, a person of ordinary skill in the art would have B.S. in Electrical Engineering, or a related field, and at least three years of experience designing, developing, and/or testing telecommunication systems. A person of ordinary skill in the art would also have familiarity with the wireless standards and well-known protocols for accessing wireless networks. This description is approximate, and a higher level of education or skill might make up

Petitioners' Exhibit 1003, p. 45
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

for less experience, and vice-versa. As of the time of the invention of the '402 Patent, I qualify as a person of ordinary skill in the art.

B. Claim Construction

74. I have been told that claim terms in an *inter partes* review proceeding are to be given their ordinary and accustomed meaning as understood by a person of ordinary skill in the art. In my analysis of the Challenged Claims, I have applied the plain and ordinary meaning as understood by a person of ordinary skill in the art at the relevant time.

VII. Descriptions of the Prior Art References

A. International Application Number PCT/US2016/033019 (WIPO Publication Number 2017/142573A1) to Sungho Moon, et al. ("Moon")

75. As I discuss below and in the remainder of this declaration, Moon teaches all aspects of claims 1–4 and 12–15 of the '402 Patent. In this section, I provide an overview of Moon, which I understand will be reproduced in Section VIII(A) of the Petition.

76. Moon describes a technique for communicating channel state information (CSI) in 5G systems using a 5G reference signal (xCSI-RS). Ex-1005 at Abstract, [0037]. The xCSI-RS is a signal that the base station transmits to the UE in the downlink, which the UE uses to estimate CSI and report it back to the base

Petitioners' Exhibit 1003, p. 46
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

station in the uplink. Ex-1005 at [0003]. "Conventional LTE (Long Term Evolution) systems since LTE Release 10 (Rel. 10) have included the Channel State Information (CSI) Reference Signal (CSI-RS) among the reference signals transmitted by a base station (BS) such as an Evolved NodeB (eNB). A User Equipment (UE) can receive the CSI-RS from the eNB and estimate a channel quality information (CQI) and other parameters, which can be reported back to the eNB via a CSI Report." *Id*. at [0003]. "[T]echniques described herein can be employed that can facilitate control signaling for fifth generation Channel State Information (xCSI) Reference Signals (xCSI-RS)". *Id*. at [0037], [0038], [0041].

77. Moon describes various aspects of the xCSI-RS, such as how they are configured, scheduled, triggered, and transmitted by the base station, and how they are received, processed, and reported by the UE. But Moon focuses on the control signaling related to the xCSI-RS. Ex-1005 at [0037]. Figure 3 of Moon provides a diagram "of an example subframe comprising xCSI-RS":

Petitioners' Exhibit 1003, p. 47
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

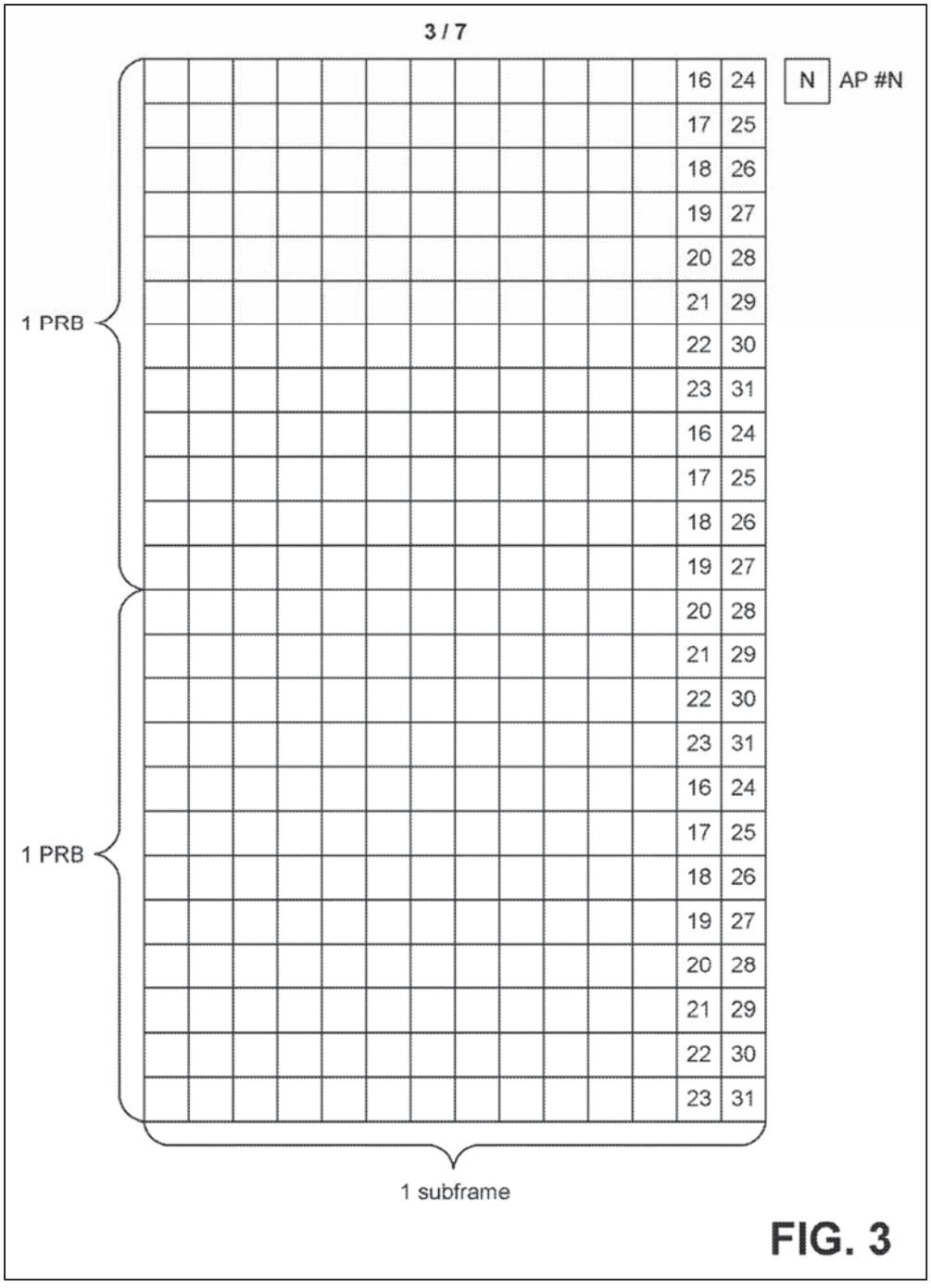


FIG. 3

Ex-1005 at [0038], Fig. 3. According to Moon,

> the example subframe of FIG. 3 is a DL OFDM-only subframe, where xPDCCH (5G Physical Downlink

Petitioners' Exhibit 1003, p. 48
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

> Control Channel) and xPDSCH (5G Physical Downlink Shared Channel) is transmitted without UL (uplink) transmissions. xPDCCH is used for scheduling xPDSCH, and thus xCSI-RS can be located in the end of the xPDSCH area. In example subframe of FIG. 3, symbol indices 12 and 13 are used for xCSI-RS

Id. at [0038]. Figure 3 is thus an example subframe with the last two symbols used for xCSI-RS transmission. But according to Moon, "the number of symbols employed for xCSI-RS transmission can vary." *Id*. at [0039]. "The number of symbols for xCSI-RS can be configured by RRC or dynamic signaling (e.g., via PDCCH, etc.)." *Id*. "For dynamic triggering of xCSI-RS, the DCI (downlink control information) for the triggering can include any of a variety of xCSI-RS configurations, such as the example configurations shown in Table 1":

Petitioners' Exhibit 1003, p. 49
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 1: CSI-RS Trigger Indication

3 bit CSI-RS Configuration	Indication
0	No xCSI-RS
1	One xCSI-RS symbol
2	Two xCSI-RS symbols from the same Tx beam (Same beam ID)
3	Two xCSI-RS symbols from different Tx beam (Different beam ID)
4	Two xCSI-RS symbols with zero powers in both symbols
5	Two xCSI-RS symbols with zero power in the second xCSI-RS symbol
6	Two xCSI-RS symbols with zero power in the first xCSI-RS symbol
7	Maintain the previous configuration

Id. at [0040], Table 1. These "DCI message(s)" can be "transmitted via xPDCCH[.]" *Id*. at [0050]. Moon's control messages can be used to "indicate an xCSI-RS configuration for subframe n, where the xCSI-RS configuration can indicate the number of xCSI-RS symbols (M), and the location of the xCSI-RS symbols (e.g., symbols (10, 11), symbols (12, 13), symbol (11), etc.), and can optionally indicate additional information." *Id*. at [0049]. "In some aspects, information (e.g., the value of M, the location of the M symbols, etc.) can be explicitly indicated in the one or

Petitioners' Exhibit 1003, p. 50
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

more control messages, while in other aspects, it can be implicitly indicated (e.g., via an indication to employ a previously indicated xCSI-RS configuration, etc.)." *Id*.

Moon's xCSI-RS can be transmitted by the base station using one or more beams, which can be the same or different for each symbol, and which can be associated with virtual cell identities (VCIDs), which are scrambling seeds that help the UE to identify the beams. *Id*. at [0041], [0045]–[0046]. "[T]he UE can feedback candidate Tx beam IDs for multiple xCSI-RS symbols," such as to identify "a best and a second best Tx beams." *Id*. at [0041].

78. Moon explains that its proposed technique for xCSI-RS can improve the performance and efficiency of 5G systems, by enabling the base station and the UE to exchange CSI in a flexible and adaptive manner, and by supporting the use of massive MIMO technology in the millimeter wave spectrum. Ex-1005 at [0036]. Under Moon's system, the "new Channel State Information Reference Signal (CSI-RS can be designed to support the downlink (DL) Transmission (Tx) beams measurement and selection[.]" *Id*.

B. R1-1609515 Titled "On network beam switching and refinement (BM P-2)," 3GPP TSG RAN WG1 #86bis, Intel ("R1-1609515")

79. As I discuss below and in the remainder of this declaration, Moon in view of R1-1609515, teaches all aspects of claims 3 and 14 of the '402 Patent. In

Petitioners' Exhibit 1003, p. 51
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

this section, I provide an overview of R1-1609515, which I understand will be reproduced in Section VIII(B) of the Petition.

80. "On network beam switching and refinement (BM P-2)" is a written contribution Intel submitted to 3GPP before the 3GPP TSG-RAN WG1 Meeting #86bis in Lisbon, Portugal on October 10-14, 2016 ("R1-1609515"). Intel submitted the document to the 3GPP standards body for consideration in developing the 5G cellular system. Ex-1007, ¶¶ 54-58; Ex-1007, Appendix 22 at 96.

Petitioners' Exhibit 1003, p. 52
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

81. R1-1609515 discloses three potential beam-refinement processes for transmission beams from a base station (or transmission-reception point ("TRP")):

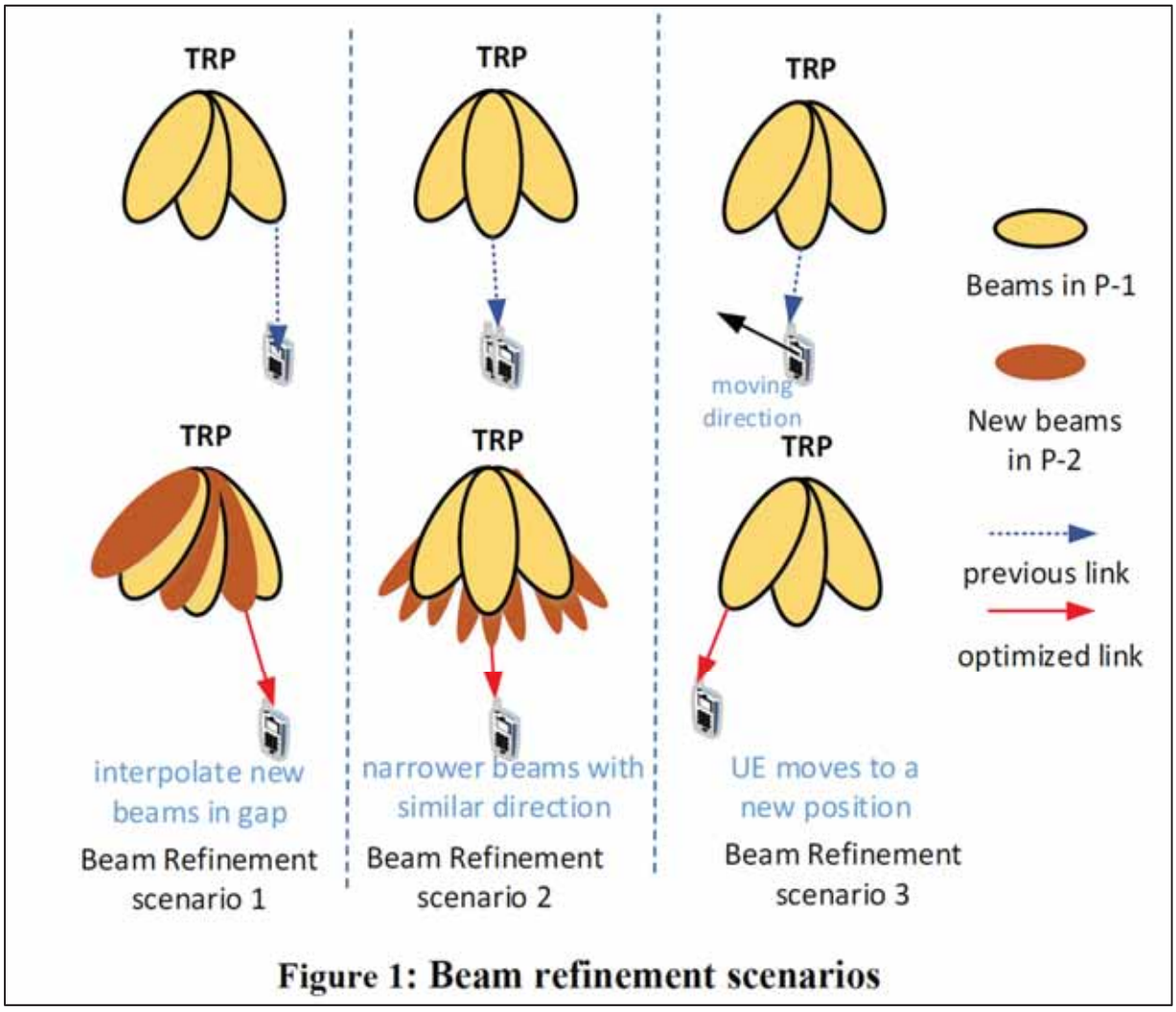


Figure 1: Beam refinement scenarios

Ex-1006 (R1-1609515) at Figure 1. R1-1609515 explains that these beam refinement processes can be used after "procedure 1 (P-1) of DL beam management, in which TRP/UE beams are acquired using beam sweeping from a full set of beams. P-1 is used to acquire the initial TRP/UE beam and to discover other candidate TRP/UE beams." Ex-1006 at 1. After this initial TRP beam acquisition, "a dedicated

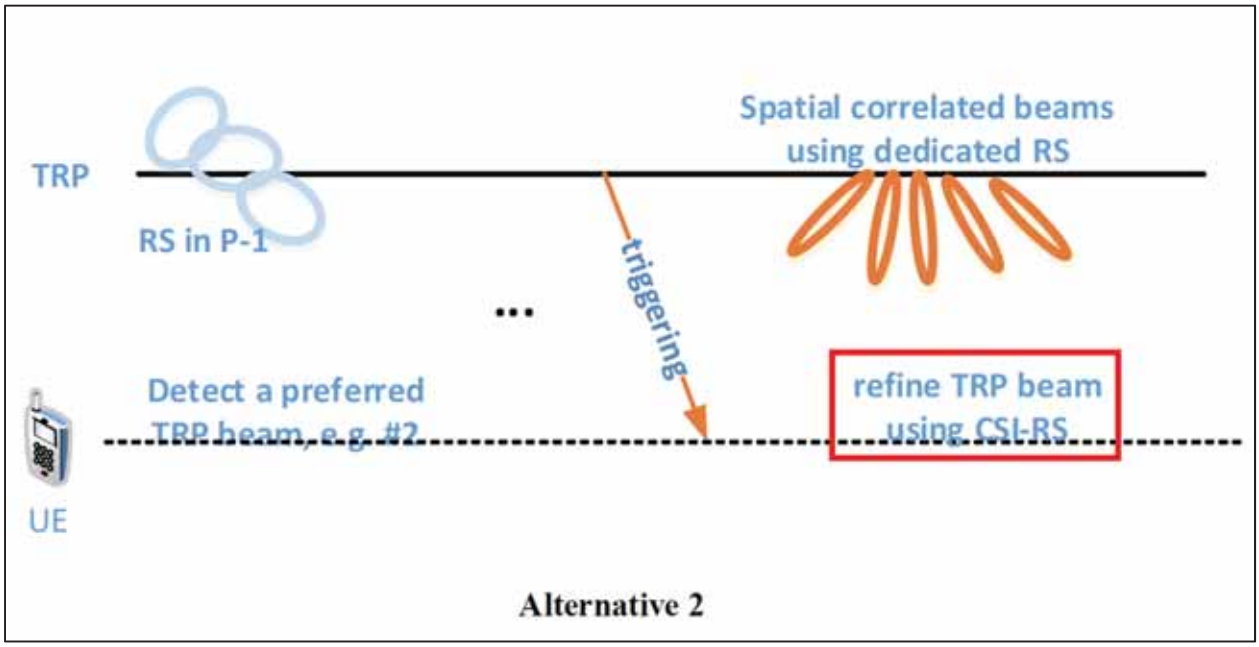
[procedure 2] P-2 is beneficial to reduce the UE power consumption. It also allows more implementation flexibility to apply finer beam in P-2 than in P-1. And at the same time, UE may respond faster to movement, rotation and channel blockage using P-2 instead of P-1." *Id*. As such, in R1-1609515, Intel provides its "views on the beam management procedure P-2." *Id*.

82. R1-1609515 provides Intel's views on "***beam refinement*** which allows TRP beam change between beams having strong spatial correlation." *Id*. (emphasis in original). Before performing this beam refinement in P-2, "TRP/UE has performed procedure P-1 at least once successfully and at least one pair of TRP/UE beam has been identified." *Id*. at 2. Then, in P-2 for beam refinement, "the TRP beam can be changed to a new beam." *Id*. As shown in R1-1609515 Figure 1 above, Intel identifies three possible beam refinement scenarios:

- Beam Refinement Scenario-1: TRP beam refinement among beams having the same beam width as P-1 but higher spatial granularity.
- Beam Refinement Scenario-2: TRP beam refinement using narrower beam width as P-1 but similar spatial beam direction.
- Beam Refinement Scenario-3: TRP beam refinement using the same beam width and the same spatial beam granularity as P-1.

Petitioners' Exhibit 1003, p. 54
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

83. Under Beam Refinement Scenario-2, "dedicated reference signals are required since different beams are used in P-2 compared to P-1." Ex-1006 at 2. Intel proposes that this beam refinement is performed using CSI-RS:



Ex-1006 at Figure 2 (annotated). In its "Proposal 1," Intel further explains its desire that "Dedicated RS, e.g. UE specific CSI-RS, is used for TRP beam refinement." Ex-1006 at 3–4 (Proposal 1).

Petitioners' Exhibit 1003, p. 55
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

VIII. Claims 1–4 and 12–15 are Unpatentable

A. Ground #1: Claims 1–4 and 12–15 are Anticipated Under 35 U.S.C. § 102(a) by Moon

1. Claim 1

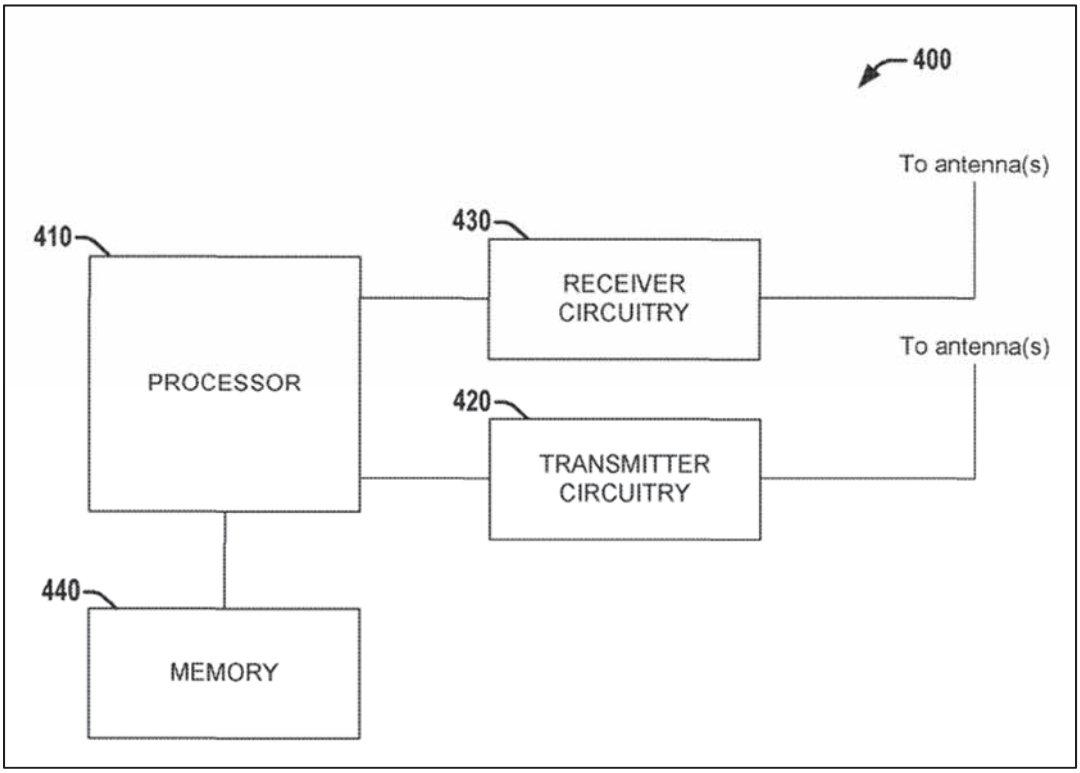
[Element 1Pre]: A method of a base station, comprising:

84. To the extent the preamble is considered limiting, Moon meets the limitation "method of a base station":

> Techniques for configuration of a user equipment (UE) for fifth generation (5G) Channel State Information (xCSI) Reference Signals (xCSI-RS) are discussed. One example apparatus **employable at a base station** comprises a processor configured to schedule a fifth generation Physical Downlink Shared Channel (xPDSCH) during one or more xPDSCH symbols of a subframe n; schedule a final M symbols of the one or more xPDSCH symbols for fifth generation Channel State Information Reference Signals (xCSI-RS); and output one or more control messages to transmitter circuitry for transmission to one or more User Equipments (UEs), wherein the one or more control messages comprise a xCSI-RS configuration for the one or more UEs, wherein the xCSI-RS configuration indicates the value of M and the final M symbols scheduled for xCSI-RS.

Petitioners' Exhibit 1003, p. 56
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Ex-1005 (Moon) at Abstract. In another example, "[r]eferring to FIG. 4, illustrated is a block diagram of a system 400 that facilitates control signaling for fifth generation (5G) Channel State Information (xCSI) Reference Signals (xCSI-RSs) by a base station according to various aspects described herein." *Id*. at [0047].



Id. at Figure 4. "In various aspects, system 400 can be included within an Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Node B (Evolved Node B, eNodeB, or eNB) or other base station in a wireless communications network." *Id*. at [0047].

Petitioners' Exhibit 1003, p. 57
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

[Element 1(a)]: the base station transmits to a UE a control signal associated with a reference signal for beam measurement;

85. Moon teaches a base station transmitting to a UE a control signal associated with a reference signal for beam measurement. For example, Moon teaches a "new Channel State Information Reference Signal (CSI-RS) ... designed to support the downlink (DL) Transmission (Tx) beams measurement and selection". Ex-1005 at [0036]. Moon teaches a control signal, for example, "Control Signaling for Fifth Generation Channel State Information Reference Signals (xCSI-RS)". Ex-1005 at Title.

86. Further, "[i]n various embodiments, techniques described herein can be employed that can facilitate **control signaling** for fifth generation Channel State Information (xCSI) Reference Signals (xCSI-RS)"). Ex-1005 at [0037] (emphasis added).

87. The control signals associated with the xCSI-RSs in Moon include radio resource control (RRC) messages and downlink control information (DCI) sent via Moon's "xPDCCH." Specifically, Moon describes that the "5G Physical Downlink Control Channel" or "xPDCCH" is "used for scheduling xPDSCH, and thus xCSI-RS can be located at the end of the xPDSCH area." Ex-1005 at [0038]. Moon explains that the "control messages" it describes "can comprise DCI message(s) transmitted via xPDCCH of subframe n." *Id*. at [0050];

88. A POSITA viewing Moon would understand that the "xPDCCH" in Moon is a control channel that carries DCI, much as the PDCCH in LTE and 5G systems carry DCI. For instance, a POSITA knows that a downlink LTE subframe comprises a control region: "In LTE, each downlink subframe . . . is normally divided into a control region, consisting of the first few OFDM symbols, and a data region, consisting of the remaining part of the subframe. . . . the control region carries L1/L2 signaling necessary to control uplink and downlink data transmissions." Ex-1008 at 79. In addition, a POSITA viewing Moon would understand that the first few OFDM symbols in Moon Figure 3 correspond to the PDCCH:

Petitioners' Exhibit 1003, p. 59
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

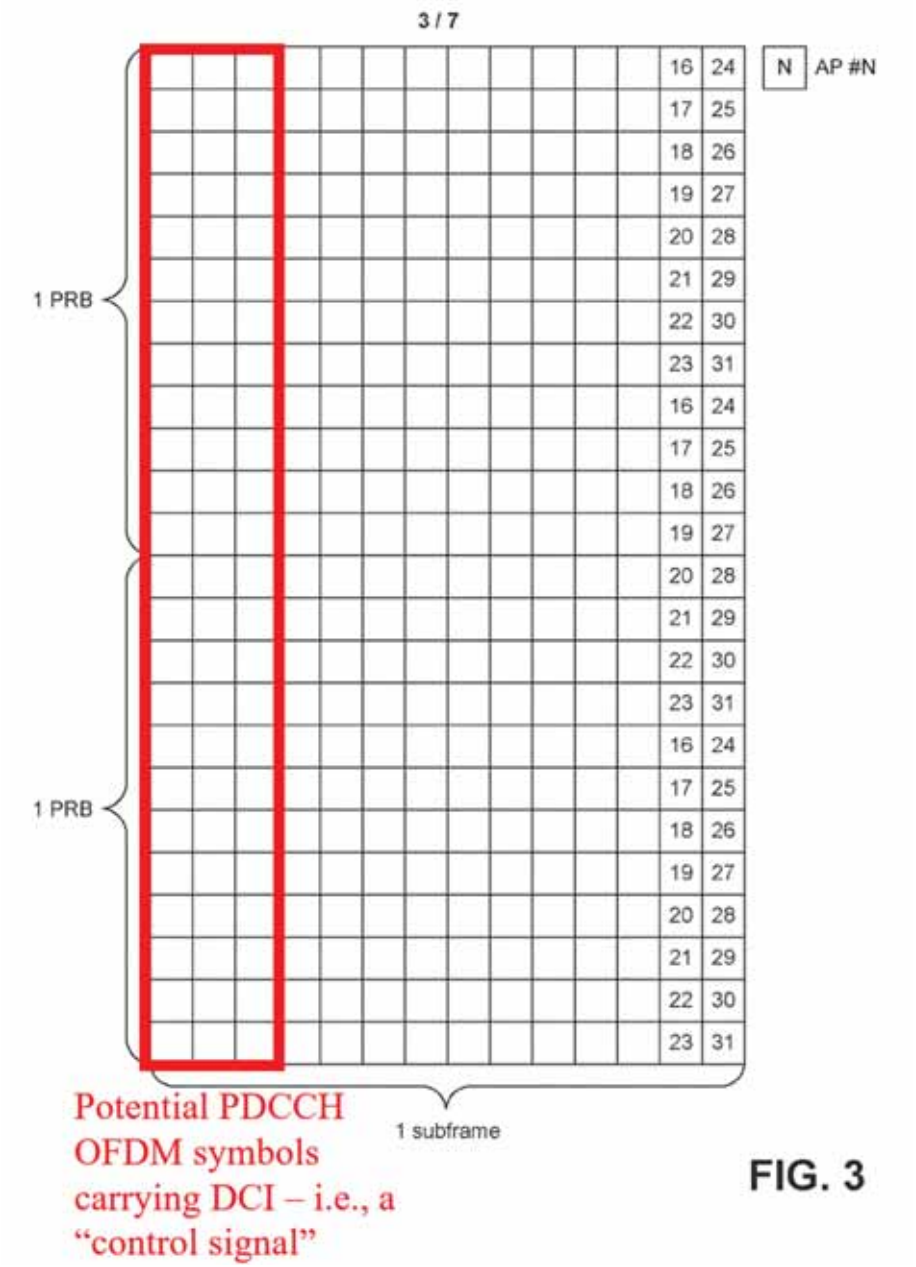
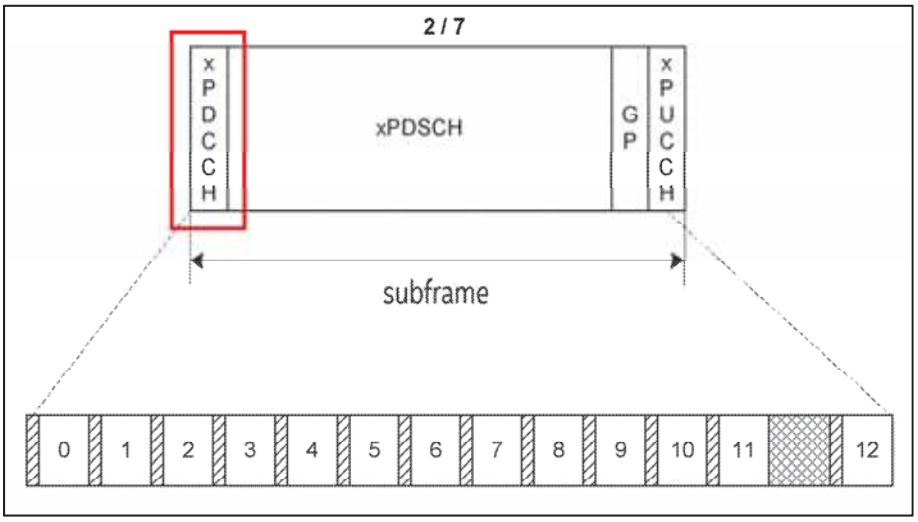


FIG. 3

Ex-1005 at Figure 3 (annotated) and [0038] ("The example subframe of FIG. 3 is a DL OFDM-only subframe where xPDCCH (5G Physical Downlink Control Channel) and xPDSCH (5G Physical Downlink Shared Channel) is transmitted without UL (uplink) transmissions.").

Petitioners' Exhibit 1003, p. 60
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

89. According to Moon, control signaling may be mapped to a few OFDM symbols at the beginning of a downlink subframe, as shown in the figure below:



Ex-1005 at Figure 2 (annotated).

90. Moon discloses control information, such as the number of symbols employed for xCSI-RS transmission, can be configured by Radio Resource Control (RRC) or by a new Physical Downlink Control Channel (xPDDCH): "[t]he number of symbols for xCSI-RS can be configured by RRC or dynamic signaling (e.g., via xPDCCH, etc.)". Ex-1005 at [0039]. Moon also explains that its various disclosures of RRC messages and DCI messages are interchangeable. Ex-1005 at [0050] ("In some aspects, the one or more control messages can comprise DCI message(s) transmitted via xPDCCH of subframe n. In the same or other aspects, the one or more control messages can comprise RRC message(s)."). In other words, where

Petitioners' Exhibit 1003, p. 61
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Moon describes a system that can implement certain functionality via RRC messaging, that same functionality could be accomplished via DCI, and vice versa.

91. Moon teaches that these DCI and RRC messages are "associated with a reference signal for beam measurement." For instance, Moon teaches that "[t]he number of symbols for xCSI-RS can be configured by RRC or dynamic signaling (e.g., via xPDCCH, etc.)." Ex-1005 at [0039]. Control signaling provides information on the location of xCSI-RS: "In various aspects described herein, the location of the xCSI-RS symbols can be determined dynamically based on the subframe type, and can be indicated via xPDCCH. In other aspects, the location of xCSI-RS can be configured via higher layer (e.g., RRC (radio resource control)) signaling between possible xCSI-RS locations (e.g., (10, 11) (or a subset thereof) or (12, 13) (or a subset thereof), etc.)." Ex-1005 at [0038].

92. Moon also teaches that DCI can trigger "any of a variety of xCSI-RS configurations, such as the example configurations shown in Table 1, below":

Petitioners' Exhibit 1003, p. 62
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 1: CSI-RS Trigger Indication

3 bit CSI-RS Configuration	Indication
0	No xCSI-RS
1	One xCSI-RS symbol
2	Two xCSI-RS symbols from the same Tx beam (Same beam ID)
3	Two xCSI-RS symbols from different Tx beam (Different beam ID)
4	Two xCSI-RS symbols with zero powers in both symbols
5	Two xCSI-RS symbols with zero power in the second xCSI-RS symbol
6	Two xCSI-RS symbols with zero power in the first xCSI-RS symbol
7	Maintain the previous configuration

Id. at [0040]. The xCSI-RS trigger indications in Table 1 are from the "same Tx beam" or from "different Tx beam." Based on these disclosures, a POSITA would recognize that the RRC and DCI "control signals" in Moon are "associated with a reference signal for beam measurement."

93. Moon teaches that control signaling such as DCI and RRC messages are associated with a reference signal "*for* beam measurement." For example, reference symbols xCSI-RS are for beam measurement: "These xCSI-RS configuration parameters can comprise one or more of the characteristics indicated

Petitioners' Exhibit 1003, p. 63
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

herein as configurable for xCSI-RS, such as the number of symbols for xCSI-RS (e.g., M = 0, 1, 2, etc.), which symbols are configured for xCSI-RS, CRG type (e.g., candidate **beam measurement**, interference measurement, etc.), whether xCSI-RS will be received from one or more Tx beams that can be from one or more TPs, etc." Ex-1005 at [0055].

94. Moon additionally describes how the xCSI-RS are used to allow a UE to feedback candidate "beam Ids for multiple xCSI-RS symbols." *Id*. at [0041]. Moon goes into further detail, explaining how a processor in a UE

> can process a set of xCSI-RS signals received via receiver circuitry 510 during subframe n (e.g., via the last M symbols of the xPDSCH of subframe n). From the processed xCSI-RS symbols, processor 520 can generate a CSI report that indicates one or more CSI parameters (e.g., CQI, PMI, RI, etc.) associated with one or more Tx beams, which processor 520 can output for transmission by transmitter circuitry 530 as part of a UCI message sent via subframe n+k.

Id. at [0056]. In other words, as was the case in LTE with CSI-RS, the UE in Moon uses the xCSI-RS symbols to measure candidate beams.

95. Based on these disclosures in Moon, a POSITA would have understood Moon to teach Element 1(a).

Petitioners' Exhibit 1003, p. 64
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

[Element 1(a)(1)]: wherein the control signal triggers aperiodical transmission of the reference signal for beam measurement

96. The ’402 Patent claims a control signal that “triggers aperiodical transmission of the reference signal for beam measurement,” in contrast to the “semi-persistent” or “periodic” transmission of such reference signals described in the specification:

> The reference signal for beam measurement may be sent periodically, aperiodically, or semi-persistently. For periodic beam reference signal, the base station may configure a proper periodicity for measurement occasion(s) when UE would perform measurement.

Ex-1001 at 6:53–57. In contrast:

> an aperiodic beam reference signal **is transmitted when there is an associated *triggering* signal**. When the UE detects the associated triggering signal (e.g., a control signal, a control channel, an uplink grant, or a downlink assignment), the UE would realize there would be beam reference signal in an associated timing occasion, e.g., the rest of the symbol(s) in the same slot or the symbol(s) in the following slot.

Id. at 6:67–7:3 (emphasis added). A POSITA thus understands that an aperiodic reference signal is transmitted when a control signal triggers the transmission in an associated timing occasion. As quoted above, the ’402 Patent specification details

Petitioners' Exhibit 1003, p. 65
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

that an associated timing occasion is the rest of the symbol(s) in the same slot or the symbol(s) in the following slot. In other words, the reference signal is transmitted in the subframe in which it was triggered by the control signal.

97. A POSITA would understand that this limitation is met by Moon's disclosure of DCI that performs "triggering of xCSI-RS":

> For **dynamic *triggering of xCSI-RS*, the DCI (downlink control information) for the *triggering*** can include any of a variety of xCSI-RS configurations, such as the example configurations shown in Table 1, below. The configuration options can include options for xCSI-RS triggering itself since there is no xCSI-RS state, and signaling of the number of xCSI-RS symbols.

Ex-1005 at [0040] (emphasis added). As depicted in Table 1, and the corresponding embodiments, Moon's dynamic triggering initiates xCSI-RS transmission only for that subframe, by indicating between zero and two xCSI-RS symbols in the subframe. Ex-1005 at [0040], Table 1, [0044] ("In some aspects, one or more bits can be included in a DCI of **subframe n** to indicate the presence of xCSI-RS **in subframe n** . . . .") (emphasis added).

98. This contrasts with the concept of "periodic" reference signals in the '402 Patent in which the base station configures the UE for beam measurement based on "a proper periodicity." Ex-1001 at 6:56. It also contrasts with the concept of

Petitioners' Exhibit 1003, p. 66
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

"semi-persistent" reference signals in the '402 Patent. Ex-1001 at 7:24–28 ("Semi-persistent reference signal could be something in between (e.g., first being configured, start periodic transmission if there is an associated signal, and could modify or pause the transmission if another associated signal is detected."). Under the embodiments disclosed in Moon, a UE would not know whether it was to receive xCSI-RS until receiving the DCI in the first few OFDM symbols of a subframe (the xPDCCH), such as those emphasized in annotated Figure 3 above. *See* Section VIII(A)(1)(a), on Element 1(a), above. According to Table 1 of Moon and the corresponding disclosure, the DCI in those xPDCCH symbols could indicate either zero, one, or two xCSI-RS in the same subframe. Ex-1005 at [0040] and Table 1.

99. Thus, a POSITA would have understood Moon to teach "a control signal" *e.g.,* DCI, that "triggers aperiodical transmission of the reference signal for beam measurement."

[Element 1(a)(2)]: wherein the control signal includes a beam-related information for transmitting the reference signal for beam measurement

100. Moon discloses a method "wherein the control signal includes a beam-related information for transmitting the reference signal for beam measurement." For instance, dependent claim 2 of the '402 Patent discloses that the "beam-related information" can be an indication of "at least a beam on which the reference signal

Petitioners' Exhibit 1003, p. 67
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

for beam measurement is transmitted." Ex-1001 at 14:14-17 (claim 2). Similarly, the DCI in Moon can include the identification of a beam. Specifically, Moon discloses "an example DCI format can comprise some or all of the following for xCSI-RS: (a) CSI-RS configuration . . . ." Ex-1005 at [0046]. Moon further explains that "in the configuration, the eNB can let the UE know which beam ID, for example, for analog beam forming, is applied in each of symbols. This beam ID can correspond to xCSI-RS scrambling seed." *Id*. at [0041].

101. A POSITA knows that CSI reference signals consist of a pseudo-random sequence $r(m)$ mapped to complex-valued modulation symbols. *See* Appendix 9 (TS 36.211 v13.1.0) at 122-128, clause 6.10.5.2.

102. A POSITA knows pseudo-random sequences are generated by a software implemented pseudo-random sequence generator initialized by a "seed." Different seeds produce different sequences. In LTE Release 13, the CSI-RS seed depends on a several parameters including a parameter called "N_{ID}^{CSI}". *See* Appendix 9 (TS 36.211 v13.1.0) at 122, clause 6.10.5.1. Like other transmitted signals, CSI-RS are processed by a channel code. At the receiver, interfering signals based on other seeds are randomized, ensuring full utilization of the processing gain provided by the channel code to receive the intended CSI-RS. In Release 13, N_{ID}^{CSI} equals the cell ID N_{ID}^{cell}. *See* Appendix 9 (TS 36.211 v13.1.0) at 122, clause 6.10.5.1.

Petitioners' Exhibit 1003, p. 68
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

103. A POSITA understands that according to Moon, the CSI-RS seed may be used as beam ID to help distinguish a CSI-RS beam from other beams, similar to the way a CSI-RS in a cell is distinguished from CSI-RS in other cells, according to LTE Release 13.

104. Thus, via "the configuration," which is transmitted via DCI control signal, a POSITA would understand that the base station provides the UE a beam ID corresponding to an xCSI-RS scrambling seed. Moon also explicitly discloses that "at least one of the DCI message(s) and/or RRC message(s) can comprise some or all of the information indicated herein . . . number of CSI ports for each of the M symbols, whether the M symbols are associated with a single Tx beam or more than one Tx beam, **beam index(es) of the Tx beam(s)**, etc." Ex-1005 at [0051].

105. Providing a "beam ID" or "beam index" in the DCI, as Moon does, also solves the very problem that the '402 Patent purported to solve. *See* Section V, above; Ex-1001 at 7:44–8:26.

106. A POSITA would understand Moon's disclosure of a beam ID or beam index within the control signal to meet element 1(a)(2).

Petitioners' Exhibit 1003, p. 69
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

[Element 1(a)(3)]: wherein the control signal . . . indicates how many symbols are used to carry the reference signal for beam measurement

107. Moon discloses a method "wherein the control signal . . . indicates how many symbols are used to carry the reference signal for beam measurement":

> Additionally, in various aspects, the number of symbols employed for xCSI- RS transmission can vary. **The number of symbols for xCSI-RS can be configured by RRC or dynamic signaling (e.g., via xPDCCH, etc.)**. Depending on the number of symbols, the number of supported CSI-RS ports can be determined. In the example subframe of FIG. 3, one symbol can cover 8 antenna ports, and with two symbols, a total of 16 ports can be covered. The number of xCSI-RS ports can be configured by RRC, and the eNB can assign necessary symbols for CSI measurement, which can be done based at least in part on channel conditions.

Ex-1005 at [0039] (emphasis added). Moon provides more detail by explaining that the base station's processor can generate control messages indicating the number of xCSI-RS symbols (M) and the location of the xCSI-RS symbols:

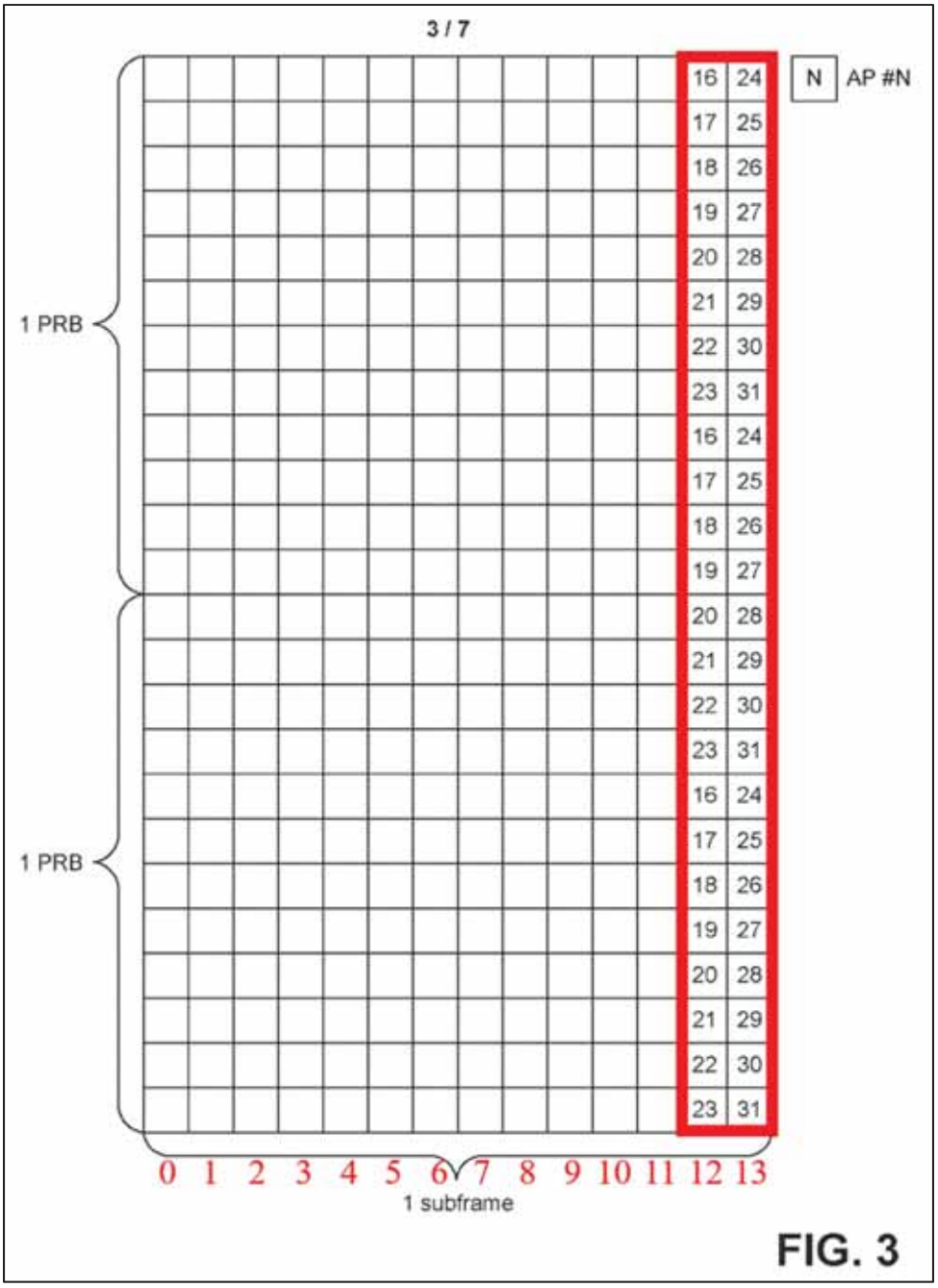
> can also generate one or more control messages that indicate an xCSI-RS configuration for subframe n, **where the xCSI-RS configuration can indicate the number of xCSI-RS symbols (M), and the location of the xCSI-RS symbols (e.g., symbols (10, 11), symbols (12, 13), symbol (11), etc.)**, and can optionally indicate additional

Petitioners' Exhibit 1003, p. 70
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

information. In some aspects, **information (e.g., the value of M, the location of the M symbols, etc.) can be explicitly indicated in the one or more control messages**, while in other aspects, it can be implicitly indicated (e.g., via an indication to employ a previously indicated xCSI-RS configuration, etc.).

Id. at [0049] (emphasis added). For instance, in Moon Figure 3, the control signal would indicate the number of xCSI-RS symbols (M) equals two, and the xCSI-RS is located in symbols 12 and 13:

Petitioners' Exhibit 1003, p. 71
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121



Id. at Figure 3 (annotated); *Id*. at [0038] ("In the example shown in FIG. 3, the xCSI-RS is located in the last two DL OFDM (orthogonal frequence division multiplexing) symbols.").

108. Moon explains that the "number of symbols employed for xCSI-RS transmission can vary" and that said number "can be configured by RRC or dynamic signaling (e.g., via xPDCCH, etc.)." Ex-1005 at [0039]. Table 1 of Moon provides an example of a variety of xCSI-RS configurations that can be included with the DCI for performing the dynamic signaling that indicates the number of symbols used by the xCSI-RS:

Table 1: CSI-RS Trigger Indication

3 bit CSI-RS Configuration	Indication
0	No xCSI-RS
1	One xCSI-RS symbol
2	Two xCSI-RS symbols from the same Tx beam (Same beam ID)
3	Two xCSI-RS symbols from different Tx beam (Different beam ID)
4	Two xCSI-RS symbols with zero powers in both symbols
5	Two xCSI-RS symbols with zero power in the second xCSI-RS symbol
6	Two xCSI-RS symbols with zero power in the first xCSI-RS symbol
7	Maintain the previous configuration

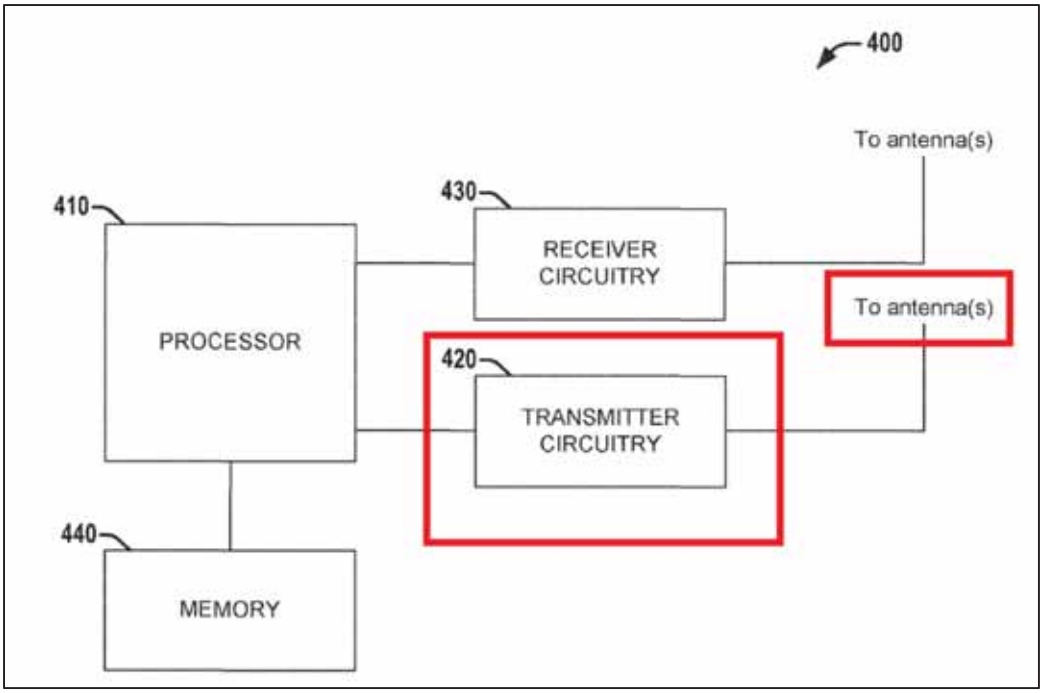
Id. at [0040], Table 1.

109. A POSITA would thus have understood Moon to teach this limitation.

Petitioners' Exhibit 1003, p. 73
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

[Element 1(b)]: the base station transmits the reference signal for beam measurement to the UE.

110. Moon discloses a method in which "the base station transmits the reference signal for beam measurement to the UE": "In some aspects, processor 410 can generate (and transmitter circuitry 420 can transmit) xCSI-RS for some or all of the M symbols of xCSI-RS." Ex-1005 at [0053] (where "RS" is "reference signal"). Figure 4 of Moon depicts this transmitter circuitry and the corresponding antenna(s) for transmitting the xCSI-RS:



Id. at Figure 4 (annotated).

111. In addition, Moon discloses that a UE receives the xCSI-RS transmitted by the base station:

> Processor 520 can process a set of one or more xCSI-RS configuration messages (e.g., DCI message(s) and/or RRC message(s)) received via receiver circuitry 510. Based on the received set of xCSI-RS configuration messages, processor 520 can determine xCSI-RS configuration parameters for a given subframe (e.g., subframe n). These xCSI-RS configuration parameters can comprise one or more of the characteristics indicated herein as configurable for xCSI-RS, such as the number of symbols for xCSI-RS (e.g., M = 0, 1, 2, etc.), which symobls [*sic*] are configured for xCSI- RS, CRG type (e.g., candidate beam measurement, interference measurement, etc.), whether xCSI-RS will be received from one or more Tx beams that can be from one or more TPs, etc. In some aspects, the set of xCSI-RS configuration messages can comprise a compact format DCI message that indicates that the xCSI-RS configuration parameters remain the same as previously configured.

Id. at [0055].

112. A POSITA would thus have understood Moon to teach this limitation.

2. Claim 2

[Element 2pre]: The method of claim 1, wherein

113. Moon anticipates claim 1 for the reasons above.

Petitioners' Exhibit 1003, p. 75
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

[Element 2]: the beam-related information indicates at least a beam on which the reference signal for beam measurement is transmitted.

114. For the reasons under Element 1(a)(2) ("wherein the control signal includes a beam-related information for transmitting the reference signal for beam measurement"), Moon similarly anticipates corresponding Element 2.

3. Claim 3

[Element 3pre]: The method of claim 1, wherein

115. Moon anticipates claim 1 for the reasons above.

[Element 3]: wherein the beam-related information indicates a first beam, and wherein the reference signal for beam measurement is transmitted on at least a refined beam of the first beam.

116. Moon discloses a control signal that includes "beam-related information" and in which "the beam-related information indicates a first beam, and wherein the reference signal for beam measurement is transmitted on at least a refined beam of the first beam." As explained by the '402 Patent specification, a "beam reference signal" is an example of a refined beam. Specifically, the '402 Patent describes the beam refinement process from both the perspective of the UE and the base station:

> A first general concept of this invention is that when a UE requests beam refinement or adjustment, the UE would indicate which beam(s) or beam(s) from which TRP(s) would require beam

Petitioners' Exhibit 1003, p. 76
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

refinement/adjustment associated with the request. **An example of requesting beam refinement or adjustment would be to request beam reference signal**.

A general second concept of this invention is that when a base station triggers beam refinement or adjustment for a UE, the base station would indicate that beam refinement or adjustment is performed on which beam(s) or beam(s) from which TRP(s) associated with the trigger. **An example of triggering beam refinement or adjustment for a UE would be to send an aperiodic trigger for beam reference signal to the UE**.

Ex-1001 at 8:13–26 (emphasis added). In these disclosures, the '402 Patent makes clear that a beam reference signal is transmitted on a refined beam.

117. As such, the same "beam index" disclosure that anticipates claim elements 1(a)(2) and 2, also anticipates claim element 3. Specifically, Moon discloses that "at least one of the DCI message(s) and/or RRC message(s) can comprise some or all of the information indicated herein . . . number of CSI ports for each of the M symbols, **whether the M symbols are associated with a single Tx beam or more than one Tx beam**, **beam index(es) of the Tx beam(s)**, etc." Ex-1005 at [0051] (emphasis added). In other words, the M symbols of the xCSI-RS can be associated with one or more "Tx beam(s)," or transmission beams, and the DCI and/or RRC messages can indicate which beam index(es) of the transmission beam

Petitioners' Exhibit 1003, p. 77
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

the M symbols are associated with. By providing that "beam index" in the DCI or RRC, Moon teaches a "beam-related information" associated with a "first beam."

118. Moon also teaches "massive MIMO." Ex-1005 at [0036]. A POSITA knows massive MIMO supports beams and refined beams through the use of arrays with a large number of antennas. And a POSITA would understand that the xCSI-RS in Moon are transmitted on "a refined beam" of that "first beam," in the same way that the '402 Patent specification describes that a "beam reference signal" is a refined beam. Ex-1001 at 8:13–26. A POSITA would also understand Moon's claims to meet this limitation:

> 11. The apparatus of any of claims 1-6, wherein M is at least two, and wherein the one or more control messages indicate whether each of the final M symbols are beamformed from a common beam or from two or more different beams.
>
> …
>
> 16. The machine readable medium of claim 14, wherein each of the last M symbols of the xPDSCH are scheduled for xCSI-RS signals associated with distinct transmit beams.

Ex-1005 at Claim 11, Claim 16.

119. A POSITA would thus have understood Moon to teach this limitation.

Petitioners' Exhibit 1003, p. 78
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

4. Claim 4

[Element 4pre]: The method of claim 1, wherein

120. Moon anticipates claim 1 for the reasons above.

[Element 4]: the control signal is transmitted via a control channel.

121. As explained in element 1(a) above, the DCI in Moon is transmitted via the xPDCCH or 5G Physical Downlink Control Channel. Ex-1005 at [0038] and [0050]. As such, a POSITA would have understood Moon to teach this limitation.

5. Claim 12

[Element 12Pre(1)]: A base station, comprising:

122. To the extent element 12Pre(1) is considered limiting, Moon anticipates claim element 12Pre(1) for the reasons described above with respect to the preamble of claim 1.

[Element 12pre2]: a control circuit; a processor installed in the control circuit; and a memory installed in the control circuit and operatively coupled to the processor; wherein the processor is configured to execute a program code stored in the memory to:

123. To the extent element 12Pre(2) is considered limiting, Moon anticipates claim element 12Pre(2) for the reasons described above with respect to the preamble of claim 1.

Petitioners' Exhibit 1003, p. 79
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

[Element 12(a)]: transmit to a UE a control signal associated with a reference signal for beam measurement

124. Moon anticipates element 12(a) for the reasons above with respect to corresponding element 1(a).

[Element 12(a)(1)]: wherein the control signal triggers aperiodical transmission of the reference signal for beam measurement

125. Moon anticipates element 12(a)(1) for the reasons above with respect to corresponding element 1(a)(1).

[Element 12(a)(2)]: and wherein the control signal includes a beam-related information for transmitting the reference signal for beam measurement

126. Moon anticipates element 12(a)(2) for the reasons above with respect to corresponding element 1(a)(2).

[Element 12(a)(3)]: and wherein the control signal . . . indicates how many symbols are used to carry the reference signal for beam measurement;

127. Moon anticipates element 12(a)(3) for the reasons above with respect to corresponding element 1(a)(3).

[Element 12(b)]: and transmit the reference signal for beam measurement to the UE.

128. Moon anticipates element 12(b) for the reasons above with respect to corresponding element 1(b).

Petitioners' Exhibit 1003, p. 80
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6. Claim 13

[Element 13Pre]: The base station of claim 12, wherein

129. Moon anticipates element 13Pre for the reasons above with respect to claim 12.

[Element 13]: the beam-related information indicates at least a beam on which the reference signal for beam measurement is transmitted.

130. Moon anticipates element 13 for the reasons above with respect to claim 2, which is identical.

7. Claim 14

[Element 14Pre]: The base station of claim 12, wherein

131. Moon anticipates element 14Pre for the reasons above with respect to claim 12.

[Element 14]: the beam-related information indicates a first beam, and wherein the reference signal for beam measurement is transmitted on at least a refined beam of the first beam.

132. Moon anticipates element 14 for the reasons above with respect to claim 3, which is identical.

8. Claim 15

[Element 15Pre]: The base station of claim 12, wherein

133. Moon anticipates element 15Pre for the reasons above with respect to claim 12.

Petitioners' Exhibit 1003, p. 81
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

[Element 15]: the control signal is transmitted via a control channel.

134. Moon anticipates element 15 for the reasons above with respect to claim 4, which is identical.

B. Ground #2: Claims 1–4 and 12–15 are Obvious Under 35 U.S.C. § 103(a) by Moon

1. A POSITA Would Have Modified Moon

a. Aperiodical Triggering

135. To the extent the triggering in Moon is not considered "aperiodical" triggering (elements [1(a)(1)] and [12(a)(1)]), a POSITA would have been motivated to implement aperiodical triggering.

136. Before the '402 Patent, RAN Working Group 1 at 3GPP was focused on developing control signaling for "aperiodic" or "dynamic" transmission of CSI-RS. Ex-1015 (R1-165642); Ex-1007, ¶¶ 75–79. Before the '402 Patent's priority date, 3GPP merged the two concepts, to the extent any differences ever existed. Indeed, at the time, 3GPP participants described "aperiodic CSI-RS" as "E.g., One-shot CSI-RS transmission with transmission on the same subframe as the triggering subframe." Ex-1015 (R1-165642) at 2. Moon itself discloses triggering CSI-RS on the same subframe as the triggering subframe. Ex-1005 at [0038], [0040], Figure 3. And 3GPP participants used the terms "dynamic" and "aperiodic" interchangeably. Ex-1013 (R1-162686) at 1 ("CSI-RS resource allocation can be performed

Petitioners' Exhibit 1003, p. 82
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

dynamically. That is, CSI-RS is transmitted by the eNB and measured by the UE only when needed, i.e., aperiodically.").

137. As such, to the extent there is any difference between aperiodic and dynamic triggering of reference signals for beam measurement (such as Moon's xCSI-RS), a POSITA would have been motivated to adapt the system of Moon to utilize "aperiodic" triggering in order to render the system compatible with 4G and 5G telecommunication systems. This is a small, trivial change (if any).

b. Refined Beam

138. To the extent the "beam-related information indicat[ing] a first beam," in Moon's control signal (e.g., DCI) does not disclose xCSI-RS "transmitted on at least a refined beam of the first beam" (elements [3] and [14]), a POSITA would have been motivated to modify Moon to implement such a system. As described above, the '402 Patent makes clear that transmission of a "beam reference signal for beam measurement," such as Moon's xCSI-RS, is an example of beam refinement. *See* Section VIII(A)(3), above; Ex-1001 at 8:13–26. And Moon discloses "DCI message(s) and/or RRC message(s) can comprise some or all of the information indicated herein . . . number of CSI ports for each of the M symbols, **whether the M symbols are associated with a single Tx beam or more than one Tx beam**, **beam index(es) of the Tx beam(s)**, etc." Ex-1005 at [0051] (emphasis added).

Petitioners' Exhibit 1003, p. 83
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

139. Nonetheless, to the extent such disclosure does not meet elements [3] and [14], it would have been obvious to modify Moon to meet those claim elements and a POSITA would have been motivated to do so. For example, Moon teaches "massive MIMO." Ex-1005 at [0036]. A POSITA knows massive MIMO supports beams and refined beams through the use of arrays with a large number of antennas. Additionally, Moon teaches UE beam refinement. Ex-1005 at [0036]. A POSITA knows that UE beam refinement (as disclosed by Moon) may be part of a procedure that refines both transmit and receive beams: "Since the refined TRP beam is expected to be spatially correlated with the previous TRP beam, UE can receive both of the TRP beams before and after refinement with the same UE beam. And UE beam can be further refined using procedure P-3." Ex-1006 (R1-1609515). In another example, Moon discusses the need to determine "a best and a second best Tx beams," which the UE can then "feedback candidate Tx beam IDs for multiple xCSI-RS symbols." Ex-1005 at [0041]. Determining a "best beam" and "second best" beam is an example of beam refinement. It also serves the same purpose as the beam refinement discussed in the '402 Patent's specification: "It is possible for UE to request the beam reference signal (e.g., an aperiodic beam reference signal) if UE detects there is a beam quality change, UE mobility, UE rotation or any other case when beam refinement or adjustment is required." Ex-1001 at 7:29–32. A POSITA

Petitioners' Exhibit 1003, p. 84
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

would thus have been motivated to meet elements [3] and [14] using Moon's signaling system.

140. Lastly, as set forth in Ground 3, below, by the time of the '402 Patent's priority date, 3GPP participants had already discussed the need to utilize CSI-RS for beam refinement in 4G and 5G telecommunications systems. Moon discloses that its system is compatible with such technologies, and so, to the extent Moon does not disclose elements [3] and [14], a POSITA would have been further motivated to modify Moon to meet those limitations. Ex-1005 at [0018] ("For example, in some embodiments, the baseband circuitry 104 may include a second generation (2G) baseband processor 104a, third generation (3G) baseband processor 104b, fourth generation (4G) baseband processor 104c, and/or other baseband processor(s) 104d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.).").

2. Independent Claims

141. Moon renders obvious claims 1 and 12. Moon discloses each element of these claims. *See* Sections VIII(A)(1) and (5), above. To the extent Moon does not disclose elements [1(a)(1)] and [12(a)(1)], it would have been obvious to modify the system for the reasons above to meet those limitations. It would have been obvious to make the "dynamic" signaling of Moon aperiodic.

Petitioners' Exhibit 1003, p. 85
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

3. Dependent Claims

142. Moon also renders obvious claims 2–4 and 13–15. Moon discloses each element of these claims. *See* Sections VIII(A)(2)–(4) and (6)–(8), above. To the extent Moon does not disclose elements [3] and [14], it would have been obvious to a POSITA to modify Moon to meet those elements (*e.g.*, to transmit the reference signal on a refined beam of the first beam identified by the control signal) based on the motivations above.

C. Ground #3: Claims 3 and 14 are Obvious Under 35 U.S.C. § 103(a) by Moon over R1-1609515.

143. As set forth in Grounds 1 and 2, Moon discloses "beam refinement" as claimed in the '402 Patent. *See*, *e.g.*, Ex-1001 at 8:23-26 ("An example of triggering beam refinement or adjustment for a UE would be to send an aperiodic trigger for beam reference signal to the UE."). Nonetheless, as explained herein, if it is determined that Moon does not disclose the "beam refinement" claims (3 and 14), then it is my opinion that it would have been obvious to modify Moon in view of R1-1609515 to meet claims 3 and 14. As such, my opinions in Ground 3 pertain only to the scenario in which it is found Moon does not already anticipate or render obvious the "beam refinement" claims (3 and 14).

Petitioners' Exhibit 1003, p. 86
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

1. A POSITA Would Have Combined Moon with R1-1609515

a. Moon and R1-1609515 Are From the Same Field of Endeavor and Are Directly Related

144. A POSITA would have been motivated to combine the teachings of Moon and R1-1609515. Both are disclosures from Intel. Both disclosures address design aspects of reference signals for beamforming in 5G new radio (NR). For example, "The present disclosure relates to wireless technology, and more specifically to techniques for communicating control signaling for Channel State Information (CSI) in fifth generation (5G) systems." Ex. 1005 at [0002]. "FIG. 4 is a block diagram illustrating a system that facilitates control signaling for fifth generation (5G) Channel State Information (xCSI) Reference Signals (xCSI-RSs)." Id. at [0007]. "The millimeter wave can be used in 5G (Fifth Generation) systems to achieve a wider bandwidth so that user throughput can be increased." Id. at [0036]. "In 5G systems, the downlink (DL) transmission in a self-contained subframe (e.g., those shown in FIG. 2) can comprise xCSI-RS scheduled via dynamic signaling." Id. at [0038]. Similarly, R1-1609515 also addresses reference signals and beamforming in 5G/NR: "Since more than one antenna panel is used at UE side in NR systems, the identified top TRP beams maybe better received by either single UE panel or multiple UE panels. As such, the reference signal to enable beam

Petitioners' Exhibit 1003, p. 87
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

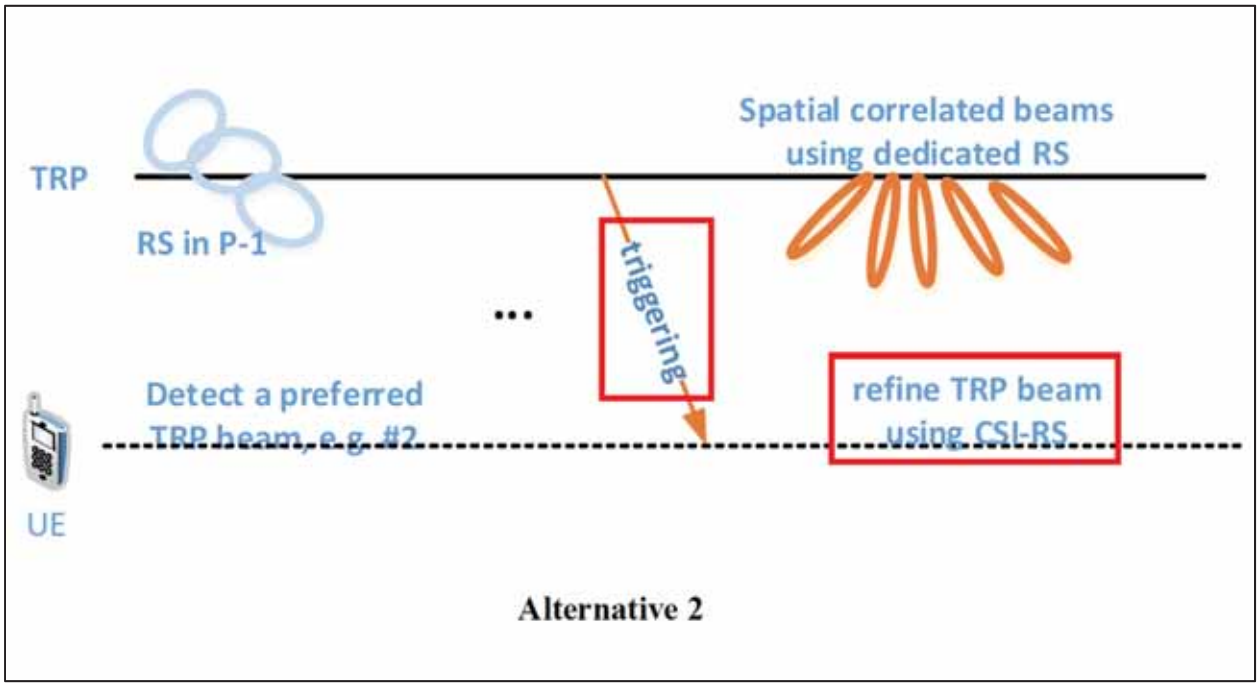
switching could be transmitted during one OFDM symbol or several OFDM symbols...” Ex. 1006 at 5.

145. Before the ’402 Patent, it would have been obvious, beneficial, and predictable to utilize Moon’s teachings regarding the use of control signaling to trigger transmission of xCSI-RS with R1-1609515’s concept of beam refinement — for example, in order to effectuate the beam change discussed in R1-1609515 at “Beam Refinement Scenario 2.” Ex-1006 at 1-3. Additionally, it would have been obvious, beneficial and predictable to utilize Moon’s teachings regarding the refinement of UE beams (Ex-1005 at [0036]) with R1-1609515’s concept of TRP beam refinement, particularly as R1-1609515 teaches to combine TRP and UE beam refinement procedures: “Since the refined TRP beam is expected to be spatially correlated with the previous TRP beam, UE can receive both of the TRP beams before and after refinement with the same UE beam. And UE beam can be further refined using procedure P-3.” Ex-1006 at 2.

146. As an initial matter, one of ordinary skill in the art when considering the teachings of Moon would have also considered the teachings of R1-1609515, as they are analogous prior art pertaining to the same field of endeavor, namely, beamforming in a 5G network.

Petitioners' Exhibit 1003, p. 88
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

147. R1-1609515 explicitly discloses refining the beam from a transmission point (e.g., an eNB) using CSI-RS via a "triggering" mechanism:



Ex-1006 at Figure 2 (annotated). Given Moon's lengthy discussion of said triggering mechanism for 5G CSI-RS using control signaling such as DCI and/or RRC messages, a POSITA would have been motivated to use Moon's teachings to implement the beam refinement process disclosed in R1-1609515.

b. A POSITA Would Have Readily Observed that Moon and R1-1609515 Address Methods Related to Large Arrays

148. A POSITA would have been motivated to combine the teachings of Moon and R1-1609515. Both disclosures address design aspects related to large arrays. For example, "The new Channel State Information Reference Signal (CSI-

Petitioners' Exhibit 1003, p. 89
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

RS) can be designed to support the downlink (DL) Transmission (Tx) beams measurement and selection in this new frame structure, by which the massive MIMO can be applied." Ex. 1005 at [0036]. A POSITA would have understood that with "massive MIMO" it is possible to generate beams and refined beams. Similarly, R1-1609515 discloses "multiple antenna panels." For example, "With multiple antenna panels at TRP side, this implies a FDM structure of the RS for TRP beam refinement to reduce the refinement latency." Ex. 1006 at 2. A POSITA understands that a large array may be divided into panels, which can be used to generate beams and refined beams.

c. A POSITA Would Have Readily Observed that Moon and R1-1609515 Address Beam Measurements.

149. A POSITA would have been motivated to combine the teachings of Moon and R1-1609515. Both disclosures address design aspects related to beam measurements. For example, "The new Channel State Information Reference Signal (CSI-RS) can be designed to support the downlink (DL) Transmission (Tx) beams measurement and selection in this new frame structure, by which the massive MIMO can be applied." Ex-1005 at [0036]. "These xCSI-RS configuration parameters can comprise one or more of the characteristics indicated herein as configurable for xCSI-RS, such as the number of symbols for xCSI-RS (e.g., M = 0, 1, 2, etc.), which symbols are configured for xCSI-RS, CRG type (e.g., candidate beam measurement,

Petitioners' Exhibit 1003, p. 90
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

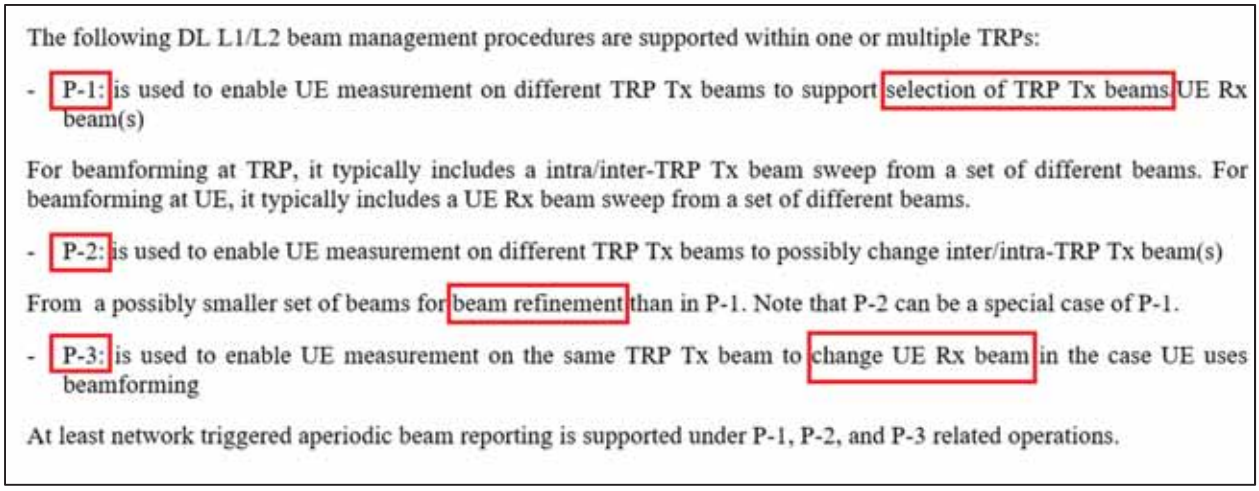
interference measurement, etc.), whether xCSI-RS will be received from one or more Tx beams that can be from one or more TPs, etc." Ex-1005 at [0055]. Similarly, R1-1609515 relates to beam measurement: "In addition, the original TRP should inform UE SS information of the target TRPs so that UE could distinguish scenario 3 from scenario 2 to perform beam measurement." Ex-1006 at 5. A POSITA thus would have understood Moon and R1-609515 to teach methods directed toward beam measurement.

d. A POSITA Would Have Desired to Apply the Solutions in R1-1609515 to Moon to Perform TRP Beam Refinement

150. A POSITA would have been familiar with 3GPP efforts to develop methods for beam selection. For example, a POSITA would have been familiar with the technical report TR 38.802 v1.0.0 (2016-11) "Study on New Radio Access Technology" (R1-1613687) published in November 2016. Appendix 10. The report utilizes the same P-1, P-2, P-3 terminology for beam management used by R1-

Petitioners' Exhibit 1003, p. 91
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

1609515:



The following DL L1/L2 beam management procedures are supported within one or multiple TRPs:

- P-1: is used to enable UE measurement on different TRP Tx beams to support selection of TRP Tx beams/UE Rx beam(s)

For beamforming at TRP, it typically includes a intra/inter-TRP Tx beam sweep from a set of different beams. For beamforming at UE, it typically includes a UE Rx beam sweep from a set of different beams.

- P-2: is used to enable UE measurement on different TRP Tx beams to possibly change inter/intra-TRP Tx beam(s)

From a possibly smaller set of beams for beam refinement than in P-1. Note that P-2 can be a special case of P-1.

- P-3: is used to enable UE measurement on the same TRP Tx beam to change UE Rx beam in the case UE uses beamforming

At least network triggered aperiodic beam reporting is supported under P-1, P-2, and P-3 related operations.

Appendix 10 (TR 38.802 at 10 (annotated)).

151. While Moon was published a few months earlier than the report, and does not use the P-1, P-2, P-3 terminology, it does teach methods which are in effect at least P-1 and P-3. For example, Moon discloses beam selection: "The new Channel State Information Reference Signal (CSI-RS) can be designed to support the downlink (DL) Transmission (Tx) **beams** measurement and **selection** in this new frame structure, by which the massive MIMO can be applied." Ex-1005 at [0036] (emphasis added). A POSITA understands that beam selection is a P-1 procedure.

152. Moon also discloses a method to change UE Rx beam: "In addition, the new Beam Refinement Reference Signal (BRRS) can be designed to support **UEs performing reception (Rx) beam direction alignment**." Ex-1005 at [0036]

Petitioners' Exhibit 1003, p. 92
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

(emphasis added). A POSITA understands that this Moon disclosure is a P-3 procedure.

153. R1-1609515 expressly discloses how to perform beam refinement by implementing a P-2 procedure. For example, "**P-2**: is used to enable UE measurement on different TRP Tx beams to possibly change inter/intra-TRP Tx beam(s). From a possibly smaller set of beams for **beam refinement** than in P-1." Ex-1006 at 1 (emphasis added).

154. In light of the fact that Moon already teaches at least P-1 and P-3 procedures, a POSITA would have desired to apply the P-2 procedure solution in R1-1609515 to Moon to perform TRP/base station beam refinement.

e. The Modification of Moon With R1-1609515 Would Have Been Obvious to a Person of Ordinary Skill in the Art

155. Given all of the above, modifying Moon using R1-1609515's teachings would have been obvious. As I already discussed, each reference: (1) comes from the same field of endeavor and are directly related; (2) address methods related to large antenna arrays; (3) address beam measurements; and (4) address beam refinement. A POSITA would have wanted to solve the obvious problem of beam tracking when using the narrow beams utilized in massive MIMO systems such as those disclosed by Moon.

Petitioners' Exhibit 1003, p. 93
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

156. Because a POSITA would have wanted to modify Moon with R1-1609515 and would have reasonably expected to succeed in doing so, the modification would have been obvious to a POSITA.

2. Moon modified by R1-1609515 Renders Claims 3 and 14 Obvious

[Element 3Pre]: The method of claim 1, wherein:

157. Moon discloses the preamble for the reasons discussed above in connection with element 3pre.

[Element 3]: the beam-related information indicates a first beam, and wherein the reference signal for beam measurement is transmitted on at least a refined beam of the first beam;

158. To the extent that Moon does not anticipate element 3, a POSITA would find it obvious to combine Moon's teachings with R1-1609515 to perform the element. As explained by Moon, "at least one of the DCI message(s) and/or RRC message(s) can comprise some or all of the information indicated herein . . . number of CSI ports for each of the M symbols, whether the M symbols are associated with a single Tx beam or more than one Tx beam, **beam index(es) of the Tx beam(s)**, etc." Ex-1005 at [0051] (emphasis added). A POSITA would understand that the "Tx beam(s)" of Moon correspond to the "TRP beams" in R1-1609515. For example, in Table 1, Moon teaches that two xCSI-RS symbols can come from

Petitioners' Exhibit 1003, p. 94
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

different Tx beams with different beam ID (for example, one beam is the "first beam," while the other beam is the "refined beam"):

Table 1: CSI-RS Trigger Indication

3 bit CSI-RS Configuration	Indication
0	No xCSI-RS
1	One xCSI-RS symbol
2	Two xCSI-RS symbols from the same Tx beam (Same beam ID)
3	Two xCSI-RS symbols from different Tx beam (Different beam ID)
4	Two xCSI-RS symbols with zero powers in both symbols
5	Two xCSI-RS symbols with zero power in the second xCSI-RS symbol
6	Two xCSI-RS symbols with zero power in the first xCSI-RS symbol
7	Maintain the previous configuration

Ex-1005 at Table 1 (annotated). Similarly, claim 28 of Moon describes an apparatus in which "each of the M symbols associated with xCSI-RS in the subframe n are associated with a distinct transmit beam."

159. Thus, the "beam index" included in Moon's DCI and/or RRC control signal constitutes "beam-related information" that "indicates a first beam." And as depicted in R1-1609515, the 5G CSI-RS are transmitted on "a refined beam of the first beam." *See* annotated R1-1609515 Figure 2, above.

Petitioners' Exhibit 1003, p. 95
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

160. A POSITA would thus have understood the Moon/R1-1609515 combination to teach this limitation.

[Element 14Pre]: The base station of claim 12, wherein:

161. Moon discloses the preamble for the reasons discussed above in connection with element 14pre.

[Element 14]: the beam-related information indicates a first beam, and wherein the reference signal for beam measurement is transmitted on at least a refined beam of the first beam;

162. For the reasons discussed above in connection with element 3, the Moon/R1-1609515 combination renders obvious corresponding element 14.

IX. Conclusion

163. As discussed above, it is my opinion that the challenged claims of the '402 Patent are not patentable.

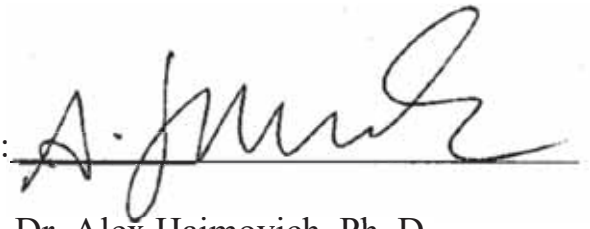
164. In signing this declaration, I recognize that the declaration will be filed as evidence in a contested proceeding before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-examination in the proceeding and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

Petitioners' Exhibit 1003, p. 96
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

165. I reserve the right to supplement my opinions in the future to respond to any arguments that Patent Owner raises and to account for new information as it becomes available to me.

166. I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Executed on this 28th day of June 2024.

By: 

Dr. Alex Haimovich, Ph. D.

Petitioners' Exhibit 1003, p. 97
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

APPENDIX 1

Overview of 3GPP Release 8 V0.3.3 (2014-09)

Contents

Foreword 6

1 Scope 7

2 References 7
2.1 Specifications 7
2.2 Tdocs 7
2.3 Work Plan, Work Items and Study Items 8
2.4 Change Request database 8

3 Abbreviations 8

4 3GPP System Architecture Evolution Specification-Evolved Packet System (SAES) UID_320005 9
4.1 Requirements for evolution of the 3GPP system architecture (AIPN-SAE) UID_320022 11
4.2 High level and common (for all accesses) functions (EPS-ComF) UID_370005 11
4.3 SAE for LTE access (SAES-LTE) UID_350025 15
4.4 SAE for Interoperation between LTE and legacy cellular PS accesses UID_350026 18
4.5 SAE for support for non-3GPP accesses (SAES-SA-FP_n3GPP) UID_350027 19
4.5.1 Conformance Test Aspects – Mobility management based on DSMIPv6 UID_450022 20
4.6 Single Radio Voice Call Continuity for 3GPP (SAES-SRVCC) UID_350030 21
4.7 Voice Call Continuity for CDMA2000 1X (SAES-VCC_1X) UID_360020 22
4.8 SAE impacts on IMS (SAES-SA_IMS) UID_350031 22
4.9 CS Fallback in EPS (SAES-CSFB) UID_390036 23
4.10 System enhancements for the use of IMS services in local breakout (SAES-IMS_LBO) UID_390039 24
4.11 EPC Data Definitions (EPC-OAM) UID_390010 25
4.12 EPC Charging (EPC-CH) UID_380038 27
4.13 Domain Name System Procedures for Evolved Packet System (DEPS) UID_400004 28
4.14 IWF between MAP based and Diameter based interfaces (SAES-MAP2Diam) UID_410007 29
4.15 CT6 aspects of SAE UID_390121 29
4.15.1 Test interworking of LTE Terminals with the USIM UID_420018 30
4.15.2 Test interworking of ISIM terminals with IMS UID_490015 31

5 3G Long Term Evolution - Evolved Packet System RAN part (LTE) UID_20068 32
5.1 Long Term Evolution of the 3GPP radio technology 33
5.1.1 Study phase and requirements 33
5.1.2 Specification phase and achievements 35
5.1.3 Radio Interface 37
5.1.4 Mobility and Radio Resource Management 41
5.1.5 Support for self configuration and optimization 41
5.1.6 System Architecture Evolution 41
5.2 LTE – Physical Layer (LTE-Phys) UID_330018 43
5.3 LTE – Radio Interface Layer 2 and 3 Protocol Aspect (LTE-L23) UID_330019 44
5.4 LTE – eUTRAN Interfaces (LTE-interfaces) UID_330020 44
5.5 LTE – RF Radio Transmission/Reception, System Performance Requirements and Conformance Testing (LTE-RF) UID_330021 45
5.6 LTE FDD repeaters (LTE-Repeaters) UID_370046 46
5.7 LTE – Terminal Conformance Test Specifications (LTE-UEConTest) UID_25029 46
5.8 E-UTRAN Data Definitions (E-UTRAN-OAM) UID_390001 47
5.8.1 E-UTRAN Network Resource Model (NRM) Integration Reference Point (IRP) UID_380036 47
5.8.2 Performance measurements for E-UTRAN UID_390002 48
5.8.3 Key Performance Indicators (KPIs) for E-UTRAN UID_390003 49
5.8.4 Subscriber and Equipment Trace for eUTRAN and EPC UID_370001 50
5.9 Self-Organizing Networks (SON) (LTE_SON-OAM) UID_390004 51
5.9.1 SON Concepts and requirements UID_390104 51

Petitioners' Exhibit 1003, p. 99
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.9.2 Self-Establishment of eNBs UID_390005 ... 52
5.9.3 SON Automatic Neighbour Relations (ANR) List Management UID_390006 ... 53

6 Home NodeB / eNodeB ... 54
6.1 Home NodeB / eNodeB (HomeNB) UID_380065 ... 54
6.1.1 Stage 1 for Home NodeB / eNodeB UID_380066 ... 54
6.1.2 Support of Closed Subscriber Group (CSG) UID_420019 ... 55
6.1.3 CSG and Idle Mode Mobility for LTE Home eNodeB UID_410012 ... 56
6.1.4 CSG and Idle Mode Mobility for 3G Home NodeB UID_410013 ... 56
6.2 UTRA HNB UID_390033 ... 57
6.2.1 Support of UTRA HNB UID_400053 ... 57
6.2.2 UTRAN Architecture for 3G HNB UID_400054 ... 58
6.2.3 FDD Home NodeB RF requirements UID_390034 ... 59
6.2.3.1 Conformance Test Aspects – UTRA HNB (FDD) UID_430023 ... 59
6.2.4 3G Home NodeB OAM&P (type 1 definition) UID_420037 ... 60

7 IP Multimedia Subsystem (IMS) ... 61
7.1 IMS Centralized Service Control (ICSRA) UID_370025 (open IETF) ... 62
7.2 IMS Multimedia Telephony and Supplementary Services (IMSTSS) UID_370059 (open IETF) ... 64
7.3 3GPP2 Input to Common IMS (CIMS_3GPP2) UID_390035 ... 70
7.4 IMS Enhancements for support of Packet Cable access (PktCbl) UID_350005 ... 73
7.5 IMS System enhancements for corporate network access (IMS_Corp) UID_360012 ... 77
7.6 Maintenance of TISPAN documentation (MAINTISP) UID_380069 ... 78
7.7 IMS Service Continuity (IMS-Cont) UID_390056 ... 80
7.8 Security Enhancements for IMS (IMS-Sec) UID_370078 ... 82
7.9 IMS initiated and controlled PSS and MBMS User Service (IMS_PSS_MBMS_US) UID_34046 ... 84
7.10 Multimedia interworking between IMS and CS networks (MIW-IMS) UID_713024 ... 86
7.11 IMS Stage-3 IETF Protocol Alignment (IMSProtoc2) UID_360029 (open IETF) ... 87
7.12 Interworking between User-to-User Signalling (UUS) and SIP (UUSIW) UID_380014 (open IETF) ... 88
7.13 Support of Overlap signalling (Overlap) UID_380018 ... 89
7.14 AS/MRFC stage 2 and 3 work (MRFC_TS) UID_380035 ... 90
7.15 IMS Restoration Procedures (IMS_RP) UID_400012 ... 91
7.16 IMS Application Server Service Data Descriptions for AS interoperability (IMS_ASIO) UID_410003 ... 91

8 WLAN interworking with a 3GPP system (I-WLAN) ... 93
8.1 I-WLAN Network Selection Principle (IWLANNSP) UID_340030 ... 93
8.2 Mobility between 3GPP-WLAN Interworking and 3GPP Systems (IWLAN_Mob) UID_370049 ... 94
8.2.1 Conformance Test Aspects – Mobility between 3GPP WLAN Interworking and 3GPP Systems UID_460006 ... 94

9 Pan-European in-vehicle emergency call (eCall) ... 96
9.1 eCall Data Transfer (EData) UID_330005 ... 96
9.2 Study on Transferring of emergency call data – in-band modem solution (eCALLIBMS) UID_360015 ... 98
9.3 eCall data transfer Phase 2: Comparison of alternative in-band modem solutions and standardization of one in-band modem solution (eCall_Phase2) UID_34042 ... 99
9.4 eCall Conformance Testing UID_450001 ... 100
9.5 Conformance Test Aspects - non-modem procedures of eCall sessions in UTRA UID_450023 ... 100

10 SA1 Features ... 102
10.1 Enhancements for Voice Group Call Service (VGCS) Applications (EVA) UID_7042 ... 102
10.2 Personal Network Management (PNM) UID_31081 ... 104
10.2.1 Key establishment between a UICC hosting device and a remote device (PNM) UID_340010 ... 105
10.3 IP Interconnection of Services (IPinterc) UID_380060 ... 106
10.3.1 Stage 1 for IP Interconnection of Services UID_380061 ... 106
10.3.2 System enhancements for interconnection interfaces between two IMSs (IMS_NNI) UID_7005 ... 107
10.3.2 SA5 Charging harmonization for NGN between 3GPP and ATIS-TMOC UID_330011 ... 108
10.4 Support of (G)MSC-S – (G)MSC-S Nc Interface based on the SIP-I protocol (SIP_Nc) UID_360025 ... 109
10.5 Earthquake and Tsunami Warning System Requirements and Solutions (ETWS) UID_370051 ... 111
10.5.1 Conformance Test Aspects – UMTS Earthquake and Tsunami Warning System FDD UID_440011 ... 112
10.6 In Case of Emergency (ICE) numbers storage and easy access on UICC UID_380059 ... 114
10.7 Local Charging Zone Requirements (LCZR) UID_330006 ... 115
10.8 Customized Alerting Tone (CAT) service UID_340029 ... 116
10.9 Service-Level Interworking for Messaging Services (MESSIW) UID_340031 ... 118
10.10 Multimedia Priority Service (PRIOR) UID_340044 ... 119
10.11 Open Service Access (OSA8) UID_360010 ... 120

Petitioners' Exhibit 1003, p. 100
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10.12 Paging Permission with Access Control (PPACR) UID_360032 123
10.12.1 Conformance Test Aspects – Paging Permission with Access Control UID_490017 124
10.13 Charging for multi-phases services (CHRGMPH) UID_380063 125

11 SA3 Features 126
11.1 Lawful Interception in the 3GPP Rel-8 (LI8) UID_350015 126
11.2 Generic Bootstrapping Architecture Push Function (GBAPush) UID_390046 127

12 SA4 Features 128
12.1 Requirements and Test methods for Wideband Terminals (RETEM_WB_T) UID_34045 128
12.2 Extending PSS and MBMS User Services for optimized Mobile TV UID_34043 129
12.3 Encoding formats, transport formats and media description signalling for interworking, QoE, and other enhancements to MTSI-MHI UID_400028 130

13 SA5 Features 133
13.1 Operations, Administration, Maintenance and Provisioning (OAM&P) 133
13.1.1 Telecom Management Methodology UID_35051 134
13.1.2 Advanced Alarming on Itf-N UID_35053 135
13.1.3 CN CS Bearer Transport Network (BTN) relative NRM UID_35056 136
13.1.4 Alignment with eTOM and M.3060 architectural concepts UID_390016 137
13.1.5 IRP SOAP Solution Set UID_400030 138
13.1.6 Create missing specifications for IRP XML definitions UID_450052 139
13.1.7 IP bearer network Performance measurement definition UID_35061 140
13.1.8 HSUPA performance measurements UID_360001 141
13.1.9 Key Performance Indicators (KPIs) for UMTS/GERAN UID_360002 142
13.1.10 Service Level Tracing in IMS (OAM8-Trace) UID_11067 143
13.2 Charging Management 144
13.2.1 Online charging correlation UID_350038 144
13.2.2 SMS online charging UID_360003 145
13.2.3 Introduce Online Charging from SMS-SC into the SMS Charging Specifications UID_410045 146

14 CT Features 147
14.1 Conferencing enhancements for Mp interface (eMp) UID_380024 147
14.2 Contact Manager for 3GPP UICC applications (eUPHBOOK) UID_320014 149

15 Improvements of the Radio Interface UID_350040 150
15.1 UMTS 700 MHz FDD UID_350035 150
15.2 UMTS 1500 MHz UID_350034 152
15.3 UMTS 1880 MHz TDD UID_410018 153
15.4 UMTS 2300 MHz TDD LCR UID_380074 154
15.5 Further Improved Minimum Performance Requirements for HSDPA UE (FDD) - Two-Branch Interference Cancellation UID_350037 155
15.6 CS Voice Service over HSPA UID_370032 156
15.6.1 Conformance Test Aspects – CS Voice Service over HSPA UID_25050 156
15.7 Performance requirements for 15 code reception with 16QAM/QPSK (FDD) UID_370033 157
15.7.1 Conformance Test Aspects – Performance requirements for 15 code reception with 16QAM/QPSK (FDD) UID_400055 157

16 RAN improvements UID_370035 158
16.1 Combination of 64QAM and MIMO for HSDPA (FDD) UID_360013 159
16.1.1 Conformance Test Aspects – Combination of 64QAM and MIMO for HSDPA (FDD) UID_410020 159
16.2 Improved L2 for uplink UID_370036 160
16.2.1 Conformance Test Aspects – Improved L2 for uplink UID_400056 161
16.2.2 Conformance Test Aspects – 1.28 Mcps TDD Improved L2 support for high data rates UID_440010 161
16.3 Enhanced Uplink for CELL_FACH State in FDD UID_370037 162
16.3.1 Conformance Test Aspects – Enhanced Uplink for CELL_FACH State in FDD UID_430024 163
16.4 Enhanced UE Discontinuous Reception (DRX) for FDD UID_370038 164
16.5 Enhancements for Serving Radio Network Subsystem (SRNS) Relocation Procedure UID_370039 165
16.6 Enhancements for FDD HSPA Evolution UID_370040 166
16.7 64QAM for 1.28 Mcps TDD HSDPA UID_380075 167
16.7.1 Conformance Test Aspects – 64QAM for 1.28 Mcps TDD HSDPA UID_400057 167
16.8 Enhanced CELL_FACH state in 1.28 Mcps TDD UID_380076 168
16.8.1 Conformance Test Aspects – Enhanced CELL_FACH State in LCR TDD UID_440009 169
16.9 Continuous Connectivity for packet data users for 1.28Mcps TDD UID_390028 170

Petitioners' Exhibit 1003, p. 101
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

16.9.1 Conformance Test Aspects – Continuous Connectivity for packet data users for 1.28 Mcps TDD UID_450024 170
16.10 HSPA VoIP to WCDMA/GSM CS continuity UID_390029 171
16.11 HS-DSCH Serving Cell Change Enhancements UID_390030 171
16.11.1 Conformance Test Aspects – HS-DSCH Serving Cell Change Enhancements UID_450026 172
16.12 MIMO for 1.28 Mcps TDD UID_400050 173
16.12.1 Conformance Test Aspects – MIMO for 1.28 Mcps TDD UID_450025 173
16.13 Dual-Cell HSDPA operation on adjacent carriers UID_400052 174
16.13.1 Conformance Test Aspects – Dual-Cell HSDPA operation on adjacent carriers UID_420015 174
16.14 Conformance Test Aspects – Receiver Type3i UID_430028 175
16.15 3.84 Mcps TDD MBMS over a Single Frequency Network Integrated Mobile Broadcast (MBSFN-DOB) 176

17 GERAN Features 178
17.1 GERAN support for GERAN - 3G Long Term Evolution interworking (GELTE) UID_50583 178
17.1.1 Testing for GERAN support for GERAN - 3G Long Term Evolution interworking UID_54583 179
17.2 U-TDOA Enhancement (GUTEN) UID_50586 180
17.3 GAN Enhancements (GANENH) UID_50587 181
17.3.1 Update TS 51.010 Mobile Station (MS) Conformance Specification for GAN Enhancements UID_53089 181
17.4 A-interface over IP (AoIP) UID_50591 182
17.5 New multicarrier BTS class (MCBTS) UID_51147 184
17.6 Support for Additional Navigation Satellite Systems (ANSS) for LCS UID_38001 185
17.7 Conformance testing for the Latency Reductions feature (CTLATRED) UID_51149 186
17.8 MS conformance testing of changes introduced by WI "Support of Packet-switched Handover for GERAN A/Gb mode" (PSHCT-MStest) UID_53091 186

18 SA1 Studies 187
18.1 Study on Customised Alerting Tone (FS_CAT) Requirements UID_7026 187
18.2 Study on Facilitating Machine to Machine Communication in GSM and UMTS (FS_M2M) UID_7027 188
18.3 Study on Network Composition UID_31089 190
18.4 Study on Requirements of IMS Multimedia Conferencing UID_320024 192
18.5 Study on support of a Public Warning System (FS_PWS) UID_320025 193
18.6 Study on Paging Permission with Access Control (FS_PPAC) UID_330016 195
18.7 Study on Non-3GPP access Network Selection Principles (NSP) UID_340033 196
18.8 Study on Value-Added Services for Short Message Service UID_340034 198
18.9 Study on Service continuity between mobile and WLAN networks UID_340035 199
18.10 Study on Services Alignment and Migration UID_370086 201

19 SA2 Studies 203
19.1 Study on 3GPP System Architecture Evolution UID_32085 203
19.2 Study on Stage 2 aspects of IMS Service Brokering UID_320028 205
19.3 Study on IMS utilizing multicast bearer services UID_7049 206
19.4 Study on Multimedia Session Continuity UID_350051 207
19.5 Study on centralized IMS services UID_380034 209
19.6 Study on Architecture of IMS based Customized Alerting Tone (CAT) UID_380078 211

20 SA3 Studies 212
20.1 Study on Home (e)NodeB Security UID_380085 212

21 SA5 Studies 213
21.1 Study of Element Operations Systems Function (EOSF) definition UID_390053 213
21.2 Study on SA5 MTOSI XML Harmonization UID_390037 214
21.3 Study of Common Profile Storage Framework of User Data for network services and management UID_390038 215
21.4 Study of Management for LTE and SAE UID_340036 216
21.5 Study on Charging Aspects of 3GPP System Evolution UID_350004 217

22 CT Studies 218
22.1 Study on AS-MRFC media server control protocol UID_7048 218
22.2 Study on IMS Restoration Procedures UID_350018 219
22.3 Study on IMS Application Server Service Data Descriptions for AS interoperability UID_360030 220
23.4 Study on Customized Alerting Tone solution for voice and video call in CS domain UID_360031 222
23.5 Study on InterWorking Function between MAP based and Diameter based interfaces UID_380023 224

Petitioners' Exhibit 1003, p. 102
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

24 RAN Studies 225
24.1 Study on Scope of future HSPA Evolution for 1.28Mcps TDD UID_370041 225
24.2 Study on Synchronized E-DCH for UTRA FDD UID_370042 226
24.3 Study on Improved network controlled mobility between LTE and 3GPP2/mobile WiMAX radio technologies UID_360016 227
24.4 Study on 3G Home NodeB/eNodeB UID_350039 229

25 GERAN Studies 231
25.1 Study on A-interface over IP (AINTIP) UID_50589 231
25.2 Study on Multi-User Reusing-One-Slot (MUROS) UID_50590 233
25.3 Study on Optimized Transmit Pulse Shape for Downlink EGPRS2-B (WIDER) UID_51148 234

26 Rel-8 Completed Items 236

27 Rel-8 Stopped Items 240

TSG#65 completed IETF dependency 242

Ongoing Rel-8 IETF dependency 242

Annex A: Change history 243

Petitioners' Exhibit 1003, p. 103
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

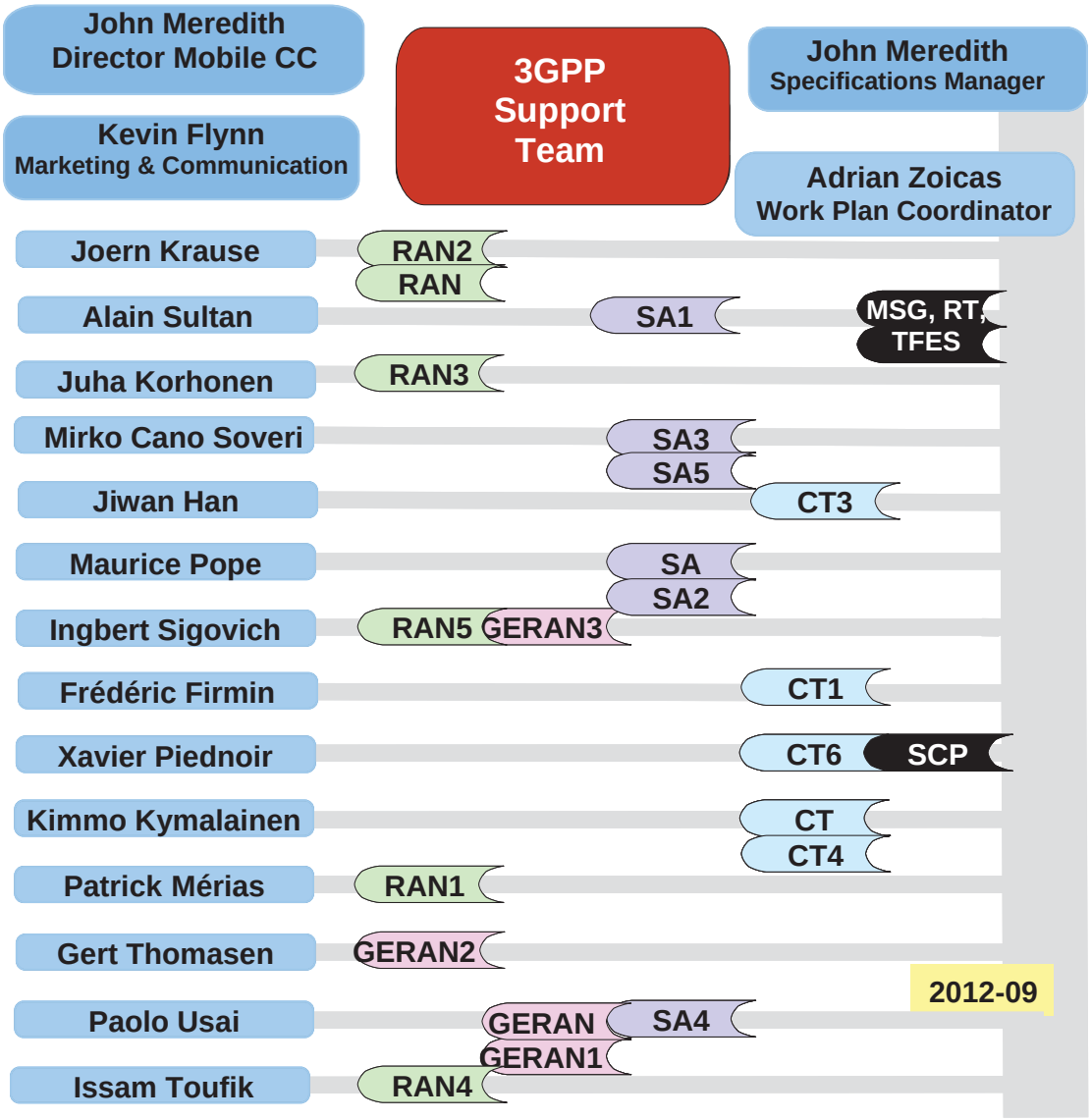
Foreword

The coloured highlight of the Unique IDentifier (UID) reflects the status of the work items e.g. ongoing, completed, etc. Stopped Features and Studies are listed at the end of the present document.

Legend:

Completed WI
Ongoing WI
Moved WI to/from another Release
Stopped WI

The present document has been produced by the ETSI MCC department.
The overall document was coordinated by Adrian Zoicas (MCC Work Plan Coordinator), who wishes to thank all the contributors for their dedication and quality of inputs.



Petitioners' Exhibit 1003, p. 104
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

1 Scope

The present document contains a high-level description of the 3GPP Release 8 Features.
Its latest version is available at: http://www.3gpp.org/ftp/Information/WORK_PLAN/Description_Releases/

3G Release 8 - See version 8 of TR 21.101.

GSM/EDGE, Phase 2+ Release 8 - See Version 8 of TR 41.101.

Freeze Dates

Release	TS/TR version)	Functional freeze date, indicative only (see note)
Rel-8	8.x.y	Stage 1 frozen March 2008
		Stage 2 frozen June 2008
		Stage 3 frozen December 2008
Note:	After "freezing", a Release can have no further additional functions added. However, detailed protocol specifications (stage 3) may not yet be complete. In addition, test specs may lag by some considerable time. A "frozen" Technical Specification is one which can have no further category B or C (new or modified functionality) Change Requests, other than to align earlier stages with later stages; thus all TSs pertaining to a Release may not necessarily be frozen at the time the Release itself is functionally frozen. Indeed since Release 7, the trend has been to freeze each of the three stages independently.	

2 References

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TS 21.101: "Technical Specifications and Technical Reports for a UTRAN-based 3GPP system". Version 8.x.y

[3] 3GPP TS 41.101: "Technical Specifications and Technical Reports for a GERAN-based 3GPP system". Version 8.x.y

2.1 Specifications

Global information on the Specifications (also called "specs") can be found at:

http://www.3gpp.org/specs/specs.htm

The latest versions of all 3GPP specifications, containing the most recent corrections and additions, are available at:

http://www.3gpp.org/ftp/Specs/latest/

For specific purposes, older versions might be needed. These versions are available at:

http://www.3gpp.org/ftp/Specs/Archive/

where the specifications are sorted by series and then by folders containing all the available versions of a given spec (one folder per spec), for all Releases.

2.2 Tdocs

The Temporary Documents (tdocs) are mainly the original papers written by the 3GPP Members, and are the inputs for elaborating the specs. They are available (sorted by 3GPP technical groups (Technical Specification Groups (TSGs) and Working Groups (WGs)) at:

http://www.3gpp.org/ftp/

starting with 'tsg....'.

Petitioners' Exhibit 1003, p. 105
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

2.3 Work Plan, Work Items and Study Items

Work Item Description ("WID") (also called WI Description) and Study Item (also called "Feasibility Studies") are forms which initial version provides the target to be reached before starting the technical work. Potential subsequent versions narrow the target and foreseen completion date according the actual progress. They are stored in:

http://www.3gpp.org/ftp/Information/WI_Sheet/

The 3GPP Work Plan is a living document, updated roughly each month, which contains the full list of Work Items and Study Items, as well as summary information for each WI, as: the WG in charge of it, its starting date and (foreseen or actual) completion date, the actual progress, etc. The Work Plan is available at:

http://www.3gpp.org/ftp/Information/WORK_PLAN/

2.4 Change Request database

A specification is originally drafted and maintained by a rapporteur, who compiles the contents from discussions in the WGs and TSGs. When it is considered to be 80% complete, it is brought under a so-called "change control" process. After this, changes to the specification can only be made using Change Requests that are usually agreed by consensus in the Working Group responsible for the specification, and then formally approved by the relevant Technical Specification Group.

The Change Request database contains all available information on Change Requests, including a Work Item code, a Change Request number that is unique within the specification (different versions are possible, but only one can ever be approved), the status of each Change Request and references to relevant temporary document numbers and meetings. This database is available in:

http://www.3gpp.org/ftp/Information/Databases/Change_Request/

Further information on CR is available at:

http://www.3gpp.org/specifications/change-requests

3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [x] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

EPC	
EPS	Evolved Packet System
E-UTRAN	
GAA	Generic Authentication Architecture
IMS	IP Multimedia Subsystem
LTE	
RAB	Radio Access Bearer
RLC	Radio Link Control
RTP	Real Time Protocol
SAES	System Architecture Evolution Specification
SIP	Session Initiated Protocol (IETF)

Petitioners' Exhibit 1003, p. 106
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

4 3GPP System Architecture Evolution Specification-Evolved Packet System (SAES) UID_320005

Resources: S1,S2,S3,S5,C1,C3,C4,C6

References

Document	Title/Contents
WID(s)	
SP-080132	WID on 3GPP System Architecture Evolution Specification (SAES) - covers S1,S2,S3
Impacted Specifications	
-	See following subclauses
New Dedicated Specifications/Reports	
-	See following subclauses

Supporting Individual Members: Motorola. Nortel, Fujitsu, Vodafone, T-Mobile International, Huawei, NTT DoCoMo, Nokia, NEC, Nokia Siemens Networks, Ericsson, Qualcomm, 3, Samsung, at&t, BT, SoftBank Mobile Corp, China Mobile, Orange, Toshiba, LG Electronics, Intel, TeliaSonera, ZTE, Telecom Italia, Alcatel-Lucent, Marvell, RITT, CATT, Sprint, Rogers Wireless, Telefonica O2 Europe, KPN, Verizon Wireless, IPWireless, Telenor.

UID	Name	Resource	Hyperlink
320005	**3GPP System Architecture Evolution Specification - Evolved Packet System (non RAN aspects)**	SP,CP	SP-080132
350027	**SAE for support for non-3GPP accesses**	S2,S3,C1,C4	SP-080132
350044	Stage 2 for Host-based Mobility aspects	S2	SP-080132
350045	Stage 2 for Network-based Mobility aspects	S2	SP-080132
360022	Stage 3 for Mobility management based on DSMIP v6	C1	CP-080493
390009	Stage 3 for Mobility management based on MIP v4	C1	CP-080493
380030	Stage 3 for Inter-system mobility between E-UTRAN and non 3GPP accesses	C1	CP-080493
360019	Stage 2 for Optimized Dual-Radio Handover with WiMAX	S2	SP-080132
390045	Stage 2 Security aspects for non-3GPP Access	S3	SP-080132
370010	Stage 3 security aspects for DSMIP v6 Access	C1	CP-080493
390172	Stage 3 security aspects for MIPv4 Access	C1	CP-080493
360021	Stage 3 for Access to the EPC via non-3GPP access networks	C1	CP-080493
370011	Stage 3 for interfaces within EPC	C4	CP-090247
340057	Stage 3 for Interfaces EPC - non-3GPP IP access	C4	CP-090247
340058	Stage 3 for AAA/HSS related	C4	CP-090247
340059	Stage 3 for EPC - AAA interface	C4	CP-090247
350030	**Single Radio Voice Call Continuity for 3GPP (SRVCC)**	S2,C1,C4	SP-070949
350130	Stage 2 for 2G/3G SRVCC	S2	SP-070949
410005	Stage 3 for SRVCC in EPS	C1	CP-080793
410006	MME to MSC interface for SRVCC	C4	CP-080793
360020	**Voice Call Continuity for CDMA2000 1X**	S2	SP-080132
350031	**SAE impacts on IMS**	S2	SP-080132
390036	**CS Fallback in EPS**	S2,C1,C4	SP-080097
400001	Stage 2 for CS Fallback in EPS	S2	SP-080097
400102	Stage 3 for CS Fallback in EPS	C1	CP-080791
400003	Stage 3 for CS Fallback in EPS	C4	CP-080791
390039	**System enhancements for the use of IMS services in local breakout**	S2	SP-080090
390010	**EPC Data Definitions**	S5	not applicable
380037	EPC Network Resource Model (NRM) Integration Reference Point (IRP)	S5	SP-070737
390011	Performance measurements for EPC	S5	SP-080061
380038	**EPC Charging**	S5	SP-070736
390018	**Issues for CT1 TR 24.801**	C1	CP-080068
390019	**Issues for CT3 TR 29.804**	C3	CP-080068
400104	**Domain Name System Procedures for Evolved Packet System (DEPS)**	C4	CP-080280
410007	**InterWorking Function (IWF) between MAP based and Diameter based interfaces**	C4	CP-080644
390021	**CT6 aspects of SAE**	C6	CP-080164
390121	CT6 aspects of SAE	C6	CP-080164
420018	Test interworking of LTE Terminals with the USIM	C6	CP-080899

Petitioners' Exhibit 1003, p. 107
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The WID SP-080132 covers:

- Administrative fixes to the Feature-level SAE WID;
- Explicit addition of specifying network-controlled dual radio handovers between 3GPP accesses (GERAN, UTRAN, E-UTRAN) and Mobile WiMAX.

To ensure competitiveness in a longer time frame, an evolution of the 3GPP **access technology** needs to be considered.

Also, the ability of the 3GPP system to cope with the rapid growth in IP data traffic, the Packet-Switched technology utilized within 3G mobile networks requires further enhancement.
A continued evolution and optimization of the system concept is also necessary in order to maintain a competitive edge in terms of both performance and cost.

Important parts of such a continued **system evolution** include:

- Reduced latency;
- Higher user data rates;
- Improved system capacity and coverage, and reduced overall cost for the operator;
- Potential network and traffic cost reduction;
- Flexible accommodation and deployment of existing and new access technologies with mobility by a common IP-based network.

The objective of this work is to produce specifications to satisfy the needs of 3GPP System Evolution, namely:

- Overall architecture impacts from SA1 Rel-7 TR 22.978 "All-IP network (AIPN) feasibility study" (FS_AIPN) UID_31059, and from SA2 TR 23.882 "Study on 3GPP System Architecture Evolution" (FS_SAE) UID_32085 e.g.:

    - Support of a variety of different access systems (existing and future), mobility and service continuity between these access systems, and access selection based on combinations of operator policies, user preferences and access network conditions;
    - How to realize improvements in basic system performance e.g. communication delay, communication quality, connection set-up time etc.;
    - How to maintain the negotiated QoS across the whole system; in particular to address include inter-domain and inter-network interworking;
    - Identify the capability expansion required taking into account migration and co-existence with the existing system.

Overall architecture impacts from TSG-RAN on 3G Long-Term Evolution (TR 25.912 Study on Evolved UTRA and UTRAN UID_20023). The architectural developments should take into account the targets for the evolution of the radio-interface, e.g.:

    - whether there is a need for a modified network architecture and/or different functional split between network nodes (compared to the current 3GPP architecture);
    - how to provide a very low latency (including C-plane) for the overall network (including core network, radio access network and radio access technology);
    - how to provide the efficient support of the various types of services, especially from the PS domain (e.g. Voice over IP, Presence).

The Stage 2 is broken down into:

TS 23.401 SAE architecture aspects dealing with GPRS enhancements for **LTE access** and support for **pre-SAE/LTE 3GPP accesses**

TS 23.402 Architecture enhancements, including PCC and AAA aspects, adding **non-3GPP access** for both roaming and non-roaming scenarios. This aims at an IETF-based solution with the intention of being applicable to non-3GPP access networks (both fixed and wireless). This also includes specifying network-controlled dual radio handovers between 3GPP accesses (GERAN, UTRAN, E-UTRAN) and Mobile WiMAX.

Aspects common to both (e.g. S1 interface, interface with HSS, LTE specific PCC architecture functionality, etc) are covered in TS 23.401.

The architecture used as a basis for the two above is based on the TSG SA guidance to SA2 given in SP-060925.

SA3 Security aspects are covered in:

Petitioners' Exhibit 1003, p. 108
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

TS 33.401 Security architecture (security features and mechanisms) for the Evolved Packet System (EPS) and the Evolved Packet Core (EPC), and the security procedures performed within EPS including EPC and E-UTRAN.

TS 33.402 Security features and the security mechanisms for inter-access mobility between 3GPP access system and non-3GPP access systems.

4.1 Requirements for evolution of the 3GPP system architecture (AIPN-SAE) UID_320022

Resources: S1

References

Document	Title/Contents
WID(s)	
SP-080132	WID on 3GPP System Architecture Evolution Specification (SAES) - covers S1,S2,S3
Impacted Specifications	
TS 22.011	Service accessibility
TS 22.246	MBMS user services; Stage 1
New Dedicated Specifications/Reports	
TS 22.278	Service requirements for the Evolved Packet System (EPS)

UID	Name	Resource	Hyperlink	Notes	TS_TR
320022	**Requirements for evolution of the 3GPP system architecture**	S1	SP-080132	SP#38 completed	22.011, 22.246, new 22.278

4.2 High level and common (for all accesses) functions (EPS-ComF) UID_370005

Resources: S2,S3

References

Document	Title/Contents
WID(s)	
SP-080132	WID on 3GPP System Architecture Evolution Specification (SAES) - covers S1,S2,S3
Impacted Specifications	
TS 33.210	3G security; Network Domain Security (NDS); IP network layer security
TS 33.310	Network Domain Security (NDS); Authentication Framework (AF)
New Dedicated Specifications/Reports	
TS 23.402	Architecture enhancements for non-3GPP accesses
TS 33.401	3GPP System Architecture Evolution (SAE); Security architecture

UID	Name	Resource	Hyperlink	Notes	TS_TR
370005	**High level and common (for all accesses) functions**	SP,CP	SP-080132	-	-
350024	Stage 2 for High level functions	S2	SP-080132	SP#40 completed	new 23.402
390044	Stage 2 Security Architecture	S3	SP-080132	SP#42 completed	33.210, 33.310, new 33.401

SA2 new TS 23.402 contains Stage 2 for High level functions.

SA3 new TS 33.401 specifies the security architecture; more specifically, the security features and the security mechanisms for EPS, and the security procedures performed within the EPS.

Petitioners' Exhibit 1003, p. 109
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CT1 aspects of System Architecture Evolution

Resources: C1

References

Document	Title/Contents
WID(s)	
CP-080493	WID on CT1 aspects of System Architecture Evolution
Impacted Specifications	
TS 23.122	Non-Access-Stratum (NAS) functions related to Mobile Station (MS) in idle mode
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3
TS 27.007	AT command set for User Equipment (UE)
New Dedicated Specifications/Reports	
TS 24.302	Access to the Evolved Packet Core (EPC) via non-3GPP access networks; Stage 3
TS 24.305	Selective Disabling of UE Capabilities (SDoUE) Management Object (MO)

UID	Name	Resource	Hyperlink	Notes	TS_TR
340051	Stage 3 (CT1) for SAE impact on services, network functions and capabilities	C1	CP-080493	CP#43 completed	24.229, 27.007, new 24.305
340049	Stage 2/3 for Network selection procedures	C1	CP-080493	CP#42 completed	23.122, new 24.302

This work covers protocols and procedures used in the EPS or used between the UE and the EPC network via non-3GPP access networks. Furthermore, existing 3GPP specifications shall be enhanced to support inter-system mobility between 3GPP legacy radio access networks and E-UTRAN. CT1 work can be split into four groups:

1) High level functions and procedures common for all accesses:
   - Stage 2/3 for Network selection procedures
   - Stage 3 (CT1) for SAE impact on services, network functions and capabilities; e.g. impact of EPS on IMS
2) Support of E-UTRA
3) Support of interoperation between EPS and legacy cellular PS accesses
4) Support of non-3GPP accesses

Unified guidelines of Diameter usage within 3GPP

Resources: C3

References

Document	Title/Contents
WID(s)	
CP-080055	WID on Unified guidelines of Diameter usage within 3GPP
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 29.909	Diameter-based protocols usage and recommendations in 3GPP

UID	Name	Resource	Hyperlink	Notes	TS_TR
370017	Unified guidelines for Diameter usage within 3GPP	C3	CP-080055	CP#42 completed	new 29.909

This work covers Unified guidelines of Diameter usage within 3GPP.

Diameter has been widely used in 3GPP, especially in CT3, CT4 and SA5. It is foreseen that Diameter will still be used more widely in SAE EPC system. However there were inconsistent rules and principles across WGs of how to derive new Diameter applications from the IETF specification. In addition, Diameter application version control across different releases is a 3GPP-specific issue and not considered by IETF when developing the Diameter BASE protocol. RFC3588 had some unresolved issues and 3GPP had to make its own solution. IETF is now trying to solve

Petitioners' Exhibit 1003, p. 110
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

known problems with a RFC3588bis and new usage recommendations. Different principles or rules of Diameter usage across 3GPP WGs may lead to unexpected inter-operability problems.

This work creates a common set of principles, rules and recommendations across 3GPP WGs to ensure Diameter-based interfaces have the same treatment for release control and generating new applications-id. Also to address in a unified manner the use/re-use of AVPs, and other Diameter BASE related decisions. To achieve maximum benefit from this work it is strongly recommended that all 3GPP Diameter-based protocols follow these recommendations.

New TR 29.909 contains guidelines accepted by consensus of all involved 3GPP WGs, including:

- Current situation of Diameter usage in different WGs (CT3, CT4, SA5) in Rel-6/7;
- Recommendations and conditions to re-use existing Diameter applications (3GPP or IETF application-id), commands, AVPs and/or AVP values);
- Recommendations and conditions to define new Diameter applications, commands, AVPs and/or AVP values. Cross-release issue had been considered;
- Whether to apply the guidelines back to existing Diameter applications or only to new SAE Diameter interfaces, including potential impacts on existing implementations, potential benefits, etc; This took into account that with the new Diameter BASE RFC3588bis, existing usage of Diameter may need to be revised in 3GPP anyway.
- Recommendations are based on ongoing work in IETF about Diameter application design (DIME wg).

TR 29.909, has a secondary role, as placeholder in an informative annex for Diameter inter-operator considerations with brief guidelines on how to deploy and realize the inter-operator Diameter-based roaming infrastructure.

Inter-working between Evolved Packet Core network and external networks

Resources: C3

References

Document	Title/Contents
	WID(s)
CP-080772	WID on Inter-working between Evolved Packet Core network and external networks
	Impacted Specifications
TS 29.061	Interworking between the Public Land Mobile Network (PLMN) supporting packet based services and Packet Data Networks (PDN)
	New Dedicated Specifications/Reports
-	-

UID	Name	Resource	Hyperlink	Notes	TS_TR
340054	Stage 3 SAE impact on existing capabilities	C3	CP-080772	CP#42 completed	29.061
340023	Stage 3 EPC interworking with external PDNs (SGi)	C3	CP-080772	CP#44 completed	29.061

This work covers inter-working with external networks, namely Stage 3 SAE impact on existing capabilities and Stage 3 EPC interworking with external PDNs (supporting SGi interface) impacting TS 29.061:

- Interworking with PDN (IP/DHCP/RADIUS/Diameter) supporting EPS
- Interworking with IMS supporting EPS
- Interworking with MBMS supporting EPS
- Message Flows and message definitions

Petitioners' Exhibit 1003, p. 111
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

PCC within System Architecture Evolution

Resources: C3

References

Document	Title/Contents
WID(s)	
CP-080576	WID on PCC within System Architecture Evolution
Impacted Specifications	
TS 29.212	Policy and Charging Control over Gx reference point
TS 29.213	Policy and Charging Control signalling flows and QoS parameter mapping
TS 29.214	Policy and Charging Control over Rx reference point
New Dedicated Specifications/Reports	
TS 29.215	Policy and Charging Control over S9 reference point

UID	Name	Resource	Hyperlink	Notes	TS_TR
340022	Stage 3 PCC within SAE	C3	CP-080576	CP#44 completed	29.212, 29.213, 29.214, new 29.215

This work covers Stage 3 PCC within SAE divided into four groups covering the main three interfaces and some common issues; impacting existing TS 29.212, TS 29.213, TS 29.214:

- Gx support for S7, S7a, S7c interfaces
- Rx protocol evolution
- S9 protocol to support roaming scenarios (new TS 29.215)
- Signalling Flows, Mapping Tables and binding

CT4 aspects of Evolved Packet System

Resources: C4

References

Document	Title/Contents
WID(s)	
CP-090247	WID on CT4 aspects of Evolved Packet System
Impacted Specifications	
TS 23.003	Numbering, addressing and identification
New Dedicated Specifications/Reports	
TS 29.274	General Packet Radio Service (GPRS); Evolved GPRS Tunnelling Protocol (eGTP) for EPS
TS 29.275	Proxy Mobile IPv6 (PMIPv6) based Mobility and Tunnelling protocols; Stage 3

UID	Name	Resource	Hyperlink	Notes	TS_TR
340062	Stage 3 (CT4) of SAE impact on existing capabilities	C4	CP-090247	CP#43 completed	new (29.274, 29.275)
340028	Stage 3 for SAE / LTE identities	C4	CP-090247	CP#43 completed	23.003

This work covers Stage 3 for SAE impact on existing capabilities (new TS 29.274, TS 29.275) and Stage 3 for SAE / LTE identities (changes to TS 23.003).

WID CP-080279 includes selection and specification of protocols and procedures to be used within EPC, between EPC and current GPRS core network, between EPC and HSS/AAA, and between 3GPP and non-3GPP access, and describes impacts and required enhancements for related network protocols, including GTP and IETF protocols based on Stage 2 architecture. The CT4 can be divided into the five categories:

- MME related interfaces based on the Diameter protocol;
- New and enhanced 3GPP AAA interfaces;
- GTP enhancements;
- PMIP based Mobility and Tunnelling protocols;
- Optimized handover procedures and protocol between E-UTRAN access and non-3GPP accesses;

Petitioners' Exhibit 1003, p. 112
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

4.3 SAE for LTE access (SAES-LTE) UID_350025

Resources: S2,C1,C3,C4

References

Document	Title/Contents
	WID(s)
SP-080132	WID on 3GPP System Architecture Evolution Specification (SAES) - covers S1,S2,S3
CP-090247	CT4 WID on aspects of Evolved Packet System (EPS)
CP-080493	CT1 WID on aspects of System Architecture Evolution
CP-080576	CT3 WID on PCC within System Architecture Evolution
	Impacted Specifications
SA2	TS 23.060, 23.002, 23.246, 23.203, 23.107, 23.234, 23.271
CT1	TS 24.007, 24.008
TS 29.213	Policy and charging control signalling flows and Quality of Service (QoS) parameter mapping - C3
	New Dedicated Specifications/Reports
TS 23.401	General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access
TS 24.301	Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3 - C1
TS 29.272	Evolved Packet System (EPS); Mobility Management Entity (MME) and Serving GPRS Support Node (SGSN) related interfaces based on Diameter protocol - C4
TS 29.274	3GPP Evolved Packet System (EPS); Evolved General Packet Radio Service (GPRS) Tunnelling Protocol for Control plane (GTPv2-C); Stage 3 - C4
TS 29.275	Proxy Mobile IPv6 (PMIPv6) based Mobility and Tunnelling protocols; Stage 3 - C4
TS 29.279	Mobile IPv4 (MIPv4) based Mobility protocols; Stage 3 - C4
TS 29.282	Mobile IPv6 vendor specific option format and usage within 3GPP - C4

UID	Name	Resource	Hyperlink	TS_TR
350025	**SAE for LTE access**	-	SP-080132	-
340060	CT4 Stage 3 for protocol between EPCs	C4	CP-090247	29.274, 29.275
350042	SAES-SA-FP_LTE with GTP variant	S2,C4	SP-080132	-
370006	Stage 2 for SAES-SA-FP_LTE with GTP variant	S2	SP-080132	23.401, 23.060, 23.002, 23.246, 23.203, 23.107, 23.234, 23.271
340055	CT4 Stage 3 for GTP v2 protocol	C4	CP-090247	29.274
350043	SAES-SA-FP_LTE with PMIP variant	S2,C4	SP-080132	-
370007	Stage 2 for SAES-SA-FP_LTE with PMIP variant	S2	SP-080132	-
370018	CT4 Stage 3 for PMIP protocol within EPC	C4	CP-090247	29.275, 29.282
410004	Mobile IPv4 (MIPv4) based Mobility protocols	C4	CP-090247	29.279
340020	Stage 3 for UE NAS mobility procedures in idle and active mode	C1	CP-080493	24.007, 24.301
340050	Stage 3 for Session management, bearer control and QoS aspects	C1	CP-080493	24.007, 24.301
340053	Stage 3 for security aspects of LTE Access	C1	CP-080493	24.008, 24.301
340025	Stage 3 for QoS mechanisms	C3	CP-080576	29.213
340026	Stage 3 for EPC - HSS interface	C4	CP-090247	29.272

CP-090247 WID on CT4 aspects of Evolved Packet System (EPS)

UID	Name	Resource	Hyperlink	TS_TR
340060	CT4 Stage 3 for protocol between EPCs	C4	CP-090247	29.274, 29.275
340055	CT4 Stage 3 for GTP v2 protocol	C4	CP-090247	29.274
370018	CT4 Stage 3 for PMIP protocol within EPC	C4	CP-090247	29.275, 29.282
410004	Mobile IPv4 (MIPv4) based Mobility protocols	C4	CP-090247	29.279
340026	Stage 3 for EPC - HSS interface	C4	CP-090247	29.272

This work produced specifications for protocols and procedures under CT4 responsibility used in EPC which can be classified into the five following categories:

1) MME related interfaces based on the Diameter protocol;
- S6a protocol specification
- S13 protocol specification
- Gr protocol interaction with S6a

Petitioners' Exhibit 1003, p. 113
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

2) New and enhanced 3GPP AAA interfaces;
- S6b protocol specification, also covering I-WLAN Mobility H2 interface
- Definition of SWx, SWm, SWa, STa, possibly replacing existing interfaces in I-WLAN

3) GTP enhancements;
- GTP-based S5 and GTP-based S8
- S10 and S11
- S3 and S4
- S1-U, impact of S12 and X2 will be evaluated

4) PMIP based Mobility and Tunnelling protocols;
- PMIP-based S5 and PMIP-based S8
- S2a and S2b

5) Optimized handover procedures and protocol between EUTRAN access and non-3GPP accesses;
- cdma2000 HRPD access
- S101, S103
- cdma2000 1xRTT access
- S102

CP-080493 WID on CT1 aspects of System Architecture Evolution

UID	Name	Resource	Hyperlink	TS_TR
340020	Stage 3 for UE NAS mobility procedures in idle and active mode	C1	CP-080493	24.007, 24.301
340050	Stage 3 for Session management, bearer control and QoS aspects	C1	CP-080493	24.007, 24.301
340053	Stage 3 for security aspects of LTE Access	C1	CP-080493	24.008, 24.301

CT1 specified protocols for mobility management, session management, and control of NAS security.

It covers work on protocols and procedures used in the EPS or used between the UE and the EPC network via non-3GPP access networks. Furthermore, existing 3GPP specifications were enhanced to support inter-system mobility between 3GPP legacy radio access networks and E-UTRAN. CT1 work can be split into four groups:

1) High level functions and procedures common for all accesses:
- Network selection procedures (stage 2 and 3)
- Impact on services, network functions and capabilities (e.g. impact of EPS on IMS, etc.)

2) Support of E-UTRA
- UE non-access stratum mobility procedures in idle and active mode
- Session management, bearer control and QoS aspects
- Security aspects for E-UTRA

3) Support of interoperation between EPS and legacy cellular PS accesses
- Inter-system mobility between E-UTRAN and GERAN/UTRAN
- Inter-system mobility between E-UTRAN and cdma2000

4) Support of non-3GPP accesses
- Access to the EPC via non-3GPP access networks
- Mobility management based on mobile IP
- Inter-system mobility between E-UTRAN and non-3GPP accesses
- Security aspects for non-3GPP Access

CP-080576 CT3 WID on PCC within System Architecture Evolution

UID	Name	Resource	Hyperlink	TS_TR
340025	Stage 3 for QoS mechanisms	C3	CP-080576	29.213

This work produced specifications for PCC protocols and procedures under CT3 responsibility used in EPS and classified into four groups covering the main three interfaces and some common issues:

Petitioners' Exhibit 1003, p. 114
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

1) Gx protocol evolution and Gxx protocol specification
2) Rx protocol evolution
3) S9 protocol to support roaming scenarios
4) Signalling Flows, Mapping Tables and binding

Petitioners' Exhibit 1003, p. 115
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

4.4 SAE for Interoperation between LTE and legacy cellular PS accesses UID_350026

Resources: S2,C1,C4

References

Document	Title/Contents
WID(s)	
SP-080132	WID on 3GPP System Architecture Evolution Specification (SAES) - covers S1,S2,S3
CP-080493	CT1 WID on aspects of System Architecture Evolution
CP-090247	CT4 WID on aspects of System Architecture Evolution
Impacted Specifications	
TS 24.008	Mobile radio interface Layer 3 specification; Core network protocols; Stage 3
New Dedicated Specifications/Reports	
TS 24.301	Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3
TS 24.302	Access to the Evolved Packet Core (EPC) via non-3GPP access networks; Stage 3

UID	Name	Resource	Hyperlink	TS_TR
350026	**SAE for Interoperation between LTE and legacy cellular PS accesses**	S2,C1,C4	SP-080132	-
370008	Stage 2 for Interoperation between LTE and 2G/3G	S2	SP-080132	23.401, 23.402
380031	Stage 3 for Inter-system mobility between E-UTRAN and 2G/3G	C1	CP-080493	24.008, 24.301
340018	Stage 2 GPRS enhancements for LTE access	S2	SP-080132	23.401
390008	Stage 2 GPRS for EPC (23.060, etc.)	S2	SP-080132	23.060
340056	Stage 3 for EPC - GPRS	C4	CP-090247	29.274, 29.275, 29.281
380032	Stage 3 for EPC to UTRAN	C4	CP-090247	29.274, 29.275, 29.281
380033	Stage 3 for EPC to 3GPP2	C4	CP-090247	29.277, 29.276
370009	Stage 2 for Interoperation between LTE and CDMA2000	S2	SP-080132	23.401, 23.402
360023	Stage 3 for Inter-system mobility between E-UTRAN and CDMA2000	C1	CP-080493	24.301, 24.302
340061	Stage 3 for MME - SGSN signalling free protocol	C4	CP-090247	29.272, 29.274

Petitioners' Exhibit 1003, p. 116
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

4.5 SAE for support for non-3GPP accesses (SAES-SA-FP_n3GPP) UID_350027

Resources: S2,S3,C1,C4

References

Document	Title/Contents
WID(s)	
SP-080132	WID on 3GPP System Architecture Evolution Specification (SAES) - covers S1,S2,S3
CP-080493	CT1 WID on aspects of System Architecture Evolution
CP-090247	CT4 WID on aspects of System Architecture Evolution
Impacted Specifications	
TS 33.210	3G security; Network Domain Security (NDS); IP network layer security
TS 33.310	Network Domain Security (NDS); Authentication Framework (AF)
New Dedicated Specifications/Reports	
TS 24.301	Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3
TS 24.302	Access to the Evolved Packet Core (EPC) via non-3GPP access networks; Stage 3
TS 24.303	Mobility management based on Dual-Stack Mobile IPv6; Stage 3
TS 24.304	Mobility management based on Mobile IPv4; User Equipment (UE) - foreign agent interface; Stage 3
TS 33.402	3GPP System Architecture Evolution (SAE); Security aspects of non-3GPP accesses

UID	Name	Resource	Hyperlink	TS_TR
350027	**SAE for support for non-3GPP accesses**	-	SP-080132	-
350044	Stage 2 for Host-based Mobility aspects	S2	SP-080132	23.402
350045	Stage 2 for Network-based Mobility aspects	S2	SP-080132	23.402
360022	Stage 3 for Mobility management based on DSMIPv6	C1	CP-080493	24.303
521011	(IETF) Stage 3 for Mobility management based on DSMIPv6	C1-IETF	CP-080493	RFC 6610 (was draft-ietf-mip6-hiopt)
521012	(IETF) Stage 3 for Mobility management based on DSMIPv6	C1-IETF	CP-080493	SP#53/IETF#81: RFC 6275 completed (was draft-ietf-mext-rfc3775bis)
390009	Stage 3 for Mobility management based on MIP v4	C1	CP-080493	24.304
380030	Stage 3 for Inter-system mobility between E-UTRAN and non 3GPP accesses	C1	CP-080493	24.008, 24.301
360019	Stage 2 for Optimized Dual-Radio Handover with WiMAX	S2	SP-080132	23.402
390045	Stage 2 Security aspects for non-3GPP Access	S3	SP-080132	33.402, 33.210, 33.310
370010	Stage 3 security aspects for DSMIPv6 Access	C1	CP-080493	24.303
390172	Stage 3 security aspects for MIPv4 Access	C1	CP-080493	24.304
360021	Stage 3 for Access to the EPC via non-3GPP access networks	C1	CP-080493	24.302, 24.312
370011	Stage 3 for interfaces within EPC	C4	CP-090247	29.274, 29.281
340057	Stage 3 for Interfaces EPC - non-3GPP IP access	C4	CP-090247	29.273, 29.275
521013	(IETF) Stage 3 for Interfaces EPC - non-3GPP IP access	C4-IETF	CP-090247	RFC 6611 (was draft-ietf-mip6-bootstrapping-integrated)
340058	Stage 3 for AAA/HSS related	C4	CP-090247	29.273
340059	Stage 3 for EPC - AAA interface	C4	CP-090247	29.273

Petitioners' Exhibit 1003, p. 117
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

4.5.1 Conformance Test Aspects – Mobility management based on DSMIPv6 UID_450022

Resources: R5

References

Document	Title/Contents
WID(s)	
RP-090754	WID on Conformance Test Aspects – Mobility management based on DSMIPv6 (Dual-Stack Mobile IPv6)
Impacted Specifications	
TS 36.508	Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Packet Core (EPC); Common test environments for User Equipment (UE) conformance testing
TS 36.523-1	Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Packet Core (EPC); User Equipment (UE) conformance specification; Part 1: Protocol conformance specification
TS 36.523-2	Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Packet Core (EPC); User Equipment (UE) conformance specification; Part 2: Implementation Conformance Statement (ICS) proforma specification
TS 36.523-3	Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Packet Core (EPC); User Equipment (UE) conformance specification; Part 3: Test Suites
New Dedicated Specifications/Reports	
-	-

Testing for CT1's UID_360022 (24.303) under Rel-8 Feature SAES

UID	Name	Hyperlink	Status_Report	rapporteur	Notes	TS_TR
450022	**Conformance Test Aspects – Mobility management based on DSMIPv6 (Dual-Stack Mobile IPv6)**	RP-090754	RP-100738	Qualcomm	RP#49 completed	36.508, 36.523-1, 36.523-2, 36.523-3

CT1's TS 24.303 provides the signalling procedures for accessing the 3GPP Evolved Packet Core network and handling the mobility between 3GPP and non-3GPP accesses via the S2c reference point defined in TS 23.402.

This work item provides conformance test specifications in order to verify correct functionality of the UE when moving between 3GPP and non-3GPP access networks.

Petitioners' Exhibit 1003, p. 118
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

4.6 Single Radio Voice Call Continuity for 3GPP (SAES-SRVCC) UID_350030

Resources: S2,C1,C4

References

Document	Title/Contents
WID(s)	
SP-070949	SA2 WID on Single Radio Voice Call Continuity for 3GPP (SRVCC)
CP-080793	WID for CT (CT1/CT4) aspects of SRVCC to make it CT Wide
Impacted Specifications	
TS 23.009, 24.008	CT1
TS 23.003, 23.008	CT4
New Dedicated Specifications/Reports	
TS 23.216	Single Radio Voice Call Continuity (SRVCC); Stage 2 - S2
TS 24.301	Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3 - C1
TS 29.274	3GPP Evolved Packet System (EPS); Evolved General Packet Radio Service (GPRS) Tunnelling Protocol for Control plane (GTPv2-C); Stage 3 - C4
TS 29.277	Optimized Handover Procedures and Protocols between EUTRAN Access and 1xRTT Access - C4
TS 29.280	Evolved Packet System (EPS); 3GPP Sv interface (MME to MSC, and SGSN to MSC) for SRVCC - C4

Supporting Individual Members: Motorola, Nortel, Vodafone, Huawei, Nokia, Nokia Siemens Networks, Ericsson, Qualcomm, at&t, Orange, TeliaSonera, Telecom Italia, Alcatel-Lucent, Verizon Wireless, Samsung.

UID	Name	Resource	Hyperlink	TS_TR
350030	**Single Radio Voice Call Continuity for 3GPP (SRVCC)**	S2,C1,C4	SP-070949	-
350130	Stage 2 for 2G/3G SRVCC	S2	SP-070949	new 23.216
410005	Stage 3 for SRVCC in EPS	C1	CP-080793	23.009, 24.008, new 24.301
410006	MME to MSC interface for SRVCC	C4	CP-080793	23.003, 23.008, new (29.274, 29.277, 29.280)

To ensure competitiveness in a longer time frame, i.e. for the next 10 years and beyond, an evolution of the 3GPP access technology needs to be considered.
Also, the ability of the 3GPP system to cope with the rapid growth in IP data traffic, the Packet-Switched technology utilized within 3G mobile networks requires further enhancement. A continued evolution and optimization of the system concept is also necessary in order to maintain a competitive edge in terms of both performance and cost.
Important parts of such a continued system evolution include

- reduced latency,
- higher user data rates,
- improved system capacity and coverage, and reduced overall cost for the operator.
- Potential network and traffic cost reduction
- Flexible accommodation and deployment of existing and new access technologies with mobility by a common IP-based network

This work addresses the Single Radio Voice Call Continuity (SRVCC) aspects of System Architecture Evolution. SA2 specified the architecture enhancements for SRVCC between E-UTRAN access and 3GPP2's 1xRTT / 3GPP's UTRAN/GERAN accesses for Circuit Switched (CS) calls that are anchored in the IMS. SA2 documented overall SRVCC architecture and Stage 2 specifications for the 3GPP components (i.e., excluding 3GPP2 specific components).

UID	Name	Resource	Hyperlink	TS_TR
410005	Stage 3 for SRVCC in EPS	C1	CP-080793	23.009, 24.008, new 24.301
410006	MME to MSC interface for SRVCC	C4	CP-080793	23.003, 23.008, new (29.274, 29.277, 29.280)

Supporting Individual Members: Nokia Siemens Networks, Nokia, Motorola, Vodafone, Telecom Italia, InterDigital, Alcatel-Lucent, Qualcomm Europe, Ericsson, Nortel Networks.

This work is linked to the 3GPP work items:

- IMS Centralized Services (ICSRA-St2) (Unique ID 380040)

Petitioners' Exhibit 1003, p. 119
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- IMS Service Continuity (IMS-Cont) (Unique ID 390056)

TSG CT enhanced the relevant 3GPP protocol specifications to support the following aspects:

- Procedures to support call control state synchronization between UE and network when SRVCC is executed from PS to CS domain (i.e., change from SIP to TS 24.008 CC state machine, including a change from CC state Null to Active)
- Procedures to support mobility management control state synchronization between UE and CS core network after SRVCC is executed (The MSC server performs LA Update on behalf of the UE)
- indication of SRVCC capabilities by the UE to the CN
- indication of supported CS voice codecs for handover preparation with the target cell
- define protocol and stage 3 procedures between MME and MSC (Sv Interface) for SRVCC from E-UTRAN to 3GPP UTRAN/GERAN, between SGSN and MSC (Sv Interface) for SRVCC from UTRAN (HSPA) to 3GPP UTRAN/GERANand between the MME and the 1x CS IWS (S102 Interface) for SRVCC from E-UTRAN to CDMA 2000 1xRTT.

4.7 Voice Call Continuity for CDMA2000 1X (SAES-VCC_1X) UID_360020

Resources: S2

References

Document	Title/Contents
	WID(s)
SP-080132	WID on 3GPP System Architecture Evolution Specification (SAES) - covers S1,S2,S3
	Impacted Specifications
TS	?
	New Dedicated Specifications/Reports
TS	?

4.8 SAE impacts on IMS (SAES-SA_IMS) UID_350031

Resources: S2

References

Document	Title/Contents
	WID(s)
SP-080132	WID on 3GPP System Architecture Evolution Specification (SAES) - covers S1,S2,S3
	Impacted Specifications
TS	?
	New Dedicated Specifications/Reports
TS	?

Petitioners' Exhibit 1003, p. 120
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

4.9 CS Fallback in EPS (SAES-CSFB) UID_390036

Resources: S2,C1,C4

References

Document	Title/Contents
	WID(s)
SP-080097	S2 WID on CS Fallback in EPS
CP-080791	C1 WID on Stage 3 for CS Fallback in EPS
	Impacted Specifications
CT1	TS 24.007, 24.008, 24.011, 29.018
CT4	TS 23.007, 23.008
	New Dedicated Specifications/Reports
TS 23.272	Circuit Switched (CS) fallback in Evolved Packet System (EPS); Stage 2 - S2
TS 23.401	General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access - S2
TS 24.301	Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3 -C1
TS 29.118	Mobility Management Entity (MME) - Visitor Location Register (VLR) SGs interface specification - C1
TR 24.801	3GPP System Architecture Evolution (SAE); CT WG1 aspects
TS 29.274	3GPP Evolved Packet System (EPS); Evolved General Packet Radio Service (GPRS) Tunnelling Protocol for Control plane (GTPv2-C); Stage 3 - C4
TS 29.277	Optimized Handover Procedures and Protocols between EUTRAN Access and 1xRTT Access - C4

UID	Name	Resource	Hyperlink	TS_TR
390036	**CS Fallback in EPS**	-	SP-080097	-
400001	Stage 2 for CS Fallback in EPS	S2	SP-080097	new (23.272, 23.401)
400102	Stage 3 for CS Fallback in EPS	C1	CP-080791	24.007, 24.008, 24.011, 29.018, new (24.301, 24.801, 29.118)
400003	Stage 3 for CS Fallback in EPS	C4	CP-080791	23.007, 23.008, 29.274, new 29.277

In order to guarantee support of legacy CS services such as voice for UEs camped on E-UTRAN, mobile operators are expected to deploy IMS. Many operators however will continue to have access to already deployed 2G/3G CS network for foreseeable future which can also be used as a fallback. Such CS fallback can help to:

- provide smooth transition to LTE by better utilising an already deployed CS infrastructure for voice services with UE with LTE and 2G/3G capability.
- decouple the deployment of IMS from the deployment of the Evolved Packet System for other operators who choose not to use LTE for legacy CS services at all but instead use UE with LTE and 2G/3G capability for delivery of CS services such as voice over 2G/3G CS domain,

In order to achieve these goals a mechanism is required to inform UE with LTE and 2G/3G capability of incoming/outgoing CS calls and thus may trigger the reselection of a suitable CS domain access (either 2G or 3G).

This work specifies the architecture enhancements for functionality to enable Fallback from E-UTRAN access to 2G/3G CS domain access. Using this functionality, voice and other CS-domain services (e.g. CS UDI video / SMS/ LCS / USSD) are realized by reuse of CS infrastructure. It documents overall CS Fallback architecture and stage 2 level specifications for the 3GPP components. Roaming aspects were documented as well.

CT1 and CT4 specified Stage3 capabilities and functionalities according to SA2 Stage 2 in TS 23.272 as follows:

- combined EPS/IMSI attach and tracking area update procedures based on similar mechanisms as those used by the combined GPRS attach and routing area update procedures from 3GPP TS 24.008, in order to register the UE to the CS domain for future Fallback from E-UTRAN access to 2G/3G CS domain access;
- IMSI or combined EPS/IMSI detach procedure, both UE and network initiated, based on similar mechanisms as those used by the GPRS detach procedure from 3GPP TS 24.008;
- CS fallback related capability for the UE to receive the CS paging request via EPS and respond to this paging via the GERAN/UTRAN, or to request a CS call in E-UTRAN and establish the call in GERAN/UTRAN;
- procedures for supporting Mobile originating and Mobile terminating SMS in EPS;
- procedures required for the support of CS fallback to 1xRTT;
- procedures on the SGs interface between the MME and the MSC, based on the Gs interface procedures.

Petitioners' Exhibit 1003, p. 121
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

4.10 System enhancements for the use of IMS services in local breakout (SAES-IMS_LBO) UID_390039

Resources: S2

References

Document	Title/Contents
WID(s)	
SP-080090	SA2 WID on System enhancements for the use of IMS services through local breakout
Impacted Specifications	
TS 23.228, 23.221, 23.203	S2
New Dedicated Specifications/Reports	
-	-

UID	Name	Resource	Hyperlink	TS_TR
390039	**System enhancements for the use of IMS services in local breakout**	S2	SP-080090	23.228, 23.221, 23.203

IMS services, like voice and video conferencing, can greatly benefit of Local BreakOut (LBO). This allows reducing cost per bit of data traffic exchanged by roaming customers, since at least part of it can be handled directly by the visited operator, with no need to waste bandwidth on the international links between the home and visited PLMNs. Moreover, LBO offers better performance to the customers, since the locally routed traffic faces lower delays.

The work introduces system enhancements for LBO into Stage 2 specifications, under the assumption that IMS signalling and IMS bearer traffic are both anchored at a PDN GW in the VPLMN. In particular it identified:

- solutions for the home Operator to control whether the IMS user may access to IMS services through a PDN in the VPLMN;
- solutions to allow the UE to establish connectivity to a single PDN GW in the VPLMN and use IMS services through local breakout;
- if methods are necessary to discover a P-CSCF in the VPLMN or in the HPLMN, after the UE has connected to the visited PDN GW;
- requirements for the connectivity between the PDNs and/or interactions with network entities such as NAT (as specified in TS 23.228);
- interactions with and support of PCC;
- legal intercept implications.

Petitioners' Exhibit 1003, p. 122
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

4.11 EPC Data Definitions (EPC-OAM) UID_390010

Resources: S5

The EPC Data Definitions Building Block of the SAES Feature covers several independent Work Tasks as follows:

- EPC Network Resource Model (NRM) Integration Reference Point (IRP)
- Performance measurements for EPC

EPC Network Resource Model (NRM) Integration Reference Point (IRP) UID_380037

References

Document	Title/Contents
	WID(s)
SP-070737	WID on EPC Network Resource Model (NRM) Integration Reference Point (IRP)
	Impacted Specifications
-	-
	New Dedicated Specifications/Reports
TS 32.751	Telecommunication management; Evolved Packet Core (EPC) Network Resource Model (NRM) Integration Reference Point (IRP); Requirements
TS 32.752	Telecommunication management; Evolved Packet Core (EPC) Network Resource Model (NRM) Integration Reference Point (IRP): Information Service (IS)
TS 32.753	Telecommunication management; Evolved Packet Core (EPC) Network Resource Model (NRM) Integration Reference Point (IRP): Common Object Request Broker Architecture (CORBA) Solution Set (SS)
TS 32.755	Telecommunication management; Evolved Packet Core (EPC) Network Resource Model (NRM) Integration Reference Point (IRP): Bulk CM eXtensible Markup Language (XML) file format definition

UID	Name	Resource	Hyperlink	TS_TR
380037	EPC Network Resource Model (NRM) Integration Reference Point (IRP)	S5	SP-070737	new (32.751, 32.752, 32.753, 32.755)

The Evolved Packet Core (EPC) is defined by 3GPP with different Network Elements from the UTMS Core Network. The Network Resource Model (NRM) of the UTMS Core Network is not applicable to EPC.

The EPC system needs to be managed. 3GPP network management paradigm necessitates the standardization of the representations of various managed resources. The standardization of the EPC system managed resources is captured in the so-called EPC Network Resource Model (NRM).

The EPC architecture and capabilities evolve from those defined for UTMS Core Network. The management of the EPC system should also evolve from that for managing the UTMS Core Network. In particular, the NRM for EPC should align and resemble those specified for the Core managed network resources.

The alignment of EPC NRM with Core NRM will have the following benefits:

- The system architecture of EPC evolves from Core network and the existing Core network NRM is proven in operation. Therefore, the alignment will result in a specification that has a higher chance of being bug free when compared to a "brand new" designed specification.
- It will minimise both the standardisation and product development efforts and maintenance efforts (i.e. the cost and time for development including testing and reduction of training cost when the management paradigms for EPC and Core network remained similar);
- It will shorten the time to market for EPC systems;
- It will facilitate a seamless coexistence with Core network management systems.

TS 32.75x-series define the EPC NRM IRP using the same principles as for the UMTS Core network NRM.
It has identical characteristics as those defined for other NRMs such as UMTS Core network NRM.
The DN of its instances uses the same name convention as all instances, whose IOCs are defined in various NRM IRPs.
Its IOCs integrate identically with other NRM (e.g. UMTS/GSM NRM IRP) with the IOCs defined in Generic NRM IRP. Operations and notifications defined in various Interface IRPs that work with existing instances of various NRM IRPs work without change with the new instances of EPC.

Similar to existing 3GPP NRM IRPs such as UTRAN and Core Network NRM IRP, the EPC NRM IRP focuses only on the representation of the network resources in question. It does not deal with the applications or usage of the IOCs.

Petitioners' Exhibit 1003, p. 123
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

This work defines the NRM for EPC, e.g. MME, HSS, Serving GW, PDN GW.

Performance measurements for EPC UID_390011

References

Document	Title/Contents
WID(s)	
SP-080061	WID on Performance measurements for EPC
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TS 32.426	Telecommunication management; Performance Management (PM); Performance measurements Evolved Packet Core (EPC) network

UID	Name	Resource	Hyperlink	TS_TR
390011	Performance measurements for EPC	S5	SP-080061	new 32.426

The Evolved Packet Core (EPC) network defined by 3GPP adds new Network Elements, such as MME, UPE, Serving gateway, Packet Data Network (PDN) gateway etc. See TS 23.401 for the non-roaming and roaming architectures for 3GPP accesses. New interfaces between Network Elements and signalling over those interfaces are also introduced and are different from the pre-Rel-8 Core Network.

Performance Management (PM) is one of basic management function for EPC, and performance measurements are the base for PM. Existing performance measurements defined in TS 32.406/7/8/9 cannot meet the EPC management requirements. Hence, it is necessary to define new performance measurements for EPC.

The management of EPC evolves from the pre-Rel-8 management architecture, and PM IRP (TS 32.41x-series) were reused, so that performance measurement definitions reuse the template defined in TS 32.404.

TS 32.426 defines performance measurements for EPC with the same template as defined in TS 32.404.

Petitioners' Exhibit 1003, p. 124
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

4.12 EPC Charging (EPC-CH) UID_380038

Resources: S5

References

Document	Title/Contents
WID(s)	
SP-070736	WID on Evolved Packet Core (EPC) Charging
Impacted Specifications	
TS 32.240	Charging architecture and principles
TS 32.251	Packet Switched (PS) domain charging
TS 32.252	Wireless Local Area Network (WLAN) charging
TS 32.296	Online Charging System (OCS): Applications and interfaces
TS 32.298	Charging Data Record (CDR) parameter description
TS 32.299	Diameter charging applications
New Dedicated Specifications/Reports	
-	-

UID	Name	Resource	Hyperlink	TS_TR
380038	**EPC Charging**	S5	SP-070736	32.240, 32.296, 32.251, 32.252, 32.298, 32.299

The Evolved 3GPP System needs reliable and efficient charging solutions. As the EPC is an evolution of UMTS, also the charging solutions should evolve.

SA5 Study UID_350004 concludes in TR 32.820 (Study on charging management; 3GPP Evolved Packet Core (EPC): Charging aspects) that reusing existing UMTS charging specifications has the following benefits:

- • It is proven in operation;
- • Minimizes both the standardisation and product development efforts (i.e. the cost and time);
- • Provides a base, on which more functionality can be developed;
- • Shortens the time to market for Evolved 3GPP systems;
- • Facilitates a seamless coexistence with UMTS charging systems.
- • Considers also non-3GPP access;
- • Enables an easy migration for the Operator to the new solution.

This work adds via CRs the charging for the EPC Architecture following the recommendations given in TR 32.820.

Petitioners' Exhibit 1003, p. 125
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

4.13 Domain Name System Procedures for Evolved Packet System (DEPS) UID_400004

Resources: C4

References

Document	Title/Contents
WID(s)	
CP-080280	WID on Domain Name System Procedures for Evolved Packet System (DEPS)
Impacted Specifications	
TS 23.003	Numbering, addressing and identification
New Dedicated Specifications/Reports	
TS 29.303	Domain Name System Procedures; Stage 3

UID	Name	Resource	Hyperlink	TS_TR
400104	**Domain Name System Procedures for Evolved Packet System (DEPS)**	C4	CP-080280	23.003, new 29.303

Rel-8 EPS work has shown that existing pre-Rel-8 DNS procedures for gateway selection are not adequate in EPS. Furthermore, EPS APN naming and subsequent DNS procedures are further complicated by the multiple protocol support (i.e. GTP and Proxy Mobile IP) in Rel-8 gateway nodes and over the inter-operator roaming connections. Well defined DNS procedures for EPS are needed for more advanced DNS usage than using A or AAAA query types.

This work provides Stage 2 procedures and Stage 3 descriptions for DNS usage that cover the EPC node selection (e.g. SGW and PGW nodes) excluding the UE initiated ePDG and Home Agent discovery and selection procedures. The DNS based node selection may be affected by the selected APN, desired protocol support (e.g. GTP or PMIP), and other operational and deployment related information (e.g. service area). The DNS procedures cover both intra- and inter-operator cases.

Petitioners' Exhibit 1003, p. 126
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

4.14 IWF between MAP based and Diameter based interfaces (SAES-MAP2Diam) UID_410007

Resources: C4

References

Document	Title/Contents
WID(s)	
CP-080644	WID on InterWorking Function (IWF) between MAP based and Diameter based interfaces
Impacted Specifications	
New Dedicated Specifications/Reports	
TS 29.305	InterWorking Function (IWF) between MAP based and Diameter based interfaces

UID	Name	Resource	Hyperlink	TS_TR
410007	**InterWorking Function (IWF) between MAP based and Diameter based interfaces**	C4	CP-080644	new 29.305

This work was triggered by the Rel-8 Study UID_380023 (FS_MAP2Diam) which produced TR 29.805 InterWorking Function (IWF) between MAP based and Diameter based interfaces.

TSG SA has set the requirement for interworking between SAE/LTE and the legacy system.
Some MAP based interfaces are used in legacy systems and CT4 choose the Diameter protocol for S6a/S6d/S13 in EPS. CT4 specified S6a/S6d/S13 related interworking scenarios to be used between EPC networks or between EPC and GPRS core network. Interworking for the other interfaces may be specified in later 3GPP Releases.

CT4 has produced protocol mapping between Diameter based S6a/S6d/S13 and MAP based Gr/Gr+/Gf for the EPS, including description of scenarios, description of mapping procedures and mapping of related messages/parameters.

4.15 CT6 aspects of SAE UID_390121

Resources: C6

References

Document	Title/Contents
WID(s)	
CP-080164	WID on CT6 aspects of System Architecture Evolution
Impacted Specifications	
TS 31.102	Characteristics of the Universal Subscriber Identity Module (USIM) application [Support of SAE identities in USIM]
TS 31.111	Universal Subscriber Identity Module (USIM) Application Toolkit (USAT) [Support of SAE identities in USAT]
New Dedicated Specifications/Reports	
-	-

UID	Name	Resource	Hyperlink	TS_TR
390121	CT6 aspects of SAE	C6	CP-080164	31.102, 31.111

CT6 is responsible within 3GPP for specifications of smart card based network authentication applications such as the Subscriber Identity Module (SIM) used in 2G systems, USIM (Universal Subscriber Identity Module) used in 3GPP systems and ISIM (IM Services Identity Module) excluding security algorithms which are developed by SA3.

This work produced specifications for USIM data and procedures used in EPS.
It specified Network Measurement Results collection via USAT.

Petitioners' Exhibit 1003, p. 127
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

4.15.1 Test interworking of LTE Terminals with the USIM UID_420018

Resources: C6

References

Document	Title/Contents
WID(s)	
CP-090711	WID on Test interworking of LTE Terminals with the USIM
Impacted Specifications	
TS 31.121	UICC-terminal interface; Universal Subscriber Identity Module (USIM) application test specification
TS 31.124	Mobile Equipment (ME) conformance test specification; Universal Subscriber Interface Module Application Toolkit (USAT) conformance test specification
New Dedicated Specifications/Reports	
-	-

UID	Name	Hyperlink	Notes	TS_TR
420018	Test interworking of LTE Terminals with the USIM	CP-100598	CP#50 completed. Steering of Roaming test cases have been introduced. Remaining issues CSG display testing (Provide Local Information, Call Control for EPS/PDN, Event Download (Access Technology Change - Multiple Access Technologies)	31.121, 31.124

Development of conformance test cases for Rel-8 terminals supporting E-UTRA/EPC covering the interworking of the USIM application and USIM application toolkit (USAT) on the UICC and E-UTRA/EPC. To cover the handling of a Pre-Rel-8 USIM used for access to E-UTRAN/EPC and also the handling of a Rel-8 or later USIM used for access to E-UTRAN/EPC it is proposed to structure the WI into these 2 main parts.

The objective of this work item proposal is the specification of test cases to verify terminal interworking with the USIM application and USIM application toolkit (USAT) on the UICC and with E-UTRA/EPC. Therefore the USIM application specification TS 31.102, the USIM application toolkit specification TS 31.111, the E-UTRA specifications (mainly TS 36.331) and EPC specifications (mainly 24.301) are considered in this WI to ensure that the terminal is acting on the network side according to the parameters specified on the USIM and vice versa. For this the existing test specifications TS 31.121 and TS 31.124are reused and will be extended where appropriate.

The following structure for the test specification is proposed:

Pre-Rel-8 USIM used for access to E-UTRAN/EPC (compatibility with existing USIM capabilities and procedures)

- Items are for study

Rel-8 or later USIM (enhanced specific LTE EFs and functions on the USIM and for USAT) used for access to E-UTRAN/EPC

- Use E-UTRA as new RAT for PLMN selection and registration for EPS services
- Handling EMM parameter for EPS Mobility Management and EPS NAS Security context (TS 24.301, TS 31.102) to be stored on a Rel-8 or later USIM
- CSG list handling for USIM and USAT
- Further PS specific USIM features used in EPC not tested yet, FFS
- Further items for USIM are FFS
- Support of E-UTRAN in Provide Local Information for NMR
- Support of EPS in USAT: BIP, Provide Local Information, Call control
- Further Items for USAT are for FFS.

Petitioners' Exhibit 1003, p. 128
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

4.15.2 Test interworking of ISIM terminals with IMS UID_490015

Resources: C6

References

Document	Title/Contents
	WID(s)
CP-100602	WID on Test interworking of IP Multimedia Services Identity Module (ISIM) terminals with IP Multimedia Subsystem (IMS)
	Impacted Specifications
TS 31.121	UICC-terminal interface; Universal Subscriber Identity Module (USIM) application test specification
TS 31.124	Mobile Equipment (ME) conformance test specification; Universal Subscriber Interface Module Application Toolkit (USAT) conformance test specification
	New Dedicated Specifications/Reports
TS 31.134	Mobile Equipment (ME) conformance test specification; IP Multimedia Services Identity Module (ISIM) interworking with IP Multimedia Subsystem (IMS) test specification

UID	Name	Hyperlink	Notes	TS_TR
490015	Test interworking of IP Multimedia Services Identity Module (ISIM) terminals with IP Multimedia Subsystem (IMS)	CP-100602	CP#52 completed.Linked to Rel-5 UID_1273 Provisioning of IP-based multimedia services (24.229, 31.103), Rel-8 UID_390021 CT6 aspects of SAE, UID_420018 Test interworking of LTE Terminals with the USIM, Rel-9 UID_450018 Testing SMS over IMS in E-UTRAN (34.229).	31.121, 31.124, new TS 31.134

Justification

Development of conformance test for Rel-8 and onwards terminals with IMS support based on the use of the IP Multimedia Services Identity Module (ISIM) application.

Objective

The objective of this work item proposal is the evaluation of existing test cases and when appropriate specification of test cases to verify terminal interworking with the ISIM application and USIM application toolkit (USAT) on the UICC and the IP Multimedia Subsystem, especially in combination with the E-UTRA/EPC. Therefore the ISIM application specification TS 31.103, the USIM application toolkit specification TS 31.111 and the IP multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP) specification TS 24.229 are considered in this WI to ensure that the terminal is acting on the network side according to the parameters specified on the ISIM and vice versa. For IMS related USIM/USAT tests the existing test specifications TS 31.121 and TS 31.124 are reused and will be extended where appropriate.

Evaluation of features and available tests to ensure the correct support of the following features (the list is not exhaustive):

- Handling of User IDs stored on the ISIM
- Usage of Home Domain Name as stored on the ISIM
- Handling of P-CSCF addresses as stored on the ISIM

Evaluation of tests and definition/adaptation of test cases to ensure the correct support of the following features

- Support of IMS with USIM/ISIM interworking: Short Message Service storage on USIM
- Support of IMS in USAT: Send Short Message, SMS-PP Data Download

Petitioners' Exhibit 1003, p. 129
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5 3G Long Term Evolution - Evolved Packet System RAN part (LTE) UID_20068

Resources: RP,S5

References

Document	Title/Contents
	WID(s)
RP-080747	WID on 3G Long Term Evolution
	Impacted Specifications
-	-
	New Dedicated Specifications/Reports
TR 36.938	Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Improved network controlled mobility between E-UTRAN and 3GPP2/mobile WiMAX radio technologies
TS 36.300	Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access (E-UTRAN); Overall description; Stage 2

Supporting Individual Members: NTT DoCoMo, Alcatel-Lucent, CATT, AT&T, Ericsson, ETRI, Freescale, Fujitsu, Intel, Institute for Infocomm Research, LG Electronics, Motorola, Mitsubishi Electric, NEC, Nokia, Nokia Siemens Networks, Nortel, Panasonic, Philips, RIM, Samsung, Sharp, Texas Instruments, T-Mobile, Toshiba, KDDI, Verizon Wireless, ZTE.

Status report in RP-080741

UID	Title	Acronym	WG	WID	SR
20068	**Rel-8 LTE – 3G Long Term Evolution - Evolved Packet System RAN part**	LTE	RP,S5	RP-070131	RP-080741
330018	**LTE – Physical Layer**	LTE-Phys	R1	RP-060630	RP-080741
330019	**LTE – Radio Interface Layer 2 and 3 Protocol Aspect**	LTE-L23	R2	RP-060630	RP-080741
330020	**LTE – eUTRAN Interfaces**	LTE-interfaces	R3	RP-060630	RP-080741
330021	**LTE – Evolved UTRA and UTRAN RF Radio Transmission/Reception, System Performance Requirements and Conformance Testing**	LTE-RF	R4	RP-060630	RP-080741
370046	**LTE – FDD repeaters**	LTE-Repeaters	R4	RP-070749	RP-090037
390001	**E-UTRAN Data Definitions**	E-UTRAN-OAM	S5		
390004	**Self-Organizing Networks (SON)**	LTE_SON-OAM	S5	SP-080275	

UID	Title	Acronym	WG	WID
390001	**E-UTRAN Data Definitions**	E-UTRAN-OAM	S5	
370001	Subscriber and Equipment Trace for E-UTRAN and EPC	E-UTRAN-OAM	S5	SP-070617
380036	E-UTRAN Network Resource Model (NRM) Integration Reference Point (IRP)	E-UTRAN-OAM	S5	SP-070738
390002	Performance measurements for E-UTRAN	E-UTRAN-OAM	S5	SP-080062
390003	Key Performance Indicators (KPIs) for E-UTRAN	E-UTRAN-OAM	S5	SP-080063

UID	Title	Acronym	WG	WID
390004	**Self-Organizing Networks (SON)**	LTE_SON-OAM	S5	SP-080275
390104	SON Concepts and requirements	LTE_SON-OAM	S5	SP-080275
390005	Self-Establishment of eNBs, including automated Software Management	LTE_SON-OAM	S5	SP-080849
390006	SON Automatic Neighbour Relations (ANR) List Management	LTE_SON-OAM	S5	SP-080066

http://www.3gpp.org/Highlights/LTE/LTE.htm

Petitioners' Exhibit 1003, p. 130
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.1 Long Term Evolution of the 3GPP radio technology

3GPP work on the Evolution of the 3G Mobile System started with the RAN Evolution Workshop, 2 - 3 Nov 2004 in Toronto, CANADA. The Workshop was open to all interested organizations, members and non members of 3GPP. Operators, manufacturers and research institutes presented more than 40 contributions with views and proposals on the evolution of the Universal Terrestrial Radio Access Network (UTRAN).

A set of high level requirements was identified in the Work Shop:

- Reduced cost per bit
- Increased service provisioning – more services at lower cost with better user experience
- Flexibility of use of existing and new frequency bands
- Simplified architecture, Open interfaces
- Allow for reasonable terminal power consumption

It was also recommended that the Evolved UTRAN should bring significant improvements to justify the standardization effort and it should avoid unnecessary options. On certain aspects, the collaboration with 3GPP SA WGs was found to be essential: the new split between the Access Network and the Core Network, and the characteristics of the throughput that new services would require demanded close architectural coordination.

With the conclusions of this Workshop and with broad support from 3GPP members, a Feasibility Study on the UTRA & UTRAN Long Term Evolution was started in Dec 2004. The objective was "to develop a framework for the evolution of the 3GPP radio-access technology towards a high-data-rate, low-latency and packet-optimized radio-access technology" The study focused on supporting services provided from the PS-domain, involving:

- Related to the radio-interface physical layer (downlink and uplink):
  - e.g. means to support flexible transmission bandwidth up to 20 MHz, introduction of new transmission schemes and advanced multi-antenna technologies
- Related to the radio interface layer 2 and 3:
  - e.g. signalling optimization
- Related to the UTRAN architecture:
  - identify the optimum UTRAN network architecture and functional split between RAN network nodes
- RF-related issues

In addition, the Next Generation Mobile Networks (NGMN) initiative provided a set of recommendations for the creation of networks suitable for the competitive delivery of mobile broadband services. The NGMN goal is "to provide a coherent vision for technology evolution beyond 3G for the competitive delivery of broadband wireless services".

The NGMN long-term objective is to "establish clear performance targets, fundamental recommendations and deployment scenarios for a future wide area mobile broadband network". In a white paper (March 2006), they provided relative priorities of key system characteristics, System recommendations and detailed requirements.

Emphasis was also on the IPR side, where the goal was "to adapt the existing IPR regime to provide a better predictability of the IPR licenses (...) to ensure Fair, Reasonable And Non-Discriminatory (FRAND) IPR costs" (NGMN White paper, Mar 2006).

All RAN WGs participated in the study, with collaboration from SA2 in the key area of the network architecture.
The first part of the study resulted in agreement on the requirements for the Evolved UTRAN.

5.1.1 Study phase and requirements

As a result, TR 25.913 contains detailed requirements for the following criteria:

Peak data rate

- Instantaneous downlink peak data rate of 100 Mb/s within a 20 MHz downlink spectrum allocation (5 bps/Hz)
- Instantaneous uplink peak data rate of 50 Mb/s (2.5 bps/Hz) within a 20MHz uplink spectrum allocation)

Control-plane latency

- Transition time of less than 100 ms from a camped state, such as Release 6 Idle Mode, to an active state such as Release 6 CELL_DCH
- Transition time of less than 50 ms between a dormant state such as Release 6 CELL_PCH and an active state such as Release 6 CELL_DCH

Petitioners' Exhibit 1003, p. 131
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Control-plane capacity

- At least 200 users per cell should be supported in the active state for spectrum allocations up to 5 MHz

User-plane latency

- Less than 5 ms in unload condition (i.e. single user with single data stream) for small IP packet

User throughput

- Downlink: average user throughput per MHz, 3 to 4 times Release 6 HSDPA
- Uplink: average user throughput per MHz, 2 to 3 times Release 6 Enhanced Uplink

Spectrum efficiency

- Downlink: In a loaded network, target for spectrum efficiency (bits/sec/Hz/site), 3 to 4 times Release 6 HSDPA)
- Uplink: In a loaded network, target for spectrum efficiency (bits/sec/Hz/site), 2 to 3 times Release 6 Enhanced Uplink

Mobility

- E-UTRAN should be optimized for low mobile speed from 0 to 15 km/h
- Higher mobile speed between 15 and 120 km/h should be supported with high performance
- Mobility across the cellular network shall be maintained at speeds from 120 km/h to 350 km/h (or even up to 500 km/h depending on the frequency band)

Coverage

- Throughput, spectrum efficiency and mobility targets above should be met for 5 km cells, and with a slight degradation for 30 km cells. Cells range up to 100 km should not be precluded.

Further Enhanced Multimedia Broadcast Multicast Service (MBMS)

- While reducing terminal complexity: same modulation, coding, multiple access approaches and UE bandwidth than for unicast operation.
- Provision of simultaneous dedicated voice and MBMS services to the user.
- Available for paired and unpaired spectrum arrangements.

Spectrum flexibility

- E-UTRA shall operate in spectrum allocations of different sizes, including 1.25 MHz, 1.6 MHz, 2.5 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz in both the uplink and downlink. Operation in paired and unpaired spectrum shall be supported
- The system shall be able to support content delivery over an aggregation of resources including Radio Band Resources (as well as power, adaptive scheduling, etc) in the same and different bands, in both uplink and downlink and in both adjacent and non-adjacent channel arrangements. A "Radio Band Resource" is defined as all spectrum available to an operator

Co-existence and Inter-working with 3GPP Radio Access Technology (RAT)

- Co-existence in the same geographical area and co-location with GERAN/UTRAN on adjacent channels.
- E-UTRAN terminals supporting also UTRAN and/or GERAN operation should be able to support measurement of, and handover from and to, both 3GPP UTRAN and 3GPP GERAN.
- The interruption time during a handover of real-time services between E-UTRAN and UTRAN (or GERAN) should be less than 300 msec.

Architecture and migration

- Single E-UTRAN architecture
- The E-UTRAN architecture shall be packet based, although provision should be made to support systems supporting real-time and conversational class traffic
- E-UTRAN architecture shall minimize the presence of "single points of failure"
- E-UTRAN architecture shall support an end-to-end QoS
- Backhaul communication protocols should be optimised

Radio Resource Management requirements

- Enhanced support for end to end QoS
- Efficient support for transmission of higher layers
- Support of load sharing and policy management across different Radio Access Technologies

Complexity

- Minimize the number of options
- No redundant mandatory features

Petitioners' Exhibit 1003, p. 132
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The Study phase was concluded in Sep 2006 and the Implementation WID for 3G Long Term Evolution was created. As expected, in particular the E-UTRA system will provide significantly higher data rates than Rel-6 WCDMA. The increase in data rate is achieved especially through higher transmission bandwidth and support for MIMO.

In particular, the study showed that simultaneous support for UTRA and E-UTRA UEs in the same spectrum allocation was possible.

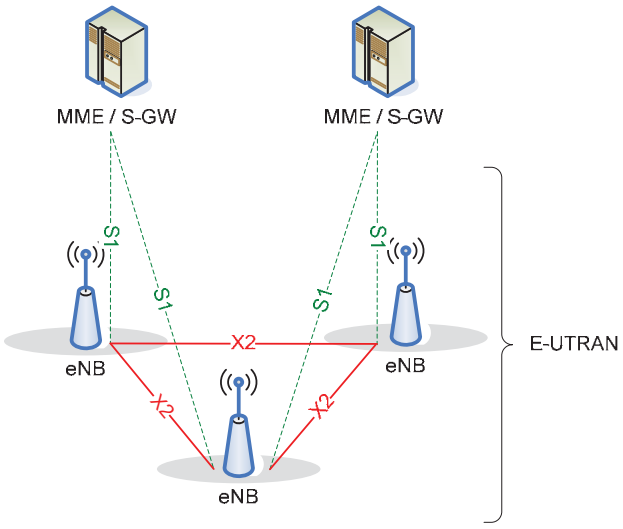
Solutions chosen for the physical layer and Layers 2/3 showed a convergence between paired spectrum and unpaired spectrum solutions for the Long Term Evolution (e.g. initial access, handover procedures, measurements, frame and slot structures).

5.1.2 Specification phase and achievements

Architecture

The E-UTRAN overall architecture is described in TS 36.300 and TS 36.401.

The E-UTRAN consists of eNBs which are interconnected with each other by the X2 interface. Each eNB is connected to the Evolved Packet Core (EPC) network by the S1 interface. On the User Plane the S1 interface terminates the Serving Gateway (S-GW), on the Signalling Plane the S1 interface terminates the Mobility Management Entity (MME).The eNBs are terminating points for Control- and User Plane towards the UEs in the Evolved UTRA.



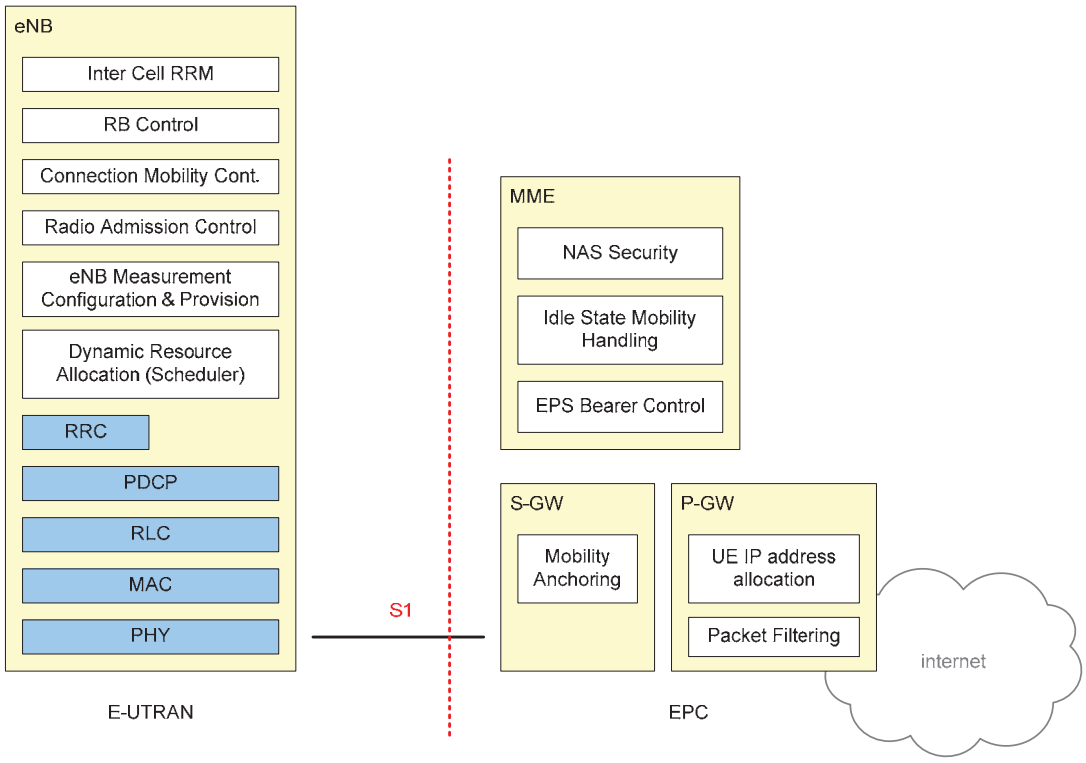
Overall Architecture

Petitioners' Exhibit 1003, p. 133
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

eNB Functions

The eNB hosts the following functions:

- Functions for Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs in both uplink and downlink (scheduling)
- IP header compression and encryption of user data stream
- Selection of an MME at UE attachment when no routing to an MME can be determined from the information provided by the UE
- Routing of User Plane data towards Serving Gateway
- Scheduling and transmission of paging messages (originated from the MME)
- Scheduling and transmission of broadcast information (originated from the MME or O&M
- Measurement and measurement reporting configuration for mobility and scheduling



Functional Split between E-UTRAN and EPC

General principles of the E-UTRAN Architecture (see TS 36.401)

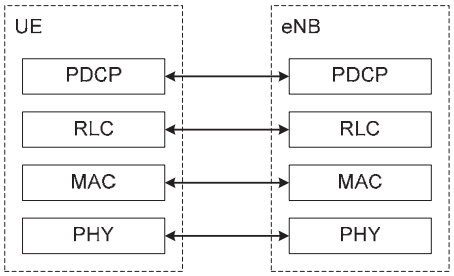
The general principles guiding the definition of E-UTRAN Architecture as well as the E-UTRAN interfaces are the following:

- Logical separation of signalling and data transport networks
- E-UTRAN and EPC functions are fully separated from transport functions. Addressing scheme used in E-UTRAN and EPC shall not be tied to the addressing schemes of transport functions. The fact that some E-UTRAN or EPC functions reside in the same equipment as some transport functions does not make the transport functions part of the E-UTRAN or the EPC.
- Mobility for RRC connection is fully controlled by the E-UTRAN.
- When defining the E-UTRAN interfaces the following principles were followed: the functional division across the interfaces shall have as few options as possible.
- Interfaces should be based on a logical model of the entity controlled through this interface.
- One physical network element can implement multiple logical nodes.

Petitioners' Exhibit 1003, p. 134
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

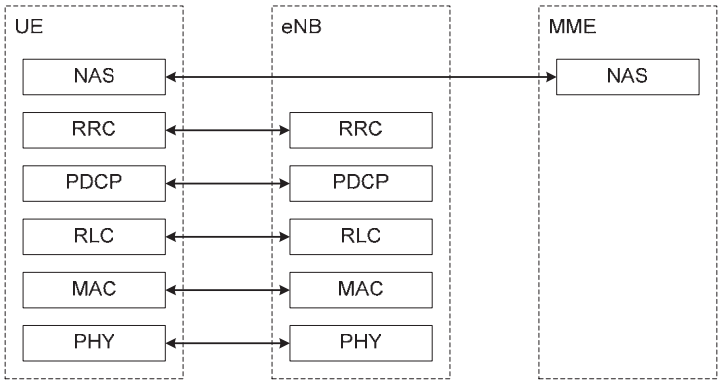
5.1.3 Radio Interface

The figure below shows the protocol stack for the user-plane, where PDCP, RLC and MAC sublayers (terminated in eNB on the network side) perform header compression, ciphering, scheduling, ARQ and HARQ.



User-plane protocol stack

The figure below shows the protocol stack for the control-plane. The NAS control protocol is mentioned for information only and is part of UE -EPC communication. The PDCP sublayer performs e.g. ciphering and integrity protection, RLC and MAC sublayers perform the same functions as for the user plane. The RRC performs broadcast, paging, RRC connection management, Radio Bearer control, Mobility functions, UE measurement reporting and control.



Control-plane protocol stack

Band Arrangement

E-UTRA is designed to operate in the frequency bands defined in table below. The requirements are defined for 1.4, 3, 5, 10, 15 and 20MHz bandwidth with a specific configuration in terms of number of resource blocks (6, 15, 25, 50, 75 and 100 RB).

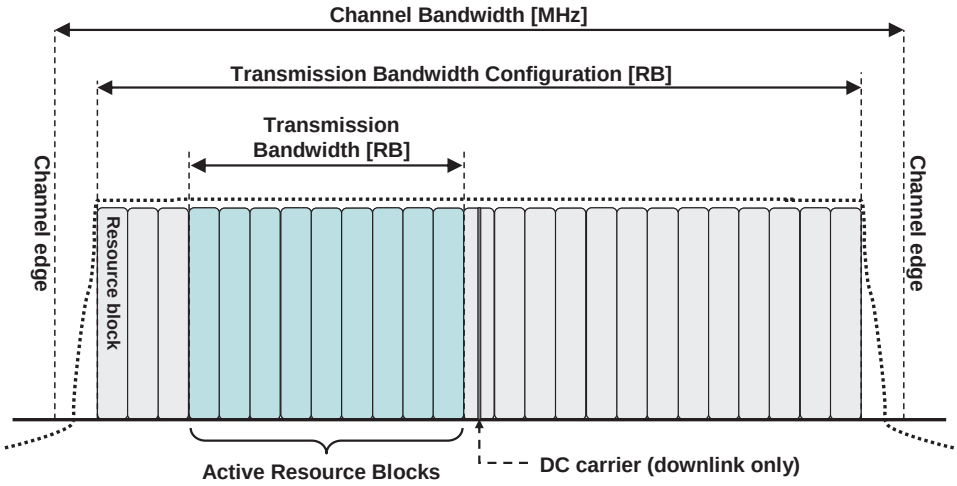
The figure below shows the relation between the total channel bandwidth, the transmission bandwidth configuration i.e. the number of resource blocks.

The channel raster is 100KHz (the center frequency must be a multiple of 100KHz).

To support transmission in paired and unpaired spectrum, two duplex modes are supported: Frequency Division Duplex (FDD), supporting full duplex and half duplex operation, and Time Division Duplex (TDD).

Petitioners' Exhibit 1003, p. 135
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

E-UTRA Band	Uplink (UL) eNode B receive UE transmit			Downlink (DL) eNode B transmit UE receive			UL-DL Band separation	Duplex Mode
	F_{UL_low}	–	F_{UL_high}	F_{DL_low}	–	F_{DL_high}	$F_{DL\_low} - F_{UL\_high}$	
1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	130 MHz	FDD
2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	20 MHz	FDD
3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	20 MHz	FDD
4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	355 MHz	FDD
5	824 MHz	–	849 MHz	869 MHz	–	894MHz	20 MHz	FDD
6	830 MHz	–	840 MHz	875 MHz	–	885 MHz	35 MHz	FDD
7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	50 MHz	FDD
8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	10 MHz	FDD
9	1749.9 MHz	–	1784.9 MHz	1844.9 MHz	–	1879.9 MHz	60 MHz	FDD
10	1710 MHz	–	1770 MHz	2110 MHz	–	2170 MHz	340 MHz	FDD
11	1427.9 MHz	–	1452.9 MHz	1475.9 MHz	–	1500.9 MHz	23 MHz	FDD
12	[TBD]	–	[TBD]	[TBD]	–	[TBD]	[TBD]	FDD
13	777 MHz	–	787 MHz	746 MHz	–	756 MHz	21	FDD
14	788 MHz	–	798 MHz	758 MHz	–	768 MHz	20	FDD
…								
33	1900 MHz	–	1920 MHz	1900 MHz	–	1920 MHz	N/A	TDD
34	2010 MHz	–	2025 MHz	2010 MHz	–	2025 MHz	N/A	TDD
35	1850 MHz	–	1910 MHz	1850 MHz	–	**1910 MHz**	N/A	TDD
36	1930 MHz	–	1990 MHz	1930 MHz	–	1990 MHz	N/A	TDD
37	1910 MHz	–	1930 MHz	1910 MHz	–	1930 MHz	N/A	TDD
38	2570 MHz	–	2620 MHz	2570 MHz	–	2620 MHz	N/A	TDD
39	1880 MHz	-	1920 MHz	1880 MHz	-	1920 MHz	N/A	TDD
40	2300 MHz	-	2400 MHz	2300 MHz	-	2400 MHz	N/A	TDD



Relation between Channel bandwidth and transmission bandwidth configuration

Transmission scheme

The multiple access scheme for the LTE physical layer is based on Orthogonal Frequency Division Multiple Access (OFDM) with a Cyclic Prefix (CP) in the downlink and a Single Carrier Frequency Division Multiple Access (SC-FDMA) with CP in the uplink.

OFDMA technique is particularly suited for frequency selective channel and high data rate. It transforms a wideband frequency selective channel into a set of parallel flat fading narrowband channels, thanks to CP. This ideally, allows the receiver to perform a low complex equalization process in frequency domain, i.e. 1 tap scalar equalization.

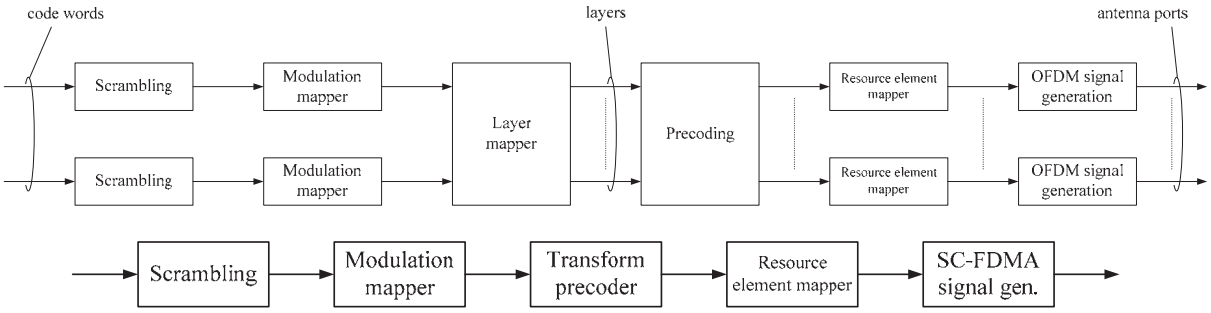
Petitioners' Exhibit 1003, p. 136
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The baseband signal representing a downlink physical channel is defined in terms of the following steps:

- scrambling of coded bits in each of the code words to be transmitted on a physical channel
- modulation of scrambled bits to generate complex-valued modulation symbols
- mapping of the complex-valued modulation symbols onto one or several transmission layers
- precoding of the complex-valued modulation symbols on each layer for transmission on the antenna ports
- mapping of complex-valued modulation symbols for each antenna port to resource elements
- generation of complex-valued time-domain OFDM signal for each antenna port

The baseband signal representing the physical uplink shared channel is defined in terms of the following steps, as shown in the below figure:

- scrambling
- modulation of scrambled bits to generate complex-valued symbols
- transform precoding to generate complex-valued symbols
- mapping of complex-valued symbols to resource elements
- generation of complex-valued time-domain SC-FDMA signal for each antenna port



Uplink physical channel processing

RF Related Requirements

In TS 36.101 and TS 36.104 different requirements can be found for the RF. In particular the following classification can be done.

For the UE transmitter, requirements are given for the following quantities:

- Transmit signal quality (Error Vector Magnitude (EVM));
- Maximum Output Power (MOP), Maximum Power Reduction (MPR), Output power dynamics;
- Output RF spectrum emission: (Occupied bandwidth, spectrum emission mask. Out of band emission, Adjacent Carrier Leakage Ratio (ACLR), spurious emission);
- Transmit intermodulation.

For the UE receiver, requirements are given for the following quantities:

- Reference sensitivity power level
- Maximum Input level
- Adjacent Channel sensitivity
- Blocking characteristic
- Spurious response
- Intermodulation characteristics
- Spurious emissions.

For the BS transmitter, requirements are given for the following quantities:

- Base station output power and output power dynamics, Transmit ON/OFF power;
- Transmitted signal quality, EVM and frequency error;
- Unwanted emissions (occupied bandwidth, ACLR, Operating band unwanted emissions, transmitter spurious emissions);
- Transmitter intermodulation.

Petitioners' Exhibit 1003, p. 137
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

For the BS receiver, requirements are given for the following quantities:

- Reference sensitivity level;
- Dynamic range;
- In-channel selectivity, Adjacent Channel Selectivity (ACS), blocking and narrow band blocking;
- Receiver spurious emissions;
- Receiver intermodulation.

In E-UTRA, the variable bandwidth of the system presents a special problem in the definition of the RF requirements; there may be the need to define some parameters as many times as there are bandwidth modes. Special attention has been given also to the coexistence issue, since LTE has to coexist with all the other already existing systems.

Performance requirements can be found in TS 36.101 and TS 36.104.

TS 36.113 covers the assessment of E-UTRA base stations, repeaters and associated ancillary equipment in respect of Electromagnetic Compatibility.

TS 36.141 specifies the Radio Frequency (RF) test methods and conformance requirements for E-UTRA Base Stations (BS) operating either in the FDD mode (used in paired bands) or the TDD mode (used in unpaired bands). These have been derived from, and are consistent with the E-UTRA Base Station (BS) specifications defined in TS 36.104.

Layer 1

The Layer 1 is defined in a bandwidth agnostic way based on resource blocks, allowing the LTE Layer 1 to adapt to various spectrum allocations. A resource block spans either 12 sub-carriers with a sub-carrier bandwidth of 15kHz or 24 sub-carriers with a sub-carrier bandwidth of 7.5kHz each over a slot duration of 0.5 ms.

The radio frame structure type 1 is used for FDD (for both full duplex and half duplex operation) and has a duration of 10 ms and consists of 20 slots with a slot duration of 0.5 ms. Two adjacent slots form one sub-frame of length 1 ms. The radio frame structure type 2 is used for TDD and consists of two half-frames with a duration of 5 ms each and containing each 8 slots of length 0.5 ms and three special fields (DwPTS, GP and UpPTS) which have configurable individual lengths and a total length of 1 ms. A sub-frame consists of two adjacent slots, except for sub-frames 1 and 6, which consist of DwPTS, GP and UpPTS. Both 5 ms and 10 ms switch-point periodicity are supported.

To support a Multimedia Broadcast and Multicast Service (MBMS), LTE offers the possibility to transmit Multicast/Broadcast over a Single Frequency Network (MBSFN), where a time-synchronized common waveform is transmitted from multiple cells for a given duration. MBSFN transmission enables highly efficient MBMS, allowing for over-the-air combining of multi-cell transmissions in the UE, where the cyclic prefix is utilized to cover the difference in the propagation delays, which makes the MBSFN transmission appear to the UE as a transmission from a single large cell. Transmission on a dedicated carrier for MBSFN with the possibility to use a longer CP with a sub-carrier bandwidth of 7.5 kHz is supported as well as transmission of MBSFN on a carrier with both MBMS transmissions and point-to-point transmissions using time division multiplexing.

Transmission with Multiple Input and Multiple Output antennas (MIMO) are supported with configurations in the downlink with two or four transmit antennas and two or four receive antennas, which allow for multi-layer transmissions with up to four streams.

Under Single-User MIMO, the base station allocates 1 or 2 streams to the selected user, in the case of Multi-User MIMO the allocation of different (1 or 2) streams is done to different users. This is supported in both UL and DL.

The physical channels defined in the downlink are:

- Physical Downlink Shared Channel (PDSCH);
- Physical Multicast Channel (PMCH);
- Physical Downlink Control Channel (PDCCH);
- Physical Broadcast Channel (PBCH);
- Physical Control Format Indicator Channel (PCFICH);
- Physical Hybrid ARQ Indicator Channel (PHICH).

The physical channels defined in the uplink are:

- Physical Random Access Channel (PRACH),
- Physical Uplink Shared Channel (PUSCH),
- Physical Uplink Control Channel (PUCCH).
- In addition, signals are defined as reference signals, primary and secondary synchronization signals.

Petitioners' Exhibit 1003, p. 138
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The modulation schemes supported in the downlink and uplink are QPSK, 16QAM and 64QAM.

The channel coding scheme for transport blocks in LTE is Turbo Coding as for UTRA, with a coding rate of R=1/3, two 8-state constituent encoders and a contention-free Quadratic Permutation Polynomial (QPP) turbo code internal interleaver. Trellis termination is used for the turbo coding. Before the turbo coding, transport blocks are segmented into byte aligned segments with a maximum information block size of 6144 bits. Error detection is supported by the use of 24 bit CRC.

There are several Physical layer procedures involved with LTE operation:

- Cell search;
- Power control;
- Uplink synchronization and Uplink timing control;
- Random access related procedures;
- HARQ related procedures.

Through the control of physical layer resources in the frequency domain as well as in the time and power domain, implicit support of interference coordination is provided in LTE.

See TS 36.201 and TS 36.211 for more information.

5.1.4 Mobility and Radio Resource Management

Radio characteristics are measured by the UE and the eNode-B and reported to higher layers in the network. These include, e.g. measurements for intra- and inter-frequency handover, inter RAT handover, timing measurements and measurements for RRM.

Measurements for inter-RAT handover are defined in support of handover to GSM, UTRA FDD and UTRA TDD.

Measurements to be performed by a UE for mobility are classified in at least three measurement types:

- Intra-frequency E-UTRAN measurements;
- Inter-frequency E-UTRAN measurements;
- Inter-RAT measurements for UTRAN and GERAN.

In E-UTRAN RRC_CONNECTED state, network-controlled UE-assisted handovers are performed and various DRX cycles are supported.

E-UTRAN supports radio access network sharing based on support for multi-to-multi relationship between E-UTRAN nodes and EPC nodes (S1-flex).

Service-based redirection between GERAN / UTRAN and E-UTRAN is supported in both directions.

E-UTRAN mechanisms to support idle and active mode mobility between E-UTRAN and cdma2000 HRPD or 1XRTT.

5.1.5 Support for self configuration and optimization

Self-configuration process is defined as the process where newly deployed nodes are configured by automatic installation procedures to get the necessary basic configuration for system operation.

This process works in pre-operational state. Pre-operational state is understood as the state from when the eNB is powered up and has backbone connectivity until the RF transmitter is switched on.

Self-optimization process is defined as the process where UE & eNB measurements and performance measurements are used to auto-tune the network.

This process works in operational state. Operational state is understood as the state where the RF interface is additionally switched on.

5.1.6 System Architecture Evolution

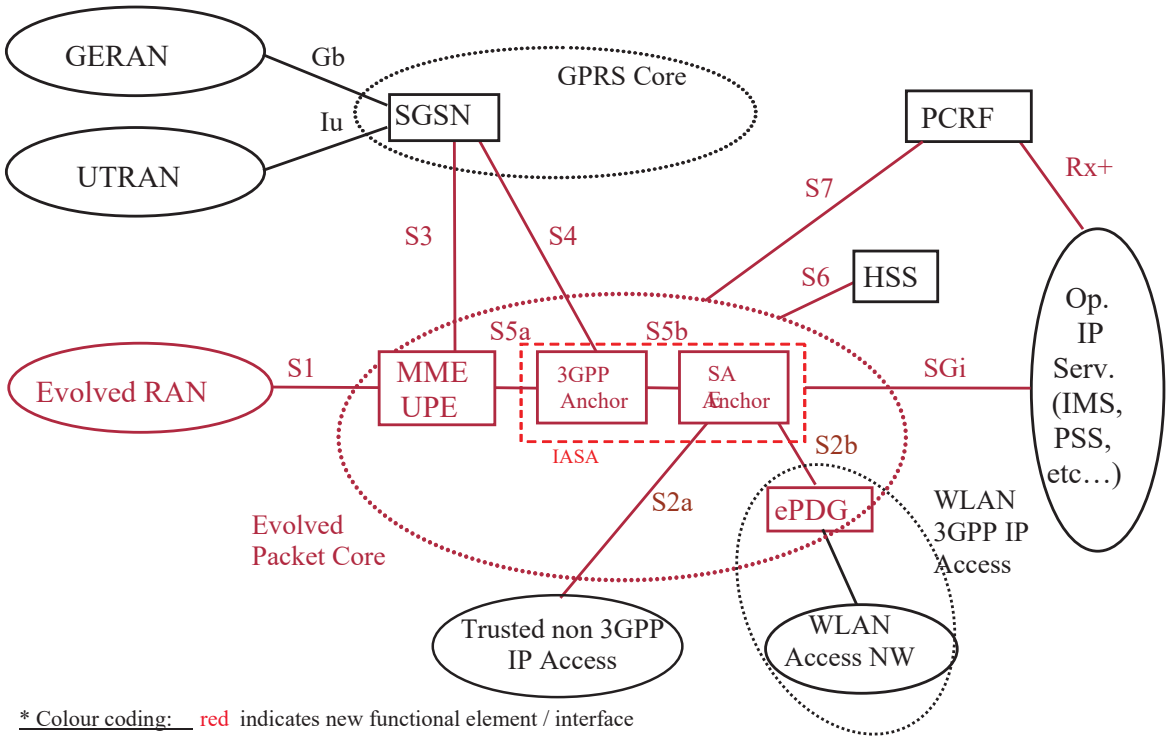
SA2 started its own Study on System Architecture Evolution (SAE) whose objective was "to develop a framework for an evolution or migration of the 3GPP system to a higher-data-rate, lower-latency, packet-optimized system that

Petitioners' Exhibit 1003, p. 139
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

supports, multiple RATs. The focus of this work is on the PS domain with the assumption that voice services are supported in this domain". It was initiated when it became clear that the future is IP with everything (the All-IP Network (AIPN) - see TR 22.978), and that access to the 3GPP network would ultimately be not only via UTRAN or GERAN but by WiFi, WiMAX, or even wired technologies. Thus SAE has as its main objectives:

- Impact on overall architecture resulting from RAN's LTE work;
- Impact on overall architecture resulting from SA1's AIPN work;
- Overall architectural aspects resulting from the need to support mobility between heterogeneous access networks.

This figure from TR 23.882 shows the evolved system architecture, possibly relying on different access technologies:



Logical high level architecture for the evolved system

New reference points have been defined:

S1: It provides access to Evolved RAN radio resources for the transport of user plane and control plane traffic. The S1 reference point shall enable MME and UPE separation and also deployments of a combined MME and UPE solution.

S2a: It provides the user plane with related control and mobility support between a trusted non 3GPP IP access and the SAE Anchor.

S2b: It provides the user plane with related control and mobility support between ePDG and the SAE Anchor.

S3: It enables user and bearer information exchange for inter 3GPP access system mobility in idle and/or active state. It is based on Gn reference point as defined between SGSNs.

User data forwarding for inter 3GPP access system mobility in active state (FFS).

S4: It provides the user plane with related control and mobility support between GPRS Core and the 3GPP Anchor and is based on Gn reference point as defined between SGSN and GGSN.

S5a: It provides the user plane with related control and mobility support between MME/UPE and 3GPP anchor.

It is FFS whether a standardized S5a exists or whether MME/UPE and 3GPP anchor are combined into one entity.

Petitioners' Exhibit 1003, p. 140
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

S5b: It provides the user plane with related control and mobility support between 3GPP anchor and SAE anchor. It is FFS whether a standardized S5b exists or whether 3GPP anchor and SAE anchor are combined into one entity.

S6: It enables transfer of subscription and authentication data for authenticating/authorizing user access to the evolved system (AAA interface).

S7: It provides transfer of (QoS) policy and charging rules from PCRF to Policy and Charging Enforcement Point (PCEP).
The allocation of the PCEP is FFS.

SGi: It is the reference point between the Inter AS Anchor and the packet data network. Packet data network may be an operator external public or private packet data network or an intra operator packet data network, e.g. for provision of IMS services. This reference point corresponds to Gi and Wi functionalities and supports any 3GPP and non-3GPP access systems.

The interfaces between the SGSN in 2G/3G Core Network and the Evolved Packet Core (EPC) will be based on the GTP protocol. The interfaces between the SAE MME/UPE and the 2G/3G Core Network will be based on the GTP protocol.

5.2 LTE – Physical Layer (LTE-Phys) UID_330018

Resources: R1

References

Document	Title/Contents
WID(s)	
RP-060630	WID on 3G Long Term Evolution – Physical Layer
Impacted Specifications	
TS 25.215	Physical layer; Measurements (FDD)
TS 25.225	Physical layer; Measurements (TDD)
New Dedicated Specifications/Reports	
TS 36.201	Evolved Universal Terrestrial Radio Access (E-UTRA); Long Term Evolution (LTE) physical layer; General description
TS 36.211	Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation
TS 36.212	Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding
TS 36.213	Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures
TS 36.214	Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer - Measurements

This work specifies the physical layer part of the 3G Long Term Evolution (3G LTE) including:

- Physical channels and mapping of transport channels
- Channel coding and physical channel mapping
- MIMO and transmit diversity
- MBMS functionality in physical layer
- Physical layer procedures
- Physical layer measurements
- UE physical layer capabilities

It includes also the verification of the performance of the 3G LTE physical layer.

Status report in RP-080741.

Petitioners' Exhibit 1003, p. 141
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.3 LTE – Radio Interface Layer 2 and 3 Protocol Aspect (LTE-L23) UID_330019

Resources: R2

References

Document	Title/Contents
WID(s)	
RP-060630	R2 WID on 3G Long Term Evolution – Radio Interface Layer 2 and 3 Protocol Aspects
Impacted Specifications	
TS 25.302	Services provided by the physical layer
TS 25.304	User Equipment (UE) procedures in idle mode and procedures for cell reselection in connected mode
TS 25.331	Radio Resource Control (RRC); Protocol specification
New Dedicated Specifications/Reports	
TS 36.302	Evolved Universal Terrestrial Radio Access (E-UTRA); Services provided by the physical layer
TS 36.304	Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode
TS 36.306	Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities
TS 36.314	Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Layer 2 - Measurements
TS 36.321	Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification
TS 36.322	Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Link Control (RLC) protocol specification
TS 36.323	Evolved Universal Terrestrial Radio Access (E-UTRA); Packet Data Convergence Protocol (PDCP) specification
TS 36.331	Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification

This work specifies the radio interface layer 2 and 3 protocol part of the 3G Long Term Evolution (3G LTE) including:

- Radio interface protocol architectures (including mobility solutions and self-optimisation of the E-UTRAN nodes)
- MAC, RLC, PDCP and RRC protocols
- UE capabilities

Status report in RP-080741.

5.4 LTE – eUTRAN Interfaces (LTE-interfaces) UID_330020

Resources: R3

References

Document	Title/Contents
WID(s)	
RP-060630	R3 WID on 3G Long Term Evolution – eUTRAN Interfaces
Impacted Specifications	
TS 25.413	UTRAN Iu interface Radio Access Network Application Part (RANAP) signalling
New Dedicated Specifications/Reports	
TS 36.401	Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Architecture description
TS 36.410	Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 layer 1 general aspects and principles
TS 36.411	Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 layer 1
TS 36.412	Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 signalling transport
TS 36.413	Evolved Universal Terrestrial Radio Access (E-UTRA) ; S1 Application Protocol (S1AP)
TS 36.414	Evolved Universal Terrestrial Radio Access Network (E-UTRAN); S1 data transport
TS 36.420	Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 general aspects and principles
TS 36.421	Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 layer 1
TS 36.422	Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 signalling transport
TS 36.423	Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 Application Protocol (X2AP)
TS 36.424	Evolved Universal Terrestrial Radio Access Network (E-UTRAN); X2 data transport

This work specifies the eUTRAN interfaces (currently S1 and X2) part of the 3G LTE including:

- Control plane protocols
- User plane protocols

RAN3 has ensured multi-vendor inter-operability and has considered aspects of self-optimization and self-configuration of the E-UTRAN nodes and possible impacts on eUTRAN interfaces.

Petitioners' Exhibit 1003, p. 142
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Status report in RP-080741.

5.5 LTE – RF Radio Transmission/Reception, System Performance Requirements and Conformance Testing (LTE-RF) UID_330021

Resources: R4

References

Document	Title/Contents
WID(s)	
RP-060630	WID on 3G Long Term Evolution – RF Radio Transmission/Reception, System Performance Requirements and Conformance Testing
Impacted Specifications	
TS 25.123	Requirements for support of radio resource management (TDD)
TS 25.133	Requirements for support of radio resource management (FDD)
New Dedicated Specifications/Reports	
TS 36.101	Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception
TS 36.104	Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception
TS 36.113	Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) and repeater ElectroMagnetic Compatibility (EMC)
TS 36.124	Evolved Universal Terrestrial Radio Access (E-UTRA); Electromagnetic compatibility (EMC) requirements for mobile terminals and ancillary equipment
TS 36.133	Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management
TS 36.141	Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) conformance testing
TR 36.942	Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Frequency (RF) system scenarios

This work specifies the radio transmission and reception performance requirements, RRM performance requirements and Base Station conformance testing part of the 3G LTE including:

- UE radio transmission and reception
- Base Station radio transmission and reception
- Base Station conformance testing
- Requirements for support of Radio Resource Management
- Selection of necessary combinations of bandwidth and frequency band to be standardised and their priority

Status report in RP-080741.

Petitioners' Exhibit 1003, p. 143
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.6 LTE FDD repeaters (LTE-Repeaters) UID_370046

Resources: R4

References

Document	Title/Contents
WID(s)	
RP-070749	WID on LTE FDD repeaters
Impacted Specifications	
TS 25.113	Base station and repeater electromagnetic compatibility (EMC)
New Dedicated Specifications/Reports	
TS 36.106	E-UTRA FDD repeater transmission and reception (Corresponding to TS 25.106)
TS 36.143	E-UTRA repeater conformance testing (Corresponding to TS 25.143)

In UTRA, FDD repeaters have proven to be useful for coverage adjustments and interference mitigation.
This is expected to remain also in E-UTRA, however it may pose new or different requirements on the repeaters.
RAN4 has developed core and conformance specifications for LTE FDD repeaters.

Status report in RP-090037.

5.7 LTE – Terminal Conformance Test Specifications (LTE-UEConTest) UID_25029

Covers Testing for Feature UID_20068 (LTE)

Resources: R5

UID	Title	WID	Status Report	TS_TR
25029	**Rel-8 LTE – Terminal Conformance Test Specification**			
25041	**3G LTE – Terminal Protocol Conformance Test Specifications**	RP-080647	RP-091060	36.521-1, 36.521-2, 36.508, 36.509, 36.523-1, 36.523-2, 36.523-3
25042	**LTE – Terminal Radio Transmission and Reception Conformance Test Specifications**	RP-080601	RP-091059	36.521-1, 36.521-2, 36.521-3, new TR 36.903 (RP#50 v100 for Approval)

Petitioners' Exhibit 1003, p. 144
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.8 E-UTRAN Data Definitions (E-UTRAN-OAM) UID_390001

Resources: S5

The E-UTRAN Data Definitions Building Block of the LTE Feature covers several independent Work Tasks as follows:

- E-UTRAN Network Resource Model (NRM) Integration Reference Point (IRP)
- Performance measurements for E-UTRAN
- Key Performance Indicators (KPIs) for E-UTRAN
- Subscriber and Equipment Trace for eUTRAN and EPC

5.8.1 E-UTRAN Network Resource Model (NRM) Integration Reference Point (IRP) UID_380036

References

Document	Title/Contents
WID(s)/Status Report	
SP-070738	WID on E-UTRAN Network Resource Model (NRM) Integration Reference Point (IRP)
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TS 32.761	Telecommunication management; E-UTRAN Network Resource Model (NRM) Integration Reference Point (IRP); Requirements
TS 32.762	Telecommunication management; E-UTRAN Network Resource Model (NRM) Integration Reference Point (IRP): Information Service (IS)
TS 32.763	Telecommunication management; E-UTRAN Network Resource Model (NRM) Integration Reference Point (IRP): Common Object Request Broker Architecture (CORBA) Solution Set (SS)
TS 32.765	Telecommunication management; E-UTRAN Network Resource Model (NRM) Integration Reference Point (IRP): Bulk CM eXtensible Markup Language (XML) file format definition

Supporting Individual Members: Ericsson, Huawei, Motorola, Nokia Siemens Networks, China Mobile, Nortel, T-Mobile, Telefonica, Vodafone, ZTE.

The E-UTRAN system is defined by 3GPP with different Network Elements from the UTRAN.
The Network Resource Model (NRM) of the UTRAN is not applicable to E-UTRAN.

The E-UTRAN system needs to be managed. 3GPP network management paradigm necessitates the standardization of the representations of various managed resources. The standardization of the E-UTRAN system managed resources is captured in the so-called E-UTRAN Network Resource Model (NRM).

The E-UTRAN architecture and capabilities evolve from those defined for UMTS. The management of the E-UTRAN system should also evolve from that for managing UMTS. In particular, the NRM for E-UTRAN should align and resemble those specified for UTRAN network resources.

The alignment of E-UTRAN NRM with UTRAN NRM leads to the following benefits:

- The system architecture of E-UTRAN evolves from UTRAN and the existing UTRAN NRM is proven in operation. Therefore, the alignment will result in a specification that has a higher chance of being bug-free when compared to a "brand new" designed specification.
- It will minimise both the standardization and product development efforts and maintenance efforts (i.e. the cost and time for development including testing and reduction of training cost when the management paradigms for E-UTRAN and UTRAN remained similar);
- It will shorten the time to market for E-UTRAN system;
- It will facilitate a seamless coexistence with UMTS management systems.

TS 32.76x-series define the E-UTRAN NRM IRP using the same principles as for the UTRAN NRM.
It has identical characteristics as those defined for other NRMs such as UTRAN/GSM NRM(s).
The DN of its instances uses the same name convention as all instances whose IOCs are defined in various NRM IRPs.
Its IOCs integrate identically with other NRM (e.g. UMTS/GSM NRM IRP) with the IOCs defined in Generic NRM IRP.

Petitioners' Exhibit 1003, p. 145
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.8.2 Performance measurements for E-UTRAN UID_390002

References

Document	Title/Contents
WID(s)/Status Report	
SP-080062	WID on Performance measurements for E-UTRAN
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TS 32.425	Telecommunication management; Performance Management (PM); Performance measurements E-UTRAN

Supporting Individual Members: Motorola, Huawei, Vodafone, Nortel, ZTE, T-Mobile, Nokia Siemens Networks, CMCC,
Telecom Italia, Orange, Ericsson, Telefonica.

The E-UTRAN system is defined by 3GPP with different Network Elements from the UTRAN, and the interfaces between Network Elements and signalling over the interfaces are also different from the UTRAN.
The performance measurements of the UTRAN are not applicable to E-UTRAN.

The E-UTRAN system needs to be managed. Performance measurements are the basic data for Performance Management (PM), and also the supporting data for the SON (Self Organizing Networks) functionalities.

Each of the E-UTRAN performance measurements shall be motivated by the use case or requirement for PM or SON.
For PM, the use case or requirement for each proposed performance measurement is in the scope of this WI.
For SON, the use case or requirement is out of the scope of this WI.
This WI defines only the E-UTRAN performance measurements which are clearly stated as mandatory over Itf-N.
In case of SON use cases, requirements or solutions are covered by other SA5 WIs on SON (UID_390004).

The E-UTRAN architecture and capabilities evolved from those defined for UMTS. The management of the E-UTRAN system should also evolve from that for UMTS. In particular, the PM IRP is reused for E-UTRAN Performance Management. So the performance measurement definition for E-UTRAN is managed via PM IRP, i.e. the performance measurement definition has a consistent format which can be collected and monitored via PM IRP.

TS 32.425 defines E-UTRAN performance measurements to be transferred over Itf-N supporting PM or SON:

1. Only the performance measurements necessary to be transferred over Itf-N are in the scope of this WI; but includes if necessary E-UTRAN performance measurements for other management interfaces (e.g. Itf-P2P).
2. This WI covers the performance measurements for macro eNodeB and home eNodeB.
3. The E-UTRAN performance measurements are defined in a top-down approach. Each measurement definition has at least one supporting use case or requirement agreed before being inserted into the TS.
   For PM purpose in E-UTRAN, the related use case or requirement was agreed under this WI.
   For SON purpose in E-UTRAN, this WI only defines the related E-UTRAN performance measurements which are clearly stated as mandatory over Itf-N in the SON use cases, requirements or solutions, which are covered by other SA5 WIs on SON (UID_390004).

The performance measurements have identical characteristics as those defined for other network domains such as UTRAN, CN, IMS, etc.
The performance measurement definition follows the same concept and requirements addressed in TS 32.401.
The performance measurement definition follows the same definition and template addressed in TS 32.404.

Petitioners' Exhibit 1003, p. 146
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.8.3 Key Performance Indicators (KPIs) for E-UTRAN UID_390003

References

Document	Title/Contents
WID(s)/Status Report	
SP-080063	WID on Key Performance Indicators (KPIs) for E-UTRAN
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TS 32.450	Telecommunication management; Key Performance Indicators (KPI) for E-UTRAN: Definitions
TS 32.451	Telecommunication management; Key Performance Indicators (KPI) for E-UTRAN: Requirements

Supporting Individual Members: Ericsson, China Mobile, Nokia Siemens Networks, Telefonica, Vodafone, Telecom Italia, T-Mobile, Nortel.

Performance Management (PM) is important for operators to manage their radio networks. For the competitiveness of E-UTRAN as a technology it is essential that PM provides the operator an indication of the E-UTRAN Network Elements (NE) performance. End-user perception of service availability and quality should be taken into account.

TS 32.450, TS 32.451 define a set of KPIs for performance evaluation of E-UTRAN NEs' in line with TR 32.816 and the following; KPIs shall:

- show the performance of a E-UTRAN NE, not how the implementation in the NE works;
- be of value to the operator in terms of improving network performance, thereby enabling enhanced end-user perception;
- be based on well described use cases;
- be based on information available on standardized interfaces;
- be standardized either by using a formula or on a high level by using a textual description;

Examples of E-UTRAN KPI categories relevant for standardization:
- Accessibility (see definition in ITU-T E.800);
- Retainability (see definition in ITU-T E.800);
- Integrity (see definition in ITU-T E.800); this contains the connection quality related KPIs;
- Mobility (this contains the Handover related KPIs);
- Utilization (this contains KPIs related to what extent available E-UTRAN resources are utilized);
- Availability (this contains KPIs that indicate the availability of the RAN towards UEs for access).

Petitioners' Exhibit 1003, p. 147
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.8.4 Subscriber and Equipment Trace for eUTRAN and EPC UID_370001

References

Document	Title/Contents
WID(s)/Status Report	
SP-070617	WID on Subscriber and Equipment Trace for eUTRAN and EPC
Impacted Specifications	
TS 32.421	Telecommunication management; Subscriber and equipment trace; Trace concepts and requirements
TS 32.422	Telecommunication management; Subscriber and equipment trace; Trace control and configuration management
TS 32.423	Telecommunication management; Subscriber and equipment trace; Trace data definition and management
TS 32.441	Telecommunication management; Trace Management Integration Reference Point (IRP): Requirements
TS 32.442	Telecommunication management; Trace Management Integration Reference Point (IRP): Information Service (IS)
TS 32.443	Telecommunication management; Trace Management Integration Reference Point (IRP): Common Object Request Broker Architecture (CORBA) Solution Set (SS)
TS 32.445	Telecommunication management; Trace Management Integration Reference Point (IRP): eXtensible Markup Language (XML) file format definition
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Ericsson, NSN, Huawei, Nortel, China Mobile, Vodafone, T-Mobile.

The use cases for the existing Subscriber and Equipment trace are valid also for eUTRAN and EPC. Therefore the existing Subscriber and Equipment Trace function and IRP need to include the eUTRAN and EPC nodes and interfaces as well as new requirements from TR 32.816 (Study on Management of LTE and SAE).
Work is also needed in RAN3, CT1, CT4.

Petitioners' Exhibit 1003, p. 148
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.9 Self-Organizing Networks (SON) (LTE_SON-OAM) UID_390004

Resources: S5

Supporting Individual Members: T-Mobile, Vodafone, Telefonica, Telecom Italia, Huawei, China Mobile, Ericsson, Motorola, Nokia Siemens Networks, Nortel, Orange, TeliaSonera, ZTE

The Self-Organizing Networks (SON) Building Block of the LTE Feature contains the following Work Tasks:

- SON Concepts and requirements
- Self-Establishment of eNBs
- SON Automatic Neighbour Relations (ANR) List Management

Main drivers for Self-Organizing Networks (SON) are:

- The number and structure of network parameters have become large and complex
- Quick evolution of wireless networks has led to parallel operation of 2G, 3G, EPC infrastructures
- The rapidly expanding number of Base Stations needs to be configured and managed with the least possible human interaction

SON is part of 3GPP Rel-8 and the ongoing work in TSG RAN needs OAM support.
SON use cases are part of the SA5 TR 32.816 Study on management of E-UTRAN and EPC.
The SA5 Rel-8 work on E-UTRAN NRM (UID_380036) is not covering application-specific operations.
Co-ordinated work on **ALL** aspects of SON, including management requirements resulting from TSG RAN, is needed.
A higher level work item is needed for SON-related requirements and results within SA5.

5.9.1 SON Concepts and requirements UID_390104

References

Document	Title/Contents
WID(s)/Status Report	
SP-080275	WID on Self-Organizing Networks (SON)
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TS 32.500	Telecommunication management; Self-Organizing Networks (SON); Concepts and requirements

Supporting Individual Members: T-Mobile, Vodafone, Telefonica, Telecom Italia, Huawei, China Mobile, Ericsson, Motorola, Nokia Siemens Networks, Nortel, Orange, TeliaSonera, ZTE.

TS 32.500 covers:

- SON requirements for OAM;
- Infrastructure for SON in the OAM system;
- Self-configuration, Self-Optimization and self-healing, Neighbour Relation handling (intra-E-UTRAN, 2G, 3G);
- Defines the necessary Interface IRPs.

Petitioners' Exhibit 1003, p. 149
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.9.2 Self-Establishment of eNBs UID_390005

References

Document	Title/Contents
WID(s)/Status Report	
SP-080849	WID on Self-Establishment of eNBs
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TS 32.501	Telecommunication management; Self-Configuration of Network Elements; Concepts and Integration Reference Point (IRP) Requirements
TS 32.502	Telecommunication management; Self-Configuration of Network Elements Integration Reference Point (IRP); Information Service (IS)
TS 32.531	Telecommunication management; Software management; Concepts and Integration Reference Point (IRP) Requirements
TS 32.532	Telecommunication management; Software management Integration Reference Point (IRP); Information Service (IS)
TS 32.533	Telecommunication management; Software management Integration Reference Point (IRP); Common Object Request Broker Architecture (CORBA) Solution Set (SS)

Supporting Individual Members: Nokia Siemens Networks, Ericsson, Huawei, T-Mobile, Vodafone, Nortel, Motorola, ZTE, Telefonica, Telecom Italia, China Mobile, Motorola, Orange, TeliaSonera.

This work standardizes the functions required in LTE for an automated establishment of new eNBs into the network. This WI does not refer to HNB.
This WI has a strong link with the WIs on E-UTRAN NRM IRP (UID_390001) and EPC NRM IRP (UID_390010).

Self-configuration includes an automated establishment of IP connectivity between the eNB and the Element Manager, an automated download of software and an automated download of radio and transport configuration data. It may also include an automatic setup of X2 and S1 interfaces. Appropriate security mechanisms are needed. Newly established eNBs might also perform self-test and send out reports about the results.

This work defines:

1. Management reference model supporting this use case;
2. Requirements;
3. Elements for NRM IRPs;
4. Interface IRPs for the interaction patterns on open interfaces;
5. Security mechanisms;
6. Mechanisms for software download related to self-establishment;
7. Reports of self-test results.

TS 32.501 covers concepts and requirements for Self-establishment of eNodeBs.

TS 32.502 contains the Stage 2 for Self-establishment of eNodeBs.

Petitioners' Exhibit 1003, p. 150
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.9.3 SON Automatic Neighbour Relations (ANR) List Management UID_390006

References

Document	Title/Contents
	WID(s)/Status Report
SP-080066	WID on SON Automatic Neighbour Relations (ANR) List Management
	Impacted Specifications
TS 32.761	Telecommunication management; E-UTRAN Network Resource Model (NRM) Integration Reference Point (IRP); Requirements
TS 32.762	Telecommunication management; E-UTRAN Network Resource Model (NRM) Integration Reference Point (IRP): Information Service (IS)
TS 32.763	Telecommunication management; E-UTRAN Network Resource Model (NRM) Integration Reference Point (IRP): Common Object Request Broker Architecture (CORBA) Solution Set (SS)
TS 32.765	Telecommunication management; E-UTRAN Network Resource Model (NRM) Integration Reference Point (IRP): Bulk CM eXtensible Markup Language (XML) file format definition
	New Dedicated Specifications/Reports
TS 32.511	Telecommunication management; Self-Organizing Networks (SON); Automatic Neighbour Relation (ANR) management; Concepts and requirements

Supporting Individual Members: Ericsson, Huawei, T-Mobile, China Mobile, Motorola, Nokia Siemens Networks, Nortel, Orange, Telefonica, TeliaSonera, Vodafone, ZTE.

In the context of LTE, it is necessary to automate, as much as possible, the discovery of neighbour relations.
The goal is to reduce the reliance on traditional configuration methods (e.g. manual configuration, configuration by planning tools in GSM case) in the context of growing complexity and scale of the new generation of mobile networks.

The Automatic Neighbour Relation (ANR) function includes the relations to LTE cells on other eUTRAN frequencies and 2G and 3G cells.

The objectives are to identify and define functions that collectively, support the automation of neighbour relations discovery and, to identify the actors of this automation and to define necessary open interfaces among various identified functions and actors.

This automation is not a replacement of the "traditional configuration methods", which must work together in a way that operators remain in control of the degree of automation and "traditional configuration methods" involved.

This work:

- Defines use cases;
- Identifies actors and defines various functional blocks that collectively support the subject automation;
- Identifies interfaces where standardization is required;
- Defines necessary security mechanisms.

TS 32.511 covers concepts and requirements for Automatic Neighbour Relation (ANR) management.

Petitioners' Exhibit 1003, p. 151
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6 Home NodeB / eNodeB

UID	Name	Acronym	Resource	Hyperlink
380065	Home NodeB / eNodeB	HomeNB	S1,C1,C4	SP-070952
390033	UTRA HNB	HNB	RP,S5	not applicable

6.1 Home NodeB / eNodeB (HomeNB) UID_380065

Resources: S1,C1,C4

UID	Name	Resource	Hyperlink	TS_TR
380065	Home NodeB / eNodeB	S1,C1,C4	SP-070952	-
380066	**Stage 1 for Home NodeB / eNodeB**	S1	SP-070952	22.011, 22.115
420019	**Support of Closed Subscriber Group (CSG)**	C4	non-existent	29.002, 29.272, 23.008, 23.003
410012	**CSG and Idle Mode Mobility for LTE Home eNodeB**	C1	CP-080498	23.122, 24.301, 24.801, 24.285
410013	**CSG and Idle Mode Mobility for 3G Home NodeB**	C1	CP-080792	23.122, 24.008, 24.285

6.1.1 Stage 1 for Home NodeB / eNodeB UID_380066

Resources: S1

UID	Name	Resource	Hyperlink	Notes	TS_TR
380066	**Stage 1 for Home NodeB / eNodeB**	S1	SP-070952	SP#39 completed	22.011, 22.115

Supporting Individual Members: Vodafone, T-Mobile, Motorola, Telecom Italia Mobile, SK Telecom, Samsung, SHARP, TOSHIBA , Fujitsu, NEC, Huawei, TeliaSonera, Alcatel-Lucent.

There is ongoing work in several 3GPP groups (e.g. RAN2, RAN4, CT1, SA3) on specifying Home NodeB and Home eNodeB (e.g. TR 25.820, TS 36.300).

"Home NodeB and Home eNodeB" refer to the deployment as small UTRA and E-UTRA cells, respectively, in domestic, small office and similar environments. The Home Node B/eNodeB interconnects with the 3G core / Evolved Packet Core (EPC) over a fixed broadband (e.g. DSL, Cable, etc.) access network.

Although many of the existing service requirements for NodeB and eNodeB access apply equally to Home NodeB/eNodeB, additional service requirements may also be needed to address e.g. security, quality, charging and access restrictions resulting from the envisaged deployment scenarios. It is expected that Home NodeB and Home eNodeB will have common requirements.

As there are ongoing trials of Home NodeBs using non-standardized solutions, this work develops common and, when needed, specific requirements for both Home NodeB/eNodeB access systems. The derived requirements support related ongoing work in other 3GPP TSGs.

Initial work focussed on reviewing this topic, drawing upon the work on SoLSA, with a view to identifying modifications to existing specifications.

Consideration was given to service requirements for e.g.:

- Home NodeB UTRA access to 3G services;
- Home eNodeB E-UTRA access to Evolved Packet System services;
- Support for Closed Subscriber Groups (CSG);
- Support of Emergency Calls;
- OAM Issues;
- Localization of Home NodeB/eNodeB to comply with Radiocommunications license conditions;
- Localization of Home NodeB/eNodeB to comply with Emergency call requirements;
- Authentication of Home NodeB/eNodeB.

Petitioners' Exhibit 1003, p. 152
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Service requirements for both UTRA an E-UTRA access for Home NodeB/eNodeB take into account access capabilities and possible limitations e.g. QoS and bandwidth restrictions. Particular attention was given to the operation of the equipment in accordance with the licence granted to the PLMN operator.

MMI-Aspects - the need for possible deployment requirements (e.g. plug&play) and remote configuration by the PLMN operator, and degree of control appropriate for the user of the Home Node B/eNodeB were considered.

Consideration was given to differential charging for different classes of subscriber e.g. the owner of the Home NodeB/eNodeB and authorized ‘visiting guest' subscribers.

6.1.2 Support of Closed Subscriber Group (CSG) UID_420019

Resources: C4

UID	Name	Resource	Hyperlink	Notes	Impacted_TS_TR
420019	**Support of Closed Subscriber Group (CSG)**	C4	non-existent	CP#43 completed. SP#42 SP-080874 22.011CR0141 confirmed Requirement to support roaming subscribers with CSG home network subscription but did NOT confirmed requirement for home network independent support of roamers in CSG	29.002, 29.272, 23.008, 23.003

At SP#42 SP-080874 22.011CR0141 confirmed the Requirement to support roaming subscribers with CSG home network subscription but did NOT confirmed requirement for home network independent support of roamers in CSG.

This impacted the following CT4 specifications: TS 23.003, TS 23.008, TS 29.002 and TS 29.272.

Petitioners' Exhibit 1003, p. 153
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.1.3 CSG and Idle Mode Mobility for LTE Home eNodeB UID_410012

Resources: C1

UID	Name	Hyperlink	Notes	TS_TR
410012	**CSG and Idle Mode Mobility for LTE Home eNodeB**	CP-080498	CP#43 completed	23.122, 24.301, 24.801, 24.285

6.1.4 CSG and Idle Mode Mobility for 3G Home NodeB UID_410013

Resources: C1

UID	Name	Hyperlink	Notes	TS_TR
410013	**CSG and Idle Mode Mobility for 3G Home NodeB**	CP-080792	CP#43 completed	23.122, 24.008, 24.285

Supporting Individual Members: Huawei, Qualcomm, T-Mobile, Vodafone, Telecom Italia, ZTE, Alcatel-Lucent.

Linked work items

SA3	Study on Home (e)NodeB Security (UID_380085)
RAN4/3/2	Study on 3G Home NodeB/eNodeB (UID_350039)
RAN3	UTRAN architecture for 3G HNB (UID_40054)
RAN2	Support of UTRA HNB (UID_400053)
RAN4	Study on 3G Home NodeB/eNodeB (UID_350039)
SA5	Study of Self-Organizing Networks (SON) related OAM interfaces for Home NodeB (UID_360007)

SA1 has completed the service requirements for LTE Home NodeB (HeNB) in the scope of Rel-8. A single standardized solution gives operators a true multi-vendor environment for both terminals and infrastructure.

Architecture and protocols are developed in several WGs e.g. RAN2, RAN3, RAN4, SA3, SA5 (see linked WIs).

These can be deployed as small (E-)UTRA cells in domestic and Small Office Home Office (SoHo) environments.
The 3G HNB interconnects with the 3G core network over a fixed broadband (e.g. DSL, Cable, etc.) access network via a HNB access gateway (concentrator).
The HeNB interconnects with the EPC core over a fixed broadband (e.g. DSL, Cable, etc.) access network.

RAN4 TR 25.820 (3G Home NodeB Study Item Technical Report) concluded that HNB introduction would have detrimental effects on legacy mobiles (e.g. battery life) and legacy system performance (MM signalling), Closed Subscriber Group (CSG) functionality is required to mitigate some of these aspects and improve the system performance as the number of Rel-8 mobile population grows.
On 3G HNB, CT defined a basic mechanism to support the CSG concept and idle mode mobility to/from CSG cells.

For HeNB deployment, there are no legacy issues like for Home NodeB (HNB) deployment in UMTS. It is thus expected that more optimized solutions for support of CSG HeNBs would be developed by 3GPP TSG CT. If this functionality is not provided in E-UTRAN in Rel-8 then E-UTRAN will have the same legacy problems in Rel-9 as GSM and UMTS have had in the past when SoLSA and HNB have been introduced.

Objective

One of the main issues with the deployment of HNBs in an existing UMTS network is to maintain backward compatibility of pre-Rel-8 terminals in a UMTS network supporting HNBs.
Hence, the work specific to 3G HNB was restricted by the requirement to reuse as much as possible legacy procedures.
CT looked at the CSG concept and the terminal Idle Mode mobility to/from macro 3G cell from/to CSG.

The design of the new EPC takes into account the requirement to support the CSG concept for HeNBs leading to a more integrated solution for HeNB support in LTE than in UMTS. The CT work:

- Defines the usage of CSG id at NAS layer at the UE side and at network side
- Defines a CSG white list to indicate the CSGs to which a UE has access
- Provides required signalling and mechanisms for LTE CSG white list configuration and management.
- Defines the idle mode mobility procedures to/from macro LTE cell from/to LTE CSG in terms of HeNB validation at CN level.

Petitioners' Exhibit 1003, p. 154
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.2 UTRA HNB UID_390033

Resources: R2,R3,R4,S5

UID	Name	Acronym	Resource	Hyperlink
390033	UTRA HNB	HNB	RP,S5	not applicable
400053	**Support of UTRA HNB**	HNB-supp	R2	RP-080752
400054	**UTRAN Architecture for 3G HNB**	HNB-arch	R3	RP-080487
390034	**FDD Home NodeB RF requirements**	HNB-RF	R4	RP-080971
430023	Conformance Test Aspects – UTRA HNB (FDD)	HNB-UEConTestFDD	R5	RP-090023
420037	**3G Home NodeB OAM&P Type 1 Management Interface**	HNB-3G_OAM	S5	SP-080708

6.2.1 Support of UTRA HNB UID_400053

Resources: R2

UID	Name	Hyperlink	Status_Report	Notes	TS_TR
400053	**Support of UTRA HNB**	RP-080752	RP-090040	RP#43 completed	25.304, 25.306, 25.331, new 25.367

Supporting Individual Members: Huawei, T-Mobile Intl, TeliaSonera, Telecom Italia, Qualcomm.

RAN2 study on legacy Home NB support for UTRA [R2-075466] concluded that the presently available mechanisms for legacy mobile mobility for UTRA Home NB deployments are not optimal and hence require compromises in deployment. In the case where UTRA and LTE Home NB deployment reach dense levels the effect on RAN & CN signalling load, UE performance and finally UE battery life may become significant.

By implementing specific mobility procedures in Rel-8 mobiles to support a CSG like cell concept, it should be possible to obviate the disadvantages posed by UTRA Home NB deployments for Rel-8 mobiles. As the percentage of Rel-8 mobiles population grows, the signalling load on the network will diminish and user experience can be enhanced.

The work specifies enhanced Rel-8 UTRA IDLE mode mobility and to consider enhancements to the ACTIVE mode mobility in order to support the CSG like cell concept (UTRA and LTE).

RAN2 investigated the adoption of agreed LTE CSG like concepts for UTRA. It is important that legacy mechanisms for UTRA Home NB co-exist with the concepts chosen by this WI to ensure pre-Rel-8 UTRAN UE are supported. The optimization of UTRA Home NB concepts for the support of legacy terminals was not excluded.

For Rel-8 the following were considered:

- Support of CSG (Closed Subscriber Group or restricted association)
- Minimize the impact to UEs camped on UTRA macro cells
- Minimize the impact to UEs in CELL_DCH on UTRA macro cells
- Cell selection/reselection from UTRA macro cell to UTRA Home NB
- Cell selection/reselection from UTRA Home NB to UTRA
- Cell selection/reselection of UEs between UTRA Home NBs
- Handover of ACTIVE UE from UTRA Home NB to UTRA macro cell
- Cell selection/reselection from UTRA Home NB to GERAN macro cell

If there is a technical need (e.g. to limit excessive interference) the following objectives were envisaged

- Handover of ACTIVE UE from macro UTRA cell to UTRA CSG Home NB in coverage of UTRA Home NB
- Support of semi-open access operation (or signalling association) where a UE can exchange signalling and limited data on non suitable UTRA Home NB

Petitioners' Exhibit 1003, p. 155
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.2.2 UTRAN Architecture for 3G HNB UID_400054

Resources: R3

UID	Name	Hyperlink	Status_Report	Notes	TS_TR
400054	**UTRAN Architecture for 3G HNB**	RP-080487	RP-090042	RP#42 completed	25.401, 25.410, 25.412, 25.413, 25.414, 25.415, new (25.467, 25.468, 25.469)

Supporting Individual Members: Alcatel-Lucent, Kineto, Nokia Siemens Networks, Nokia, Huawei, Telefonica, NEC, Motorola, TeliaSonera, Samsung, Vodafone, TIM, T-Mobile, AT&T.

RAN3 Study on deployment of 3G Home Node B in UTRAN concluded that the support of the 3G Home Node B could be ensured in principle within the framework in the UTRAN architecture defined in TS 25.401, with the support of pre-Rel-8 UEs and Core Networks. It was also concluded that new functions such as the HNB Registration and UE Registration would be supported via the new protocol Home NodeB Application Protocol (HNBAP) between the 3G HNB and HNB-GW.

However, [R3-081588] lists a number of possible alternatives for the definition of the protocol stacks at the Iuh interface (between the 3G HNB and the 3G HNB-GW), and reports that the functional split between 3G HNB and 3G HNB-GW for the legacy UTRAN functions remains for further study, as well as the HNB-GW Discovery procedure.

This work

- specifies an architecture for 3G HNB access, comprising
  - a reference network architecture
  - an exhaustive list of new HNB specific functions together with the definition of the functional split between the 3G HNB and the 3G HNB-GW.
- defines and specifies the Iuh interface between the 3G HNB and the 3G HNB-GW comprising
  - the signalling transport with the aim to reduce the number of alternatives considered in section 7.3 in TR 25.820 for the signalling transport protocol stack at the Iuh interface (between the 3G HNB and the 3G HNB-GW), in any “CN” (CS/PS/BC) domain, a single solution (i.e. no alternatives) shall be specified for 3G HNBs of the new Home NodeB BS class which is expected to be specified by RAN4. The use of this architecture for Home Node B operating in unrestricted access mode shall not be precluded as per SA1 requirements
  - the user data transport- the C-plane functions (e.g. HNB Registration and UE Registration).
- specifies the HNB-GW Discovery procedure mentioned in [R3-081588]
- specifies the impacts of the HNB (auto)-configuration aspects on the UTRAN signalling.

RAN3 liaised for feedback based on the RAN3 agreed architecture and functions for 3G HNB with:

- SA1 for service aspects
- SA2 for the general architectural aspects
- SA3 for security aspects
- SA5 for configuration aspects
- RAN2 for mobility and access control aspects
- RAN4 for radio aspects
- CT1 for the use of NAS message in the various access control mechanisms

Petitioners' Exhibit 1003, p. 156
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.2.3 FDD Home NodeB RF requirements UID_390034

Resources: R4

UID	Name	Hyperlink	Status_Report	Notes	TS_TR
390034	**FDD Home NodeB RF requirements**	RP-080971	RP-090041	RP#43 completed	25.104, 25.141, new 25.967

Supporting Individual Members: Motorola, T-Mobile International, Nokia Siemens Networks, NEC, Alcatel-Lucent.

Within the course of increasing UMTS terminal penetration and Fixed-Mobile Convergence, an upcoming demand for 3G Home NodeBs is observed to provide attractive services and data rates in the home environment.

UTRAN is not optimally suited for this application as UTRAN was developed and defined under the assumption of coordinated network deployment whereas home NodeBs are typically associated with uncoordinated and large scale deployment.

This work amends the UTRAN NodeB related RF specifications as proposed in TR 25.820 to support the Home NodeBs application. The scope of this work is limited to the UTRA FDD mode.

TR 25.820 on Home (e)NodeB feasibility concluded on RAN4 related matters that:

- Home NodeBs will not significantly degrade the performance of networks deployed in other channels.
- Dedicated carrier deployment of Home Node B's is feasible for both open and closed subscriber group systems in a wide range of deployment configurations.
- Co-channel carrier deployment of Home Node B's is feasible for both open and closed subscriber group systems. However, especially in the case of CSG there will be an increased level of interference relative to dedicated deployment; interference mitigation techniques have been studied to reduce this.
- Home Node Bs can provide reasonable performance whether deployed in isolation or whether multiple Home Node Bs are deployed in the same area. However, in high density deployments, techniques may be needed to mitigate inter-HNB interference.
- Home Node Bs can be engineered to radiate only when it is confirmed that such an emission complies with regulatory requirements in force where that Home NodeB is operating.
- Home NodeBs can support UE speeds up to 30 km/h.

6.2.3.1 Conformance Test Aspects – UTRA HNB (FDD) UID_430023

Resources: R5

UID	Name	Hyperlink	Status_Report	Notes	TS_TR
430023	**Conformance Test Aspects – UTRA HNB (FDD)**	RP-090023	RP-100482	RP#48 completed	34.108, 34.123-1, 34.123-2, 34.123-3

RAN2 study on legacy Home NB support for UTRA [R2-075466] concluded that the available mechanisms for legacy mobile mobility for UTRA Home NB deployments are not optimal and hence require compromises in deployment.
In case UTRA Home NB deployment reaches dense levels the effect on RAN and CN signalling load, UE performance degradation and UE battery life reduction may become significant.
Core specifications have therefore been enhanced for Rel-8 to support UTRA HNB by introducing the Closed Subscriber Group (CSG) concept for access and mobility control.
Corresponding work on the related UE conformance testing is now needed.

Impacted core specifications relevant for RAN5 test specifications for UTRA HNB (FDD) are:

TS 25.304	User Equipment (UE) procedures in idle mode and procedures for cell reselection in connected mode
TS 25.331	Radio resource control (RRC) protocol specification
TS 25.367	Mobility Procedures for Home NodeB (Stage 2)

Petitioners' Exhibit 1003, p. 157
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.2.4 3G Home NodeB OAM&P (type 1 definition) UID_420037

Resources: S5

UID	Name	Hyperlink	Notes	TS_TR
420037	**3G Home NodeB OAM&P Type 1 Management Interface**	SP-080708	SP#44 completed	new (32.581, 32.582, 32.583, 32.584)

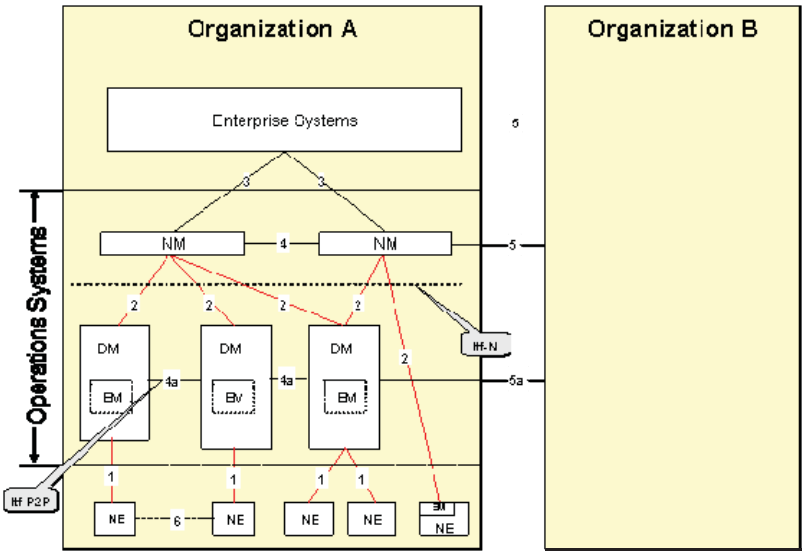
Supporting Individual Members: Huawei , Nokia Siemens Networks, Ericsson, Vodafone, T-Mobile, Telefonica, Alcatel-Lucent, IPAccess, China Mobile, Telecom Italia, Airvana, Motorola, ZTE, Qualcomm, Samsung.

SA5 provided OAM solution for 3G HNB complementing work in the Broadband Forum and 3GPP TSG RAN. SA5 standardized management services specific to HNB along the following:

- Quantity of HNB is likely to be large
- There may be many HNB vendors
- HNB may be purchased easily by end-users in market
- Location of HNB could be in a private residence which may not be accessible for frequent on-site maintenance

SA5 studied HNB OAM and SON aspects. The management differences between HNB and macro NodeB are listed in TR 32.821 (Study of Self-Organizing Networks (SON) related OAM Interfaces for HNB). TR32.821 lists requirements for managing HNB and the consequences on the management interface for HNB.

SA5 agreed to standardize the interfaces type 1 and 2 for Home NodeB OAM&P shown in the following figure. However, standardization of management on interface type 2 is not covered in Rel-8.



This work provides the OAM solution for 3G HNB on interface type 1 management. The work includes:

Petitioners' Exhibit 1003, p. 158
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7 IP Multimedia Subsystem (IMS)

UID	Name	Acronym	Resource	Hyperlink
370025	**IMS Centralized Service Control (ICSRA)**	ICSRA	S1,S2,C1,C3,C4	SP-070924
370059	**IMS Multimedia Telephony and Supplementary Services**	IMSTSS	S1,S5,C1,C3,C4	-
390035	**3GPP2 Input to Common IMS**	CIMS_3GPP2	S1,S2,S3,C1,C3,C4	SP-080220
350005	**IMS Enhancements for support of Packet Cable access**	PktCbl	S2,S3,C1,C3,C4	-
360012	**IMS System enhancements for corporate network access**	IMS_Corp	S2,S1,C1,C4	SP-080095
380069	**Maintenance of TISPAN documentation**	MAINTISP	S2,C1,C3,C4	-
390056	**IMS Service Continuity**	IMS-Cont	S2,S1,C1	SP-080092
370078	**Security Enhancements for IMS**	IMS-Sec	S3,C1,C4	SP-070496
34046	**IMS initiated and controlled PSS and MBMS User Service**	IMS_PSS_MBMS_US	S4,S3	SP-080201
713024	**Multimedia interworking between IMS and CS networks**	MIW-IMS	C3,C4	CP-070729
360029	**IMS Stage 3 IETF Protocol Alignment**	IMSProtoc2	C1	CP-080794
380014	**Interworking between User-to-User Signalling (UUS) and SIP**	UUSIW	C1,C3	CP-070782
380018	**Support of Overlap signalling**	Overlap	C3,C1,C4	CP-070731
380035	**AS/MRFC Stage 2 and 3**	MRFC_TS	C1	CP-070784
400012	**IMS Restoration Procedures**	IMS_RP	C4,C1	CP-080447
410003	**IMS Application Server Service Data Descriptions for AS interoperability**	IMS_ASIO	C4	CP-080451

Petitioners' Exhibit 1003, p. 159
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.1 IMS Centralized Service Control (ICSRA) UID_370025 (open IETF)

Resources: S1,S2,C1,C3,C4,IETF

References

Document	Title/Contents
WID(s)	
SP-070924	S1 WID on IMS Centralized Service Control - Requirement and Architecture (ICSRA)
CP-080492	CT WID on IMS Centralized Service Control – Protocol, Addressing, Subscriber Data (ICSPASD)
Impacted Specifications	
TS 22.101	Service aspects; service principles
TS 23.206	Voice Call Continuity (VCC) between Circuit Switched (CS) and IP Multimedia Subsystem (IMS); Stage 2 - S2
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3 - C1
TS 23.003	Numbering, addressing and identification - C4 Add ICS specific IMPI and temporary IMPU
TS 29.232	Media Gateway Controller (MGC) - Media Gateway (MGW) interface; Stage 3 - C4 Extension to Mc interface protocol for supporting Mb user plane
TS 23.018	Basic call handling; Technical realization - C4 Updates to the call set-up and termination procedures, and interactions with supplementary services
TS 29.002	Mobile Application Part (MAP) specification - C4 Update subscriber profile and MAP messaging to indicate attempt of IMS login by MSC Server enhanced for ICS
New Dedicated Specifications/Reports	
TS 23.292	IP Multimedia System (IMS) centralized services; Stage 2 - S2
TS 24.292	IP Multimedia Core Network subsystem Centralized Services; Stage 3 - C1
TS 24.293	ICS Protocol over USSD bearer (C1)
TS 29.292	Mobile Radio Interface NAS signalling - SIP translation/conversion - C3

Supporting Individual Members: Alcatel-Lucent, Nortel Networks, AT&T, Telecom Italia, Samsung, LG Electronics, Nokia Siemens Networks, Nokia, Huawei, Ericsson, Motorola, NEC, Orange, ZTE, Fujitsu, Verizon, Telcordia, RIM.

UID	Name	Resource	Hyperlink	WI_rapporteur	Notes	TS_TR
380039	Stage 1	S1	SP-070924	AT&T	SP#39 completed	22.101
380040	Stage 2	S2	SP-070924	Alcatel-Lucent	SP#40 completed	23.292, 23.206
400205	Stage 3	C1,C3,C4,IETF	CP-091046	Ericsson	CP#46 completed	-
400005	CT1 aspects	C1	CP-091046	Ericsson	CP#46 completed	24.229, new (24.292, 24.286)
521014	(IETF) CT1	C1-IETF	CP-091046	Roland Jesske	Submitted to IESG for publication	draft-ietf-salud-alert-info-urns
521015	(IETF) CT1	C1-IETF	CP-091046	Andrew Allen	CP#59 completed	RFC 6871 (was draft-ietf-mmusic-sdp-media-capabilities)
521016	(IETF) CT1	C1-IETF	CP-091046	Andrew Allen	CP#64 complete	RFC 7195 (was draft-ietf-mmusic-sdp-cs)
521017	(IETF) CT1	C1-IETF	CP-091046	Andrew Allen	CP#62 completed	RFC7006 (was draft-ietf-mmusic-sdp-miscellaneous-caps)
400006	CT3 aspects	C3	CP-091046	Mavenir	CP#43 completed	new 29.292
400007	CT4 aspects	C4	CP-091046	Ericsson	CP#42 completed	23.003, 29.232, 23.018, 29.002
521018	(IETF) CT4 aspects	C4-IETF	CP-091046	Andrew Allen	CP#64 complete	RFC 7254 (was draft-montemurro-gsma-imei-urn)
400105	Deleted – I1 interface	C1	CP-080492	Huawei	CP#41 work stopped	24.293

Communication networks are evolving towards packet-based infrastructures. A single common consolidated core network offers service providers the possibility of reduced core network complexity and maintenance. As service providers shift their core network infrastructure from the CS domain to a consolidated common IMS infrastructure, the need was identified to enable the consistent provision of services to subscribers over a variety of accesses, including CS domain and PS domain accesses.

A Study on Centralized IMS Services (FS_ICS) UID_380034 has been conducted by SA1 (TR 22.892) and SA2 (TR 23.892) on call/session establishment via CS domain access and IP-CAN and on calls/sessions transferred across CS domain access and IP-CAN, including the interactions with domain selection.
Handling of the multiple media enabled by the multimedia telephony communication service has been investigated.
Requirements and architecture solutions in the TRs are applicable to terminals with or without VCC capabilities.
Impact on legacy terminals with the same subscription (e.g. USIM swapping) have also been studied.

With this background, the result of this work is:

- SA1 captured the findings from TR 22.892 and developed further into TS 22.101;

Petitioners' Exhibit 1003, p. 160
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- SA2 developed Stage 2 meeting TS 22.101 requirements for ICS in new TS 23.292 (Stage 2 being based on TR 23.892 conclusions).

The provision of a consistent user experience is described in the cases:

- where users access services via CS or PS access; and
- where domain transfer between CS and PS access is required.

CT WGs specified the necessary Stage 3 as follows:

- CT1:
  - enhancements to IMS call control protocol (based on SIP and SDP) and to UE functionality;
  - ICS Protocol over USSD (Unstructured Supplementary Service Data) bearer;
- CT3: protocol translation/conversion for the MSC Server;
- CT4:
  - ICS specific naming/addressing and any required Core Network protocol enhancements and/or additions;
  - Enhancements to Mc interface to support the Mb user plane interface;
  - Investigate any impacts to the subscriber data in the CS domain and IMS;

Petitioners' Exhibit 1003, p. 161
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.2 IMS Multimedia Telephony and Supplementary Services (IMSTSS) UID_370059 (open IETF)

Resources: S1,S5,C1,C3,C4,IETF

UID	Name	Acronym	Resource	Rapporteur
370060	**General aspects of IMS Sup Services**	IMSSS-Gal	S1,C1,C3,C4	Ericsson
370062	**IMS Multimedia Telephony Service**	IMS-MMTel	S1,S5	-
380006	**CCBS)/CCNR on IMS**	CCBS_CCNR	C1,C3,IETF	Deutsche Telekom
390058	**Flexible Alerting**	FA	S1,C1	Nortel
380009	**Communication Wait on IMS**	CW_IMS	C1,C3,IETF	Deutsche Telekom
370103	**IMS Charging**	CH8	S5	Alcatel-Lucent

General aspects of IMS Sup Services (IMSSS-Gal) UID_370060

Resources: S1,C1,C3,C4

References

Document	Title/Contents
WID(s)	
SP-070691	S1 WID on TISPAN Service and Capability for Core IMS (TISCAP-R8)
CP-080213	WID on Documentation of TISPAN NGN R1 and R2 in 3GPP TSG CT
Impacted Specifications	
TS 22.101	Service aspects; Service principles
TS 22.115	Service aspects; Charging and billing
TS 22.228	Service requirements for the IMS
TS 24.141	Presence service using the IP Multimedia (IM) Core Network (CN) subsystem; Stage 3
TS 24.147	Conferencing using the IP Multimedia (IM) Core Network (CN) subsystem; Stage 3
TS 24.173	IMS Multimedia telephony service and supplementary services; Stage 3
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3
TS 24.247	Messaging service using the IP Multimedia (IM) Core Network (CN) subsystem; Stage 3
TS 24.341	Support of SMS over IP networks; Stage 3
TS 29.162	Interworking between the IM CN subsystem and IP networks
TS 29.163	Interworking between the IP Multimedia (IM) Core Network (CN) subsystem and Circuit Switched (CS) networks
TS 29.228	IP Multimedia (IM) Subsystem Cx and Dx Interfaces; Signalling flows and message contents
TS 29.229	Cx and Dx interfaces based on the Diameter protocol; Protocol details
New Dedicated Specifications/Reports	
TS 24.604	Communication Diversion (CDIV) using IP Multimedia (IM)Core Network (CN) subsystem; Protocol specification
TS 24.605	Conference (CONF)using IP Multimedia (IM) Core Network (CN) subsystem; Protocol specification
TS 24.606	Message Waiting Indication (MWI)using IP Multimedia (IM) Core Network (CN) subsystem; Protocol specification
TS 24.607	Originating Identification Presentation (OIP) and Originating Identification Restriction (OIR) using IP Multimedia (IM) Core Network (CN) subsystem; Protocol specification
TS 24.608	Terminating Identification Presentation (TIP) and Terminating Identification Restriction (TIR)using IP Multimedia (IM) Core Network (CN) subsystem; Protocol specification
TS 24.610	Communication HOLD (HOLD) using IP Multimedia (IM) Core Network (CN) subsystem; Protocol specification
TS 24.611	Anonymous Communication Rejection (ACR) and Communication Barring (CB)using IP Multimedia (IM) Core Network (CN) subsystem; Protocol specification
TS 24.616	Malicious Communication Identification (MCID)using IP Multimedia (IM) Core Network (CN) subsystem; Protocol specification
TS 24.623	Extensible Markup Language (XML) Configuration Access Protocol (XCAP) over the Ut interface for Manipulating Simulation Services
TS 24.628	Common Basic Communication procedures using IP Multimedia (IM)Core Network (CN) subsystem; Protocol specification
TS 24.629	Explicit Communication Transfer (ECT)using IP Multimedia (IM)Core Network (CN) subsystem;; Protocol specification
TS 24.647	Advice Of Charge (AOC) using IP Multimedia (IM)Core Network (CN) subsystem; Protocol Specification
TS 24.654	Closed User Group (CUG) using IP Multimedia (IM) Core Network (CN) subsystem, Protocol Specification
TS 29.658	TISPAN; SIP Transfer of IP Multimedia Service Tariff Information; Protocol specification

Supporting Individual Members: BT, Telecom Italia, TeliaSonera, T-Mobile, Ericsson, Vodafone, Alcatel-Lucent, Nortel Networks.

UID	Name	Acronym	Resource	Hyperlink	Rapporteur	Notes	TS_TR
370060	**General aspects of IMS Sup Services**	IMSSS-Gal	S1,C1,C3,C4	SP-070691	Ericsson	CP#43 completed	-

Petitioners' Exhibit 1003, p. 162
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

370023	Service and Capability for Core IMS - inclusion of TISPAN requirements	TISCAPR8	S1	SP-070691	Ericsson	SP#39 completed	22.228, 22.115, 22.101
380001	Documentation of TISPAN R1 and R2 in CT1	REDOC_TIS-C1	C1	CP-080213	NSN	CP#41 completed	24.141, 24.147, 24.173, 24.229, 24.247, 24.341, 24.604, 24.605, 24.606, 24.607, 24.608, 24.610, 24.611, 24.616, 24.623, 24.628, 24.629, 24.647, 24.654
380002	Documentation of TISPAN R1 and R2 in CT3	REDOC_TIS-C3	C3	CP-080213	NSN	CP#43 completed	29.162, 29.163, 29.658
380003	Documentation of TISPAN R1 and R2 in CT4	REDOC_TIS-C4	C4	NSN	NSN	CP#41 completed	29.228, 29.229

SA1 WID SP-070691 on Service and Capability for Core IMS, addressed the transfer in 3GPP of TISPAN Stage 1 service and capability requirements, needed to implement the core IMS specification for the Common IMS concept. This work is limited to the transfer, adaption and integration of requirements from TISPAN Stage 1 TS 0181005v2.1.0 WID 1040 "Service and capability requirements" (Release2) into he 3GPP TS 22.228, TS 22.101 and TS 22.115.

Requirements impacting TS 22.173 and TS 22.182 were covered by separate WIDs.

CT was dealing with shifting the ownership of TISPAN R1 and R2 Stage-3 into the 3GPP CT WGs. This work provides for redocumentation of existing TISPAN NGN R1 and NGN R2 specifications in 3GPP Rel-8. In addition minor technical enhancements were provided. However, the work does not cover any major functional change.

How to handle SIP charging (TS 183 058) in 3GPP is for further study. Whether Basic Communication (TS 183 028) should become a standalone specification or can be documented in TS 24.229 is for further study. Handling of SMS (24.341) – 183 051 –(No technical change – generic reference to release 7) is for further study.

Handling of IMS messaging (24.247) – 183 041 (No technical change – references 3GPP 24.147 6.4.0) and Presence (24.141) – 283 030 – (has OMA parts – references 3GPP 24.141 7.0.0) are for further study. Responsibility for Stage 1 and Stage 2 is currently still with TISPAN.

IMS Multimedia Telephony Service (IMS-MMTel) UID_370062

Resources: S1,S5

References

Document	Title/Contents
	WID(s)
SP-070569	S1 WID on Merging TISPAN MMTel [requirements] for Common IMS
SP-080848	S5 WID on Multimedia Telephony Service and Supplementary Services (MMTel) Charging
	Impacted Specifications
TS 22.173	IP Multimedia Core Network Subsystem (IMS) Multimedia Telephony Service and supplementary services; Stage 1
TS 32.298	Telecommunication management; Charging management; Charging Data Record (CDR) parameter description [Add MMTel ASN.1 structure]
TS 32.299	Telecommunication management; Charging management; Diameter charging applications [Add MMTel AVPs and descriptions]
	New Dedicated Specifications/Reports
TS 32.275	Telecommunication management; Charging management; MultiMedia Telephony (MMTel) charging

Supporting Individual Members SP-070569: BT, Telecom Italia, TeliaSonera, T-Mobile, Vodafone, Nokia Siemens Networks, Alcatel-Lucent, RIM, Portugal Telecom, Orange, Ericsson.

Supporting Individual Members SP-080848: Alcatel-Lucent, Verizon Wireless, Nortel, Motorola

UID	Name	Acronym	Resource	Hyperlink	Rapporteur	Notes	TS_TR
370062	**IMS Multimedia Telephony Service**	IMS-MMTel	S1,S5	-	-	SP#43 completed	-
370024	Merging TISPAN MMTel [requirements] for Common IMS	TMMTEL	S1	SP-070569	NSN	SP#38 completed	22.173

Petitioners' Exhibit 1003, p. 163
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

380041	Multimedia Telephony Service and Supplementary Services (MMTel) offline Charging	MMTel-CH	S5	SP-080848	Alcatel-Lucent	CP#43 completed	32.275, 32.298/299

SA1 addressed the transfer in 3GPP of TISPAN Stage 1 Multimedia Telephony (MMTEL) Release 2, needed to implement the MMTEL for the Common IMS concept.

As a result, TISPAN Stage 1 TS 181 002 v.2.2.3 (Release 2) was transferred and integrated into 3GPP TS 22.173. Requirements relevant to MMTEL contained in TISPAN TS 181 005 v2.1.0 were also integrated in TS 22.173.

The SA5 IMS charging specifications were not fully covering MMTel supplementary services. Thus, supplementary service charging was included in IMS session charging.

SA5 introduced MMTel charging in 3GPP IMS as a new TS 32.275. Existing TS 32.298 and TS 32.299 added MMTel supplementary services AVPs from Telephone Application Server and corresponding charging fields in the Charging Data Records (CDRs).

Call Completion on Busy Subscriber (CCBS)/Call Completion on Non-Reachable (CCNR) on IMS UID_380006

Resources: C1,C3

References

Document	Title/Contents
	WID(s)
CP-080215	WID on NGN IMS Supplementary Services; Call Completion on Busy Subscriber (CCBS), Call Completion No Reply (CCNR)
	Impacted Specifications
TS 24.173	IMS Multimedia telephony service and supplementary services; Stage 3
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3
TS 29.163	Interworking between the IP Multimedia (IM) Core Network (CN) subsystem and Circuit Switched (CS) networks - C3
	New Dedicated Specifications/Reports
TS 24.642	Completion of Communications to Busy Subscriber (CCBS) and Completion of Communications by No Reply (CCNR) using IP Multimedia (IM)Core Network (CN) subsystem; Protocol Specification

Supporting Individual Members: Deutsche Telekom, T-Mobile, Huawei, Nokia Siemens Networks, Telecom Italia.

UID	Name	Acronym	Resource	Hyperlink	Notes	TS_TR
380007	CT1 part	CCBS_CCNR	C1	CP-080215	CP#43 completed	24.642, 24.229, 24.173
380008	CT3 part	CCBS_CCNR	C3	CP-080215	CP#42 completed	29.163
521019	(IETF) Stage 3	CCBS_CCNR	C1-IETF,C3-IETF	CP-080215	CP#60 completed	RFC 6910 (was draft-ietf-bliss-call-completion)

As part of the agreement of moving common IMS work from ETSI TISPAN to 3GPP, there is a need to ensure that the work on simulation services that are still not frozen within TISPAN is continued within 3GPP. Within TISPNA the WI 3035 (TS183042) on the description for CCBS and CCNR is still within the draft status.

This work creates Stage 3 for CCBS/CCNR-like service in 3GPP IMS. New capabilities are in line with RFC3427. Interoperability between networks was taken into consideration. Interworking was specified.

Petitioners' Exhibit 1003, p. 164
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Flexible Alerting (FA) UID_390058

Resources: S1,C1

References

Document	Title/Contents
	WID(s)
CP-080219	WID on IMS Flexible Alerting Supplementary Service
	Impacted Specifications
TS 22.173	IP Multimedia Core Network Subsystem (IMS) Multimedia Telephony Service and supplementary services; Stage 1
TS 24.173	IMS Multimedia telephony service and supplementary services; Stage 3
	New Dedicated Specifications/Reports
TS 24.239	IP Multimedia Subsystem (IMS) Flexible alerting supplementary service - C1

Supporting Individual Members: Nortel Networks, Ericsson, Alcatel-Lucent, Qualcomm Europe, Tatara Systems, US Cellular, Motorola, Sprint.

UID	Name	Acronym	Resource	Hyperlink	Rapporteur	Notes	TS_TR
390058	**Flexible Alerting**	FA	S1,C1	CP-080219	Nortel	CP#43 completed	-
390059	Stage 1 FA	FA	S1	-	Telecom Italia	SP#40 completed	22.173
390015	Stage 3 FA	FA	C1	CP-080219	Nortel	CP#43 completed	24.239, 24.173

During the joint workshop on common IMS in January 2008, 3GPP and 3GPP2 agreed on principles to incorporate parts of 3GPP2 MMD/IMS related specifications into 3GPP within the Rel-8 timeframe. This work incorporates the Flexible Alerting supplementary service specified in 3GPP2 X.P0055: MMD Supplementary Services.

SA1 covered Stage 1 in TS 22.173.

CT1 covered Stage 3 in TS 24.173 and new TS 24.239.

Communication Wait on IMS (CW_IMS) UID_380009

Resources: C1,C3

References

Document	Title/Contents
	WID(s)
CP-080214	WID on NGN IMS Supplementary Services; Call Waiting (CW) [Definition of Communication Wait Service]
	Impacted Specifications
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3
TS 24.173	IMS Multimedia telephony service and supplementary services; Stage 3
TS 29.163	Interworking between the IP Multimedia (IM) Core Network (CN) subsystem and Circuit Switched (CS) networks - C3
	New Dedicated Specifications/Reports
TS 24.615	Communication Waiting (CW) using IP Multimedia (IM) Core Network (CN) subsystem; Protocol Specification

Supporting Individual Members: Deutsche Telekom, T-Mobile, Huawei Technologies; NSN, Telecom Italia.

UID	Name	Acronym	Resource	Hyperlink	Rapporteur	Notes	TS_TR
380009	Communication Wait on IMS		C1,C3,IETF				-
380010	CT1 part	CW_IMS	C1	CP-080214	Deutsche Telekom	CP#43 completed	24.615, 24.229, 24.173
521020	(IETF) Stage 3	CW_IMS	C1-IETF	CP-080214	Roland Jesske	Submitted to IESG for publication	draft-ietf-salud-alert-info-urns
380011	CT3 part	CW_IMS	C3	CP-080214	Deutsche Telekom	CP#42 completed	29.163

As part of the agreement of moving common IMS work from ETSI TISPAN to 3GPP, there is a need to ensure that the work on simulation services that are still not frozen within TISPAN is continued within 3GPP. Within TISPAN the WI 3027 (TS183015) on the description for CW like service is still within the draft status.

This work creates Stage 3 for CW-like service in 3GPP IMS. New capabilities are in line with RFC3427. Interoperability between networks was taken into consideration. Interworking was specified.

Advice of Charge (AoC) support in IMS Charging UID_380042

Resources: S5

Petitioners' Exhibit 1003, p. 165
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

References

Document	Title/Contents
WID(s)	
SP-070739	WID on Advice of Charge (AoC) support in IMS Charging
Impacted Specifications	
TS 32.240	Telecommunication management; Charging management; Charging architecture and principles
TS 32.260	Telecommunication management; Charging management; IP Multimedia Subsystem (IMS) charging
TS 32.296	Telecommunication management; Charging management; Online Charging System (OCS): Applications and interfaces
TS 32.298	Telecommunication management; Charging management; Charging Data Record (CDR) parameter description
TS 32.299	Telecommunication management; Charging management; Diameter charging applications [Add AVPs for AoC]
New Dedicated Specifications/Reports	
TS 32.280	Telecommunication management; Charging management; Advice of Charge (AoC) service

Supporting Individual Members: Nokia Siemens Networks, Alcatel-Lucent, Amdocs, Ericsson, Orange, Nortel, T-Mobile.

UID	Name	Acronym	Hyperlink	Notes	TS_TR
380042	**AoC support in IMS Charging**	IMSTSS	SP-070739	SP#43 completed	32.240, 32.260, 32.296, 32.298, 32.299, new 32.280

AoC service is standardized in 3GPP and available for CS and PS networks based on Charge Advice Information (CAI).
TISPAN introduced AoC based on Tariff Information according to ITU Recommendations and ETSI specifications.
AoC service is becoming available in 3G IMS networks, hence the usage of AoC should be defined in 3GPP.

AoC is currently listed in the 3GPP charging requirements TS 22.115.
High level description on AoC Information and Charging levels is specified in TS 22.086 and TS 23.086.
AoC is based on the Charge Advise Information (CAI) defined in TS 22.024.
Support of subscribed AoC in CAMEL for CS and PS networks is specified in TS 23.078.
Requirement for AoC support in TISPAN is handled in WID02037 and considers the SIP transfer of charging information in WID 3113.

The transport of tariff information, the evaluation and the advice to the mobile subscriber is not described in IMS.

This work introduces AoC in 3GPP IMS Charging and is limited to support AoC information on the corresponding charging interfaces as well as in the OCS (Online Charging System).

A new TS 32.280 contains definitions for AoC and description of AoC in IMS Charging. It contains the AoC Information for charging purposes. The determination for SIP transport of tariff information followed the requirements in TS 22.273. The mechanism for tariff change and support of the tariff format adhered on the existing 3GPP principles. Additions, e.g. for different use case or simplifications is For Further Study.

AoC service provision and information transfer is made available as a SIP-based IMS service.
Transfer of tariff information is outside the scope of this WID but is For Further Study in other 3GPP groups.

The presentation of the AoC information at the UE/ME is outside the scope of this WID but is For Further Study in other 3GPP groups.

Petitioners' Exhibit 1003, p. 166
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Add Interconnection Border Control Function (IBCF) to IMS Charging UID_370003

Resources: S5

References

Document	Title/Contents
WID(s)	
SP-070621	WID on Add Interconnection Border Control Function (IBCF) to IMS Charging
Impacted Specifications	
TS 32.260	Telecommunication management; Charging management; IP Multimedia Subsystem (IMS) charging Add flows and AVP/CDR tables for IBCF [Match the assignments of other IMS nodes]
TS 32.298	Telecommunication management; Charging management; Charging Data Record (CDR) parameter description [Add IBCF CDR field description, Match the assignments of other IMS nodes]
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Alcatel-Lucent, AT&T, Nortel, Ericsson, Amdocs, Huawei, NSN, T-Mobile.

UID	Name	Acronym	Hyperlink	Notes	TS_TR
370003	**Add Interconnection Border Control Function (IBCF) to IMS Charging**	IMSTSS	SP-070621	SP#39 completed	32.260, 32.298

The Interconnect Border Control Function (IBCF) is becoming available in 3G networks, but SA5 IMS Charging TSs do not recognize nor keep charging records for the IBCF. This work is linked to:

- System enhancements for fixed broadband access to IMS (UID_32074)
- System enhancements for fixed broadband access to IMS - TISPAN Rel-1 related aspects (UID_7001)

SA5 current IMS charging specifications cover all IMS entities (e.g. S-CSCF, I-CSCF, P-CSCF, SIP-AS, MGCF, MRFC, BGCF) excepting IBCF. Thus it is impossible to generate CDRs in IBCF as required by the Rel-7 Stage 2 IMS specifications.

This work adds full functionality for IBCF into IMS Charging TS 32.260 and TS 32.298.

Petitioners' Exhibit 1003, p. 167
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.3 3GPP2 Input to Common IMS (CIMS_3GPP2) UID_390035

Resources: S1,S2,S3

References

Document	Title/Contents
WID(s)	
SP-080220	S1 WID on 3GPP2 Input to Common IMS - covers S1,S2,S3
Impacted Specifications	
TS 22.141	Presence service; Stage 1
TS 22.153	Multimedia priority service
TS 22.173	IP Multimedia Core Network Subsystem (IMS) Multimedia Telephony Service and supplementary services; Stage 1
TS 22.228	Service requirements for the Internet Protocol (IP) multimedia core network subsystem (IMS)
TS 23.002	Network architecture
TS 23.141	Presence service; Architecture and functional description; Stage 2
TS 23.167	IP Multimedia Subsystem (IMS) emergency sessions
TS 23.203	Policy and charging control architecture
TS 23.228	IP Multimedia Subsystem (IMS); Stage 2 (SA2)
TS 33.141	Presence service; Security
TS 33.203	3G security; Access security for IP-based services
TS 33.210	3G security; Network Domain Security (NDS); IP network layer security
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Alcatel-Lucent, Camiant, China Unicom, Ericsson, Huawei, KDDI, Motorola, Nortel, Qualcomm, Sprint, US Cellular, Verizon, ZTE, Nokia Siemens Networks, SK Telecom, NEC.

UID	Name	Resource	Hyperlink	TS_TR
390035	**3GPP2 Input to Common IMS**	-	SP-080220	-
390050	**Stage 1 CIMS_3GPP2 (SA1)**	S1	SP-080220	22.228, 22.173, 22.101, 22.153
390051	**Stage 2 CIMS_3GPP2 (SA2)**	S2	SP-080220	23.002, 23.141, 23.203, 23.167, 23.228
390052	**Security CIMS_3GPP2 (SA3)**	S3	SP-080220	33.141, 33.203, 33.210

During the joint workshop on common IMS in January 2008, 3GPP and 3GPP2 agreed on principles to incorporate parts of 3GPP2 MMD/IMS related specifications into 3GPP. This work item covers work to incorporate SA WG related 3GPP2 IMS specifications, including security, OA&M into 3GPP.

This work item covers documentation of existing 3GPP2 MMD/IMS specifications to be handled by SA WGs in Rel-8.

- **3GPP2 stage 1 specifications to be incorporated include:**
- S.R0058: IP Multimedia Domain – System Requirements
- S.R0062: Presence for Wireless Systems – Stage 1 Requirements
- S.R0120: All-IP System – MMD Policy Enhancements – System Requirements
- S.R0123: Enhanced MMD Security – Stage 1 Requirements
- S.R0125: VoIP Supplementary Services Feature Descriptions (e.g., Flexible Alerting, CRBT)

- **3GPP2 stage 2 specifications to be incorporated include:**
- X.S0013-002: All-IP Core Network Multimedia Domain - IP Multimedia Subsystem – Stage 2
- X.S0013-007: All-IP Core Network Multimedia Domain: IP Multimedia Subsystem - Charging Architecture
- X.S0013-008: All-IP Core Network Multimedia Domain: IP Multimedia Subsystem - Accounting Information Flows and Protocol
- X.S0013-012: All-IP Core Network Multimedia Domain: Service Based Bearer Control – Stage 2
- X.S0027-001: Presence Service: Architecture and Functional Description
- X.S0027-002: Presence Security
- X.S0049: All-IP Network Emergency Call Support
- X.P0053: All-IP System – MMD Policy Enhancements
- X.P0055: MMD Supplementary Services (e.g. Flexible Alerting, CRBT)
- S.S0086: IMS Security Framework

Petitioners' Exhibit 1003, p. 168
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Security for Common IMS is covered by the Feature IMS-Sec (Security Enhancements for IMS UID_370078).

Resources: C1,C3,C4

References

Document	Title/Contents
	WID(s)
CP-080795	CT1 WID on 3GPP2 Input to Common IMS
	Impacted Specifications
TS 23.218	IP Multimedia (IM) session handling; IM call model; Stage 2 (CT1)
TS 24.141	Presence service using the IP Multimedia (IM) Core Network (CN) subsystem; Stage 3 - C1
TS 24.147	Conferencing using the IP Multimedia (IM) Core Network (CN) subsystem; Stage 3 - C1
TS 24.173	IMS Multimedia telephony service and supplementary services; Stage 3 - C1
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3 - C1
TS 24.247	Messaging service using the IP Multimedia (IM) Core Network (CN) subsystem; Stage 3 - C1
TS 24.604	Communication Diversion (CDIV) using IP Multimedia (IM)Core Network (CN) subsystem; Protocol specification - C1
TS 24.605	Conference (CONF)using IP Multimedia (IM) Core Network (CN) subsystem; Protocol specification - C1
TS 24.606	Message Waiting Indication (MWI)using IP Multimedia (IM) Core Network (CN) subsystem; Protocol specification - C1
TS 24.607	Originating Identification Presentation (OIP) and Originating Identification Restriction (OIR) using IP Multimedia (IM) Core Network (CN) subsystem; Protocol specification - C1
TS 24.608	Terminating Identification Presentation (TIP) and Terminating Identification Restriction (TIR)using IP Multimedia (IM) Core Network (CN) subsystem; Protocol specification - C1
TS 24.610	Communication HOLD (HOLD) using IP Multimedia (IM) Core Network (CN) subsystem; Protocol specification - C1
TS 24.611	Anonymous Communication Rejection (ACR) and Communication Barring (CB)using IP Multimedia (IM) Core Network (CN) subsystem; Protocol specification - C1
TS 24.629	Explicit Communication Transfer (ECT) using IP Multimedia (IM) Core Network (CN) subsystem; Protocol specification - C1
TS 24.930	Signalling flows for the session setup in the IP Multimedia core network Subsystem (IMS) based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3 - C1
TS 29.163	Policy and Charging Control signalling flows and QoS parameter mapping - C3
TS 29.212	Policy and charging control over Gx reference point - C3
TS 29.213	Policy and Charging Control signalling flows and QoS parameter mapping - C3
TS 29.214	Policy and charging control over Rx reference point - C3
TS 29.228	IP Multimedia (IM) Subsystem Cx and Dx Interfaces; Signalling flows and message contents - C4
TS 29.229	Cx and Dx interfaces based on the Diameter protocol; Protocol details - C4
TS 29.328	IP Multimedia Subsystem (IMS) Sh interface; Signalling flows and message contents - C4
TS 29.329	Sh interface based on the Diameter protocol; Protocol details - C4
	New Dedicated Specifications/Reports
TS 24.238	Session Initiation Protocol (SIP) based user configuration; Stage 3 - C1

Supporting Individual Members: Alcatel-Lucent, Camiant, China Unicom, Ericsson, Huawei, KDDI, Motorola, Nortel, Qualcomm Europe, Sprint, US Cellular, Verizon, Nokia Siemens Networks.

UID	Name	Resource	Hyperlink	TS_TR
390013	**Stage 3 CIMS_3GPP2 (CT1)**	C1	CP-080795	23.218, 24.141, 24.147, 24.173, 24.229, 24.238, 24.247, 24.604, 24.605, 24.606, 24.607, 24.608, 24.610, 24.611, 24.629, 24.930
390026	**Stage 3 CIMS_3GPP2 (CT3)**	C3	CP-080795	29.163, 29.212, 29.213, 29.214
390027	**Stage 3 CIMS_3GPP2 (CT4)**	C4	CP-080795	29.228, 29.229, 29.328, 29.329

This work item covers the incorporation of CT WGs related 3GPP2 IMS specifications into 3GPP.

This work covers documentation of existing 3GPP2 MMD/IMS specifications to be handled by CT WGs in Rel-8.

- **3GPP2 specifications to be incorporated include:**
- X.S0013-003: All-IP Core Network Multimedia Domain: IP Multimedia (IMS) Session Handling; IP Multimedia (IM) Call Model; Stage 2
- X.S0013-004: All-IP Core Network Multimedia Domain: IP Multimedia Call Control Protocol Based on SIP and SDP Stage 3

Petitioners' Exhibit 1003, p. 169
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- X.S0013-005: All-IP Core Network Multimedia Domain: IP Multimedia Subsystem Cx Interface Signalling Flows and Message Contents
- X.S0013-006: All-IP Core Network Multimedia Domain: Cx Interface Based on the Diameter Protocol; Protocol Details
- X.S0013-009: IMS/MMD Call Flow Examples
- X.S0013-010: All-IP Core Network Multimedia Domain: IP Multimedia Subsystem Sh Interface; Signalling Flows and Message Contents - Stage 2
- X.S0013-011: All-IP Core Network Multimedia Domain: Sh Interface Based on Diameter Protocols Protocol Details - Stage 3
- X.S0013-013: All-IP Core Network Multimedia Domain: Service Based Bearer Control – Tx Interface Stage-3
- X.S0013-014: All-IP Core Network Multimedia Domain: Service Based Bearer Control – Ty Interface Stage-3
- X.S0013-016: All-IP Core Network Multimedia Domain: Messaging service using the IP Multimedia (IM) Subsystem (IMS)
- X.S0027-003: Presence Service using IP Multimedia Core Network Subsystem; stage 3
- X.S0029: Conferencing Using the IP Multimedia (IM) Core Network (CN) Subsystem
- X.S0049: All-IP Network Emergency Call Support
- X.S0050: Session Initiation Protocol (SIP) - ISDN User Part (ISUP) Interworking
- X.P0055: MMD Supplementary Services

Petitioners' Exhibit 1003, p. 170
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.4 IMS Enhancements for support of Packet Cable access (PktCbl) UID_350005

Cable requirements are driven by cable deployments. As such, this work does not place additional requirements on mobile networks or non-cable network operators.

UID	Name	Resource	Hyperlink
350005	**IMS Enhancements for support of Packet Cable access**	-	-
350008	**IMS Enhancements for Cable Client Types and Deployment Models**	S2,C1	SP-070105
350011	**IMS Inter-working aspects in Support of Cable Regulatory requirements**	S2,C1,C3	SP-070107
340008	**IMS Enhancements for Security Requirements in Support of Cable Deployments**	S3,C1,C3,C4	SP-060933

IMS Enhancements for Cable Client Types and Deployment Models (PktCbl-Deploy) UID_350008

Resources: S2, C1

References

Document	Title/Contents
WID(s)	
SP-070105	S2 WID on IMS Enhancements for Cable Client Types and Deployment Models
CP-070122	C1 WID on IMS Protocol Enhancements for Cable Client Types and Deployment Models
Impacted Specifications	
TS 23.228	IP Multimedia Subsystem (IMS); Stage 2 [Changes to support cable client configuration requirements]
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members SP-070105: CableLabs, Nortel, Cisco, Samsung, Siemens, Motorola, Hewlett-Packard

UID	Name	Resource	Hyperlink	TS_TR
350008	**IMS Enhancements for Cable Client Types and Deployment Models**	S2,C1	SP-070105	-
350009	Architecture aspects of PktCbl-Deploy	S2	SP-070105	23.228
350010	CT1 aspects of PktCbl-Deploy	C1	CP-070122	-

Cable networks support certain deployment models and client types currently not supported by 3GPP Rel-7 IMS. This work addresses IMS architectural enhancements needed to support cable client types and deployment models.

The following client types and scenarios were identified:

- Embedded client types (e.g. embedded cable modems and IMS clients)
- Software-based Clients that are retrieved, or installed, on computing platforms that are not under operator control
- Clients that may use different physical layer technologies to access the cable network (e.g. DOCSIS, WiFi, Ethernet)
- Clients that can connect via NAT and/or Firewall devices
- Clients without existing relationship with Service Providers (i.e. no prior pre-configuration on the client or in the Service Provider's network)

Requirements:

- Ability to configure and manage these client types
- Ability to update the configuration of clients dynamically
- Ability to configure devices without requiring pre-configuration
- Ability to choose a Service Provider to obtain configuration

Currently, the IMS defines protocol-specific data element definitions. Enhancing this to allow for a wider choice of protocols provides more flexibility to cable (and other) architectures that may leverage existing or newer protocols for various reasons (e.g. one protocol may not cater to all the requirements).

Petitioners' Exhibit 1003, p. 171
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

SA2 TS 23.228 was impacted by this work, however no CT specification was effected vs. WID (TS 24.229, TS 24.167; no record in CR Database).

IMS Inter-working aspects in Support of Cable Regulatory requirements (PktCbl-Intw) UID_350011

Resources: S2, C1,C3

References

Document	Title/Contents
WID(s)	
SP-070107	S2 WID on IMS Inter-working Aspects in Support of Cable Regulatory requirements
CP-070575	C1 WID on IMS Inter-working Protocol Aspects in Support of Cable Regulatory requirements
Impacted Specifications	
TS 23.228	IP Multimedia Subsystem (IMS); Stage 2 [S2 - Protocol enhancements addressing regional and performance requirements of cable deployments]
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3 - C1,C3
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: CableLabs, Nortel, Cisco, Samsung, Alcatel-Lucent, Siemens, Motorola, Hewlett-Packard, Ericsson.

UID	Name	Resource	Hyperlink	TS_TR
350011	**IMS Inter-working aspects in Support of Cable Regulatory requirements**	S2,C1,C3	SP-070107	-
350012	Architecture PktCbl-Interwork	S2	SP-070107	23.228
350013	CT1,CT3 PktCbl-Interwork	C1,C3	CP-070575	24.229

This work addresses IMS inter-working aspects driven by the regulatory requirements of cable networks, including:

- Local Number Portability (LNP) for the IMS
- Equal Access Circuit Carrier
- SIP to ISUP interworking of Local Number Portability and Equal Access Circuit Carrier parameters

Local Number Portability for the IMS is limited to telephony services, and therefore only applies to TEL URIs and SIP URIs with the parameter user=phone. Other forms of SIP URIs are not subject to LNP.

Equal Access Circuit Carrier Routing is for the purpose of preferred Circuit Switched transit carrier selection.

SA2 TS 23.228, CT3 TS 29.163 were impacted by this work, however CT1 TS 24.229 was not effected vs. WID (no record in CR Database).

Petitioners' Exhibit 1003, p. 172
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

IMS Enhancements for Security Requirements in Support of Cable Deployments (PktCbl-Sec) **UID_340008**

Resources: S3,C1,C4

References

Document	Title/Contents
WID(s)	
SP-060933	S3 WID on IMS Enhancements for Security Requirements in Support of Cable Deployments
CP-070124	C3 WID on IMS Protocol Aspects for Security Requirements in Support of Cable Deployments
Impacted Specifications	
TS 23.008	Organization of subscriber data [C4 - Changes to address security enhancements of cable clients]
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3 [C1 - provisioning, configuration and management of clients in cable networks]
TS 29.228	IP Multimedia (IM) Subsystem Cx and Dx Interfaces; Signalling flows and message contents [C4 - Changes to address security enhancements of clients in cable networks]
TS 29.229	Cx and Dx interfaces based on the Diameter protocol; Protocol details [C4 - Changes to address security enhancements of clients in cable networks]
TS 33.203	3G security; Access security for IP-based services
TS 33.210	3G security; Network Domain Security (NDS); IP network layer security [security requirements for cable deployment models]
TS 33.220	Generic Authentication Architecture (GAA); Generic bootstrapping architecture [security requirements for cable deployment models]
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: CableLabs, Cisco, Lucent, Motorola, Nortel, Samsung, Siemens.

UID	Name	Resource	Hyperlink	TS_TR
340008	**IMS Enhancements for Security Requirements in Support of Cable Deployments**	-	SP-060933	-
350033	SA3 Aspects of PktCbl-Sec	S3	SP-060933	33.203, 33.210, 33.220
350006	CT1 Aspects of PktCbl-Sec	C1	CP-070124	24.229
380029	CT3 Aspects of PktCbl-Sec	C3	CP-070124	29.163
350007	CT4 Aspects of PktCbl-Sec	C4	CP-070124	29.228, 29.229, 23.008

Cable networks support deployment models and client types, currently not completely supported or enabled in 3GPP Rel-7 IMS. This work enhances IMS to address security aspects of clients in cable network deployments e.g.:

- Subscriber first selects and installs a UE independent of the Service Provider and without pre-provisioning of Service Provider information or credentials;
- Service Provider is then able to provide emergency, informative or trial services without requiring pre-configuration of information;
- UE downloads necessary configuration data at boot-time;

For supporting the needed range of cable client types, the IMS was enhanced to support multiple types of client credentials. This required a framework capable of supporting, at a minimum, the following types of credentials used in cable environment:

- ISIM or USIM within UICC;
- Username and Pre-shared key;
- Certificates;

Cable requirements being driven by cable deployments, no additional requirements on mobile networks or non-cable network operators were posed. Enhancements were pursued so that any other broadband access networks with similar requirements (e.g. TISPAN NASS) may choose to support the enhancements required for cable networks.
These enhancements are only for non-3GPP access networks and not intended for 3GPP access networks.

In SA3 TS 33.203 a normative annex on Access security with TLS has been added to address Security Requirements for cable deployments.

Petitioners' Exhibit 1003, p. 173
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

In an environment where multiple types of security are supported, the solution must enable a mechanism for automatic discovery of the security mechanism to be used, and to ensure compatible interworking between client and network. Note: there is no intention to overcome the requirements that for IMS access over UTRAN and GERAN based 3GPP systems UICC-based mechanisms are the only supported mechanisms.

In order to support the needed cable deployment models, the cable enhancements to IMS shall support a framework for the following signalling security requirements to be negotiated between the UE and P-CSCF:

- Signalling with clients behind NAT and Firewall devices
- Client types that cannot rely on the underlying platform
- Performance efficiency for wide variety of clients
- Ability for the network to make use of lower layer access security and relax the creation of security associations between the UE and the P-CSCF based on operator discretion (for example. when the underlying access is granted via the Data Over Cable Service Interface Specification (DOCSIS), IP-CAN)

CT1, CT4 affected specifications: TS 24.229, TS 23.008, TS 29.228 and TS 29.229.

Petitioners' Exhibit 1003, p. 174
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.5 IMS System enhancements for corporate network access (IMS_Corp) UID_360012

Resources: S2,S1,C1,C4,IETF

References

Document	Title/Contents
WID(s)	
SP-080095	S1 WID on IMS System enhancements for corporate network access
CP-080220	C1 WID on IMS protocol enhancements for corporate network access
Impacted Specifications	
TS 23.003	Numbering, addressing and identification (C4) Identities associated with business communication
TS 23.008	Organization of subscriber data (C4) Enhancements to HSS for business communication
TS 23.228	IP Multimedia Subsystem (IMS); Stage 2 (S2) Changes to fulfil requirements for access to corporate network
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3 (C1) Enhancements to SIP in order to support business communications
TS 24.503	TISPAN; IP Multimedia Call Control Protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP) Stage 3 [3GPP TS 24.229 (Release 7), modified] (C1)
TS 29.228	IP Multimedia (IM) Subsystem Cx and Dx Interfaces; Signalling flows and message contents (C4) Enhancements to Cx protocol to support wildcarded public user identities and any issue with PNP numbers
TS 29.229	Cx and Dx interfaces based on the Diameter protocol; Protocol details (C4) Enhancements to Cx protocol to support wildcarded public user identities and any issue with PNP numbers
TS 29.433	TISPAN; IP Multimedia; Diameter based protocol for the interfaces between the Call Session Control Function and the User Profile Server Function/Subscription Locator Function; Signalling flows and protocol details [3GPP TS 29.228 and 29.229 modified] (C4)
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Telecom Italia, Alcatel-Lucent, Ericsson, Orange, Telenor, TeliaSonera, NSN, RIM.

UID	Name	Hyperlink	Rapporteur	Notes	TS_TR
390049	SA1 aspects	SP-080095	Telecom Italia	SP#40 completed	-
360014	SA2 aspects	SP-080095	Orange	no Stage 2 impacts	23.228
390022	CT1 aspects	CP-080220	Alcatel-Lucent	CP#47 completed	24.229, 24.503
531002	(IETF) CT1	CP-080220	Keith Drage	CP#65 completed	RFC 7316 (was draft-vanelburg-dispatch-private-network-ind)
390023	CT4 aspects	CP-080220	Alcatel-Lucent	CP#42 completed	29.228, 29.229, 23.003, 23.008, 29.433

The standardization of fixed broadband access to IMS is addressed by a number of SDOs, e.g. ETSI and ITU-T in the framework of NGN. A set of enhancements to the IMS has already been implemented in Rel-7 based on TISPAN Rel-1 requirements. There is a need to capture new requirements from the industry for IMS in 3GPP Rel-8, especially to support requirements coming from TISPAN R2. One of these requirements is to support corporate, private and residential network access to IMS.

This work implements necessary enhancements to IMS within 3GPP to fulfil this new requirement. It covers IMS architectural enhancements necessary in the 3GPP system to support the access to IMS from e.g. corporate, private, residential networks. One of the scenarios required to be supported is the connection of a corporate network to IMS, where the corporate network has an IMS subscription and the users of the corporate network are owned and managed by the corporate network.

CT WGs work

There is a need to capture enhancements to IMS covering corporate network access. Business communication is covered by ETSI TISPAN, which defines only the Next Generation Corporate Network (NGCN) and AS aspects, and potentially the configuration issues of an IMS providing such business communication. Common IMS is defined by 3GPP, and any required modifications to IMS should therefore be covered within appropriate 3GPP specifications.

The SA1 parent feature (SP-080095) also mentions residential networks. Extension of this CT WGs work item to cover access to IMS by residential networks is for further study.

Petitioners' Exhibit 1003, p. 175
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

This work provides IMS protocol enhancements in the 3GPP system supporting the access to IMS from NGCNs. (scenarios are covered by ETSI TISPAN in DTS/TISPAN-02040). Such extensions to core IMS include:

- distinction of private network traffic from public network traffic, and any special handling of the signalling associated with such distinguished private network traffic by the core IMS, e.g. identity, emergency calls
- protocol issues wildcarded public user identities
- support of PNP numbers
- extension of trust domains to include the NGCN
- support of complex equipment on customer's premises, i.e. the end device is no longer a SIP UA as seen from IMS

7.6 Maintenance of TISPAN documentation (MAINTISP) UID_380069

Resources: S2,C1,C3,C4,IETF

References

Document	Title/Contents
	WID(s)
SP-070916	WID on Maintenance of TISPAN release 2 common IMS
CP-080229	WID on Maintenance of TISPAN release 2 common IMS
SP-070823	WID on Documentation of TISPAN NGN R1 and R2 in 3GPP SA WG2
	Impacted Specifications
TS 23.167	IP Multimedia Subsystem (IMS) emergency sessions (SA2)
TS 23.228	IP Multimedia Subsystem (IMS); Stage 2 (SA2)
TS 23.231	SIP-I based circuit-switched core network; Stage 2 (SA2)
TS 24.447	TISPAN; NGN IMS Supplementary Services; Advice Of Charge (AOC) (CT1)
TS 24.451	TISPAN; Support of SMS and MMS over NGN IMS subsystem; Stage 3 [Endorsement of 3GPP TS 24.341 Release 7] (CT1)
TS 24.454	TISPAN; PSTN/ISDN simulation services; Protocol specification Closed User Group (CUG) (CT1)
TS 24.503	TISPAN; IP Multimedia Call Control Protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP) Stage 3 [3GPP TS 24.229 (Release 7), modified] (CT1)
TS 24.505	TISPAN; PSTN/ISDN simulation services: Conference (CONF); Protocol specification (CT1)
TS 24.508	PSTN/ISDN simulation services Terminating Identification Presentation (TIP) and Terminating Identification Restriction (TIR); Protocol specification (CT1)
TS 24.516	TISPAN; PSTN/ISDN simulation services; Malicious Communication Identification (MCID); Protocol specification (CT1)
TS 24.528	TISPAN; Common Basic Communication procedures; Protocol specification (CT1)
TS 24.529	TISPAN; PSTN/ISDN simulation services: Explicit Communication Transfer (ECT); Protocol specification (CT1)
TS 29.458	TISPAN; SIP Transfer of IP Multimedia Service Tariff Information; Protocol specification (CT3)
TS 29.527	TISPAN; Endorsement of the SIP-ISUP Interworking between the IP Multimedia (IM) Core Network (CN) subsystem and Circuit Switched (CS) networks [3GPP TS 29.163 (Release 7), modified] (CT3)
	New Dedicated Specifications/Reports
TS 24.406	TISPAN; PSTN/ISDN simulation services; Message Waiting Indication (MWI): Protocol specification (CT1)
TS 24.407	TISPAN; PSTN/ISDN simulation services; Originating Identification Presentation (OIP) and Originating Identification Restriction (OIR); Protocol specification (CT1)
TS 24.410	TISPAN; NGN Signalling Control Protocol; Communication HOLD (HOLD) PSTN/ISDN simulation services; Protocol specification (CT1)
TS 24.411	TISPAN; PSTN/ISDN simulation services: Anonymous Communication Rejection (ACR) and Communication Barring (CB); Protocol specification (CT1)
TS 24.423	TISPAN; PSTN/ISDN simulation services; Extensible Markup Language (XML) Configuration Access Protocol (XCAP) over the Ut interface for Manipulating NGN PSTN/ISDN Simulation Services (CT1)
TS 24.430	TISPAN; Presence Service Capability; Protocol Specification [3GPP TS 24.141 V7.0.0, modified and OMA-TS-Presence_SIMPLE-V1_0, modified] (CT1)
TS 29.412	TISPAN; Interworking; Trunking Gateway Control Procedures for interworking between NGN and external CS networks (CT3)
TS 29.421	TISPAN; NGN Release 1; Endorsement of 3GPP TS 29.162 Interworking between IM CN Sub-system and IP networks (CT3)
TS 29.433	TISPAN; IP Multimedia; Diameter based protocol for the interfaces between the Call Session Control Function and the User Profile Server Function/Subscription Locator Function; Signalling flows and protocol details [3GPP TS 29.228 and 29.229 modified] (CT4)
TS 23.506	TISPAN; IP Multimedia Subsystem (IMS); Stage 2 description [3GPP TS 23.228 Release 7, modified]
TS 23.507	TISPAN; Voice Call Continuity (VCC); Stage 2 [3GPP TS 23.206 Release 7, modified] (SA2)
TS 23.517	TISPAN; IP Multimedia Subsystem (IMS); Functional architecture (SA2)
TS 23.521	Telecommunications and Internet converged Services and Protocols for Advanced Networks (TISPAN); Support of Short Message Service (SMS) over NGN IMS subsystem; Stage 2; [Endorsement of 3GPP TS 23.204 Release 7] (SA2)

Petitioners' Exhibit 1003, p. 176
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Supporting Individual Members SP-070916: Telecom Italia, BT, TeliaSonera, T-Mobile, Ericsson, Vodafone, Portugal Telecom, Alcatel-Lucent. Huawei, Nokia, Nokia Siemens Networks, Orange, China Mobile, Nortel, AT&T.

Supporting Individual Members CP-080229: Alcatel-Lucent, BT, Deutsche Telekom, Ericsson, Huawei Technologies, Nokia, Nokia Siemens Networks, Nortel Networks, Telecom Italia

Supporting Individual Members SP-070823: Alcatel-Lucent, Deutsche Telekom, Huawei, Ericsson, Nortel Networks, Nokia, Nokia Siemens Networks, Telecom Italia.

UID	Name	Acronym	Resource	Hyperlink	WI_rapporteur	Notes	TS_TR
380005	**Maintenance of TISPAN R2**	MAINT_R2	C1,C3,C4	CP-080229	Alcatel-Lucent	CP#39 completed	24.406, 24.407, 24.410, 24.411, 24.423, 24.430, 24.447, 24.451, 24.454, 24.503, 24.505, 24.508, 24.516, 24.528, 24.529, 29.412, 29.421, 29.433, 29.458, 29.527, 29.624
521021	**Deleted - (IETF) Maintenance of TISPAN R2**	MAINT_R2	C1-IETF	CP-080229	Andrew Allen	CP#64 Draft removed from 3GPP documentation	draft-avasarala-dispatch-comm-div-notification
380043	**Documentation of TISPAN NGN R1 and R2 in 3GPP SA2**	IMS_Comm_Doc	S2	SP-070823	Nokia Siemens Networks	SP#40 completed	23.228, 23.204, 23.167
380044	**Maintenance of TISPAN release 2 common IMS**	IMS_Comm_Mtce8	S2	SP-070916	Telecom Italia	SP#38 completed	23.506, 23.507,23.517, 23.521

During the 3GPP SA WG2 and TISPAN WG2 joint meeting on Common IMS in Nov 2007 in Ljubljana, 3GPP and TISPAN agreed on the principles of shifting TISPAN specifications to 3GPP within the Rel-8 timeframe. This work item covers this activity.

As part of the agreement of moving common IMS work from ETSI TISPAN to 3GPP, there is a need to ensure that maintenance occurs of the TISPAN R2 deliverables, published as ETSI standards. TISPAN has a CR process similar to 3GPP, where as essential corrections are identified, they should be made to older releases to which they are appropriate. This WI allocates a WI code to be used on such essential corrections to TISPAN R2, with mirrors 3GPP Rel-8 onwards.

Additionally, if the maintenance process can be made simpler by some re-documentation, e.g. by changing the TISPAN deliverable from being dependent on a specific version of a 3GPP specification, to being one where the dependency is on a specific release but not a specific version, then such changes are also allowed under this work item. Such redocumentation must not result in any technical change.

Due to some issues with 3GPP maintaining directly the TISPAN specifications, the mechanism for doing this will be to create new 3GPP Rel-8 specifications with identical contents to those of the TISPAN R2 specifications. These new specifications will exist independently of any transfer of material into 3GPP specifications that will represent 3GPP Rel-8 output. The corollary of this is that in association with this work item, ETSI TISPAN will need to delete the contents of their specifications and replace them with references to these new 3GPP specifications.

This work item does not provide any new feature or enhancement of a feature; but only a work item code to be used for maintenance of TISPAN R2; such changes shall be essential corrections, as defined by 3GPP and TISPAN CR process.

This work item also provides a work item code for appropriate re-documentation to assist the above, with the constraint that such a change shall not result in any technical change to TISPAN R2 or to frozen 3GPP releases.

Petitioners' Exhibit 1003, p. 177
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.7 IMS Service Continuity (IMS-Cont) UID_390056

Resources: S2,S1,C1

References

Document	Title/Contents
	WID(s)
SP-080092	S2 WID on IMS Service Continuity (IMS-Cont)
CP-080491	C1 WID on IMS Service Continuity - Stage 3
	Impacted Specifications
TS 23.292	IP Multimedia System (IMS) centralized services; Stage 2 - S2
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3 - C1
	New Dedicated Specifications/Reports
TS 23.237	IP Multimedia Subsystem (IMS) service continuity - S2
TS 24.216	Communication Continuity Management Object (MO) - C1
TS 24.237	IP Multimedia Subsystem (IMS) Service Continuity; Stage 3 - C1

Supporting Individual Members: BT, KDDI, Huawei, LG Electronics, NEC, Orange, Qualcomm, SK Telecom, Telcordia, Telecom Italia, Toshiba, Marvell, Nortel, Motorola, Nokia, Nokia Siemens Networks, Infineon Technologies.

UID	Name	Resource	Hyperlink	TS_TR
390056	**IMS Service Continuity**	S2,S1,C1	SP-080092	-
390072	**Stage 1 IMS Service Continuity**	S1	SP-080092	-
390057	**Stage 2 IMS Service Continuity**	S2	SP-080092	23.237, 23.292
400011	**Stage 3 IMS Service Continuity**	C1	CP-080491	24.237, 24.229, 24.216

SA2 work

SA2 analyzed the related VCC Rel-7 and the Rel-8 TR 23.893 Study on Multimedia Session Continuity (FS_MMSC UID_350051), and agreed to pursue two specifications; one related to Centralized IMS Service Control (TS 23.292) and the other related to IMS Service Continuity (TS 23.237).

VCC Rel-7 only covers voice media and supports domain transfer between CS and IMS within 3GPP; developed within the distributed control of services framework. These limitations raise requirements on the current architecture and its logical entities for covering more effectively the wider scope and providing Service Continuity within the centralized control of services framework.

In Rel-8 several WIDs/SIDs (e.g. encompassing VCC Rel-7, ICS, MMSC) are dealing with different aspects and scopes of Service Continuity. Hence, these different aspects need to be included into a single TS handling the general Service Continuity issue.

The work provides IMS Service Continuity by using the IMS Centralized Services framework, based on the conclusions from TR 23.893 (Multimedia session continuity) and TR 23.892 (IMS centralized services) as follows:

- CS-PS session continuity using the IMS Centralized Services. This is an enhancement of the VCC Rel-7 and includes enhancements and possible renaming of VCC Application functionalities defined in TS 23.206;
- PS-PS session continuity;
- PS-PS session continuity in conjunction with PS-CS continuity;
- Mobility of media components of a session between different terminals under the control of the same user.

IMS Service Continuity was restricted to Service Continuity using IMS procedures, i.e. mobility mechanisms on the IP-CAN (Internet Protocol Connectivity Access Network) level are not within the scope of this WID.

This WID does not overlap with the features SAES and Single Radio Voice Call Continuity for 3GPP (SAES-SRVCC).

CT1 work

This work enhances the relevant 3GPP protocol specifications to support the following aspects:

Petitioners' Exhibit 1003, p. 178
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Procedures to support PS-CS service continuity using the IMS Centralized Services (see TS 23.292). This is an enhancement of the VCC Rel-7 and includes migration and evolution of the Rel-7 VCC procedures from TS 24.206 for support of service continuity, e.g. continuity of mid call services.
- Procedures to support PS-PS session continuity
- Procedures to support PS-PS session continuity in conjunction with PS-CS continuity
- Procedures to support mobility of media components of a session between different terminals under the control of the same subscriber

This work item considered necessary terminal/UE enhancements to enable the objective.

Consistent user experience is ensured where users need continuity of services between heterogeneous access systems (e.g. different radio accesses).

Billing/charging impact was evaluated. Specifically, the ability to generate the appropriate accounting parameters as subscribers move between various access networks is necessary.

No new protocol is expected for security issues covered in the parent feature.

Petitioners' Exhibit 1003, p. 179
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.8 Security Enhancements for IMS (IMS-Sec) UID_370078

Resources: S3,C1,C4

References

Document	Title/Contents
	WID(s)
SP-070496	S3 WID on Security Enhancements for IMS
CP-070781	C1 WID on NASS Bundled Authentication
	Impacted Specifications
TS 23.008	Organization of subscriber data - C4 (Add line identity relating to NBA over the Cx interface)
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3 - C1 (Specify NBA as alternative to existing security mechanisms)
TS 29.228	IP Multimedia (IM) Subsystem Cx and Dx Interfaces; Signalling flows and message contents - C4 (Add parameters, information element names and mappings relating to NBA over the Cx interface)
TS 29.229	Cx and Dx interfaces based on the Diameter protocol; Protocol details - C4 (Add ABNF relating to NBA over the Cx interface)
TS 33.141	Presence service; Security
TS 33.203	3G security; Access security for IP-based services
TS 33.803	Coexistence between TISPAN and 3GPP authentication schemes
TS 33.978	Security aspects of early IP Multimedia Subsystem (IMS)
	New Dedicated Specifications/Reports
-	-

Supporting Individual Members: Alcatel-Lucent, BT, Ericsson, Nokia Siemens Networks, Nokia, Rogers Wireless, Telecom Italia, Telenor, T-Mobile, Vodafone.

UID	Name	Resource	Hyperlink	TS_TR
370078	**Security Enhancements for IMS**	S3,C1,C4	SP-070496	-
360017	**Stage 2 for IMS-Sec**	S3	SP-070496	33.203, 33.141, 33.803
390054	**CT1 part of Stage 3 for IMS-Sec**	C1	-	-
390154	**CT4 part of Stage 3 for IMS-Sec**	C4	-	-
380012	**CT1 part of NASS Bundled Authentication**	C1	CP-070781	24.229
380013	**CT4 part of NASS Bundled Authentication**	C4	CP-070781	29.229, 29.228, 23.008

SA3 extended the existing IMS security architecture to meet the new security requirements coming from common IMS.

Stage 2 security enhancements for IMS address TS 33.203, TS 33.141, TR 33.978, TR 33.828 and TR 33.803. A series of normative annexes added to TS 33.203, take into account alternative authentication methods to Full IMS AKA:

- NASS-IMS Bundled Authentication (NBA);
- SIP Digest - based authentication;
- Access security with TLS;
- 3GPP2 Access;

Another new annex covers the co-existence of authentication schemes; explaining how to handle in Common IMS the following authentication mechanisms: Full IMS AKA, Early IMS (re-named GIBA, GPRS-IMS Bundled Authentication), NBA, SIP Digest.

SA3 continued the work on co-existence of authentication schemes, ensuring that all IMS security solutions could co-exist. It assessed how an operator can control what authentication schemes can be used in his network.

SA3 identified requirements and specified solutions on media protection for IMS.

SA3 identified which parts of the work performed in TISPAN should be moved to 3GPP, and how the work in TISPAN is integrated into 3GPP specifications.

SA3 specified mechanisms to protect users from unsolicited IMS communication and reduced the number of options for solving the same requirement. Lawful interception was also covered.

Petitioners' Exhibit 1003, p. 180
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CT WGs work on NASS (Network Attachment Sub-System) Bundled Authentication

TISPAN R1 has an authentication mechanism entitled NASS Bundled Authentication (NBA).
NBA works by extending the successful authentication in the NASS layer to the service layer.

During the network attachment, the NASS authenticates the UE and allocates an IP address. It stores the layer-2 and layer-3 identities in the NASS profile. When UE registers with the P-CSCF, the P-CSCF queries the NASS (actually the CLF functional entity), to obtain its location information. The P-CSCF embeds the location information into the SIP message and forwards it towards the S-CSCF for verification. The S-CSCF verifies this location information with the location information obtained from the UPSF. On successful verification, the user is authenticated at the IMS layer.

As part of the Common IMS work, SA3 have agreed to re-document the TISPAN R1 mechanism as a normative annex to TS 33.203. As a result, work is necessary in specifications owned by TSG CT. Preventing fraud attack is an important aspect of this WID that CT1 must implement in the protocol based on the SA3 requirements.

CT1, CT4 documented NASS Bundled Authentication (NBA) in TSG CT owned specifications.

Petitioners' Exhibit 1003, p. 181
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.9 IMS initiated and controlled PSS and MBMS User Service (IMS_PSS_MBMS_US) UID_34046

Resources: S4,S3,IETF

References

Document	Title/Contents
WID(s)	
SP-080201	WID on IMS initiated and controlled PSS and MBMS User Service
Impacted Specifications	
TS 26.234	Transparent end-to-end Packet-switched Streaming Service (PSS); Protocols and codecs - S4
TS 26.346	Multimedia Broadcast/Multicast Service (MBMS); Protocols and codecs - S4
TS 33.246	3G Security; Security of Multimedia Broadcast/Multicast Service (MBMS) - S3
New Dedicated Specifications/Reports	
TS 26.237	IMS based PSS and MBMS User Service; Protocols - S4

Supporting Individual Members: Ericsson, RealNetworks, Apple Inc, Huawei, Orange, Telecom Italia, China Mobile, Verizon Wireless.

UID	Name	Resource	Hyperlink	Notes	TS_TR
34046	**IMS initiated and controlled PSS and MBMS User Service**	S2,S4,C3,C4	SP-080201	SP#39 WID approved	-
34146	**IMS initiated and controlled PSS and MBMS User Service**	S2,S4,C3,C4	SP-080201	SP#43 completed	26.237, 26.234, 26.346, 33.246
521022	**(IETF) IMS initiated and controlled PSS and MBMS User Service**	S4-IETF	SP-080201	SP#53/IETF#81: RFC 6080 included in 26.237	draft-ietf-sipping-config-framework

This work is linked to SA4 Extending PSS and MBMS User Services for optimized Mobile TV (PSS_MBMS_OMTV) UID_34043.

IMS facilitates multimedia service creation and deployment. It allows operators to apply policy controls over the traffic, control QoS and charging with a single management infrastructure. It allows the use of a common PS infrastructure. Today the IMS is mainly deployed for Voice and Multimedia Telephony applications with the support of enablers like presence and group management.

Multimedia services based on PSS and MBMS use protocols like RTSP, FLUTE and HTTP. This limits the possibilities of service blending and cost optimizations on the infrastructure. It would be beneficial to allow for PSS and MBMS User Services to be initiated and controlled via SIP.

Also, as customers use already-deployed PSS services, the ARPU can be increased by bundling these services into IMS applications that would bring all the features of IMS stated above (QoS, charging etc.). It should be possible to re-use the full functionality of PSS or MBMS as it stands today.

For these reasons 3GPP specified IMS initiated and controlled PSS and MBMS User Service. The same reasons have been guiding the specifications on IPTV in TISPAN, ATIS IIF (IPTV Interoperability Forum) and Open IPTV Forum.

The objective is to provide convergence and avoid inconsistencies with IMS-based IPTV solution provided in TISPAN, ATIS IIF and Open IPTV Forum, by aligning architecture and procedures defined in their specifications and adaptation towards 3GPP PSS and MBMS User Service. The specification work has been done in the following order:

1) Unicast streaming over PSS: e.g. Mobile TV using PSS, streaming radio services
2) MBMS streaming: e.g. Mobile TV using MBMS
3) Other Multimedia streaming/download services

SA4 does not foresee any impact on IMS core itself. This work enables the use of IMS charging in the context of PSS and MBMS User Service. It has no impact on charging specifications. The service allows:

- Blending of PSS and MBMS User Services with IMS communication services;
- A unique registration and profile management for all multimedia services.

This work specified:

Petitioners' Exhibit 1003, p. 182
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- how to use the SIP protocol to initiate and control PSS and MBMS User Services
- how to use the core IMS functions and enablers in order to utilize mechanisms such as QoS and Policy control to improve the service experience

Petitioners' Exhibit 1003, p. 183
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.10 Multimedia interworking between IMS and CS networks (MIW-IMS) UID_713024

Resources: C3,C4

References

Document	Title/Contents
	WID(s)
CP-070729	C3 WID on Multimedia interworking between IM CN subsystem and circuit switched networks
	Impacted Specifications
TR 29.863	Feasibility Study for the multimedia inter-working between the IP Multimedia Core Network (CN) Subsystem (IMS) and Circuit Switched (CS) networks - C3
TS 29.163	Interworking between the IP Multimedia (IM) Core Network (CN) subsystem and Circuit Switched (CS) networks - C3
TS 29.332	Media Gateway Control Function (MGCF) - IM Media Gateway (IM-MGW); Mn interface - C4
	New Dedicated Specifications/Reports
-	-

Supporting Individual Members: Nortel, Vodafone, Orange, Nokia, Siemens, Ericsson, Huawei.

UID	Name	Resource	Hyperlink	TS_TR
713024	**Multimedia interworking between IMS and CS networks**	S2,C3,C4	CP-070729	-
7013	**Note: Stages 1 and 2 defined in earlier Release**	S2	-	-
7014	**Stage 3 of MW-IMS**	C3	CP-070096	29.863, 29.163
380021	**Stage 3 for MW-IMS, MONA extension**	C3	CP-070729	29.863, 29.163
380022	**Mn interface (MGCF – IM MGW)**	C4	CP-070729	29.332

NOTE: SA1 Stage 1 and SA2 Stage 2 have been defined in earlier Releases.

Within UMTS, the capability of IP-based Multimedia (IM) services enables supporting basic multimedia calls to and from Circuit Switched (CS) networks (i.e. PSTN, ISDN and GSM/UMTS CS networks). These multimedia calls will require interworking functions within the IMS.

The UMTS architecture includes Media Gateway (MGW) functionality for interworking between the GGSN Gi reference point and CS networks for the user plane, and Media Gateway Control Function (MGCF) and Signalling Gateway (SGW) functionality to allow interworking between the Call Session Control Function (CSCF) and CS networks in the control plan.

This work provides functionality for supporting basic multimedia calls required within the:

- MGW to deliver the user plane aspects between IMS and CS networks;
- MGCF and SGW to deliver the control plane aspects between IMS and CS networks;

In order to support basic multimedia calls, the work addressed the control plane interworking:

- between the AMR codec used in the IMS and possibly other codec types used in CS networks) in order to support basic multimedia calls;
- the mapping required between 3GPP profile of SIP and ISUP/BICC, SDP, 324M control protocols, if required) to enable the IMS to communicate with CS networks;

The areas addressed encompass transport protocol, transcoding and signalling issues for negotiation and mapping of bearer capabilities and QoS information.

As a first step, CT3 Rel-7 TR 29.863 was continued to study all implications of the user and control plane interworking.

Subsequently the functionality was added:

- Stage 3 of MW-IMS and Stage 3 for MW-IMS (MONA extension) to existing CT3 TS 29.163;

Mn interface (MGCF – IM MGW) to existing CT4 TS 29.332;

Petitioners' Exhibit 1003, p. 184
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.11 IMS Stage-3 IETF Protocol Alignment (IMSProtoc2) UID_360029 (open IETF)

Resources: C1,IETF

References

Document	Title/Contents
WID(s)	
CP-080794	WID on IMS Stage-3 IETF Protocol Alignment
Impacted Specifications	
TR 24.930	Signalling flows for the session setup in the IP Multimedia core network Subsystem (IMS) based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3
TS 23.218	IP Multimedia (IM) session handling; IM call model; Stage 2
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Alcatel-Lucent, Huawei, Nortel Networks, Nokia, Nokia Siemens Networks.

UID	Name	Resource	Hyperlink	Rapporteur	Notes	TS_TR
360129	**CT1 aspects of IMS Stage 3 IETF Protocol Alignment - phase 2**	C1	CP-080794	Alcatel-Lucent	CP#43 completed	23.218, 24.229, 24.930
521023	**(IETF)**	C1-IETF	CP-080794	Andrew Allen	CP#58 completed. ietf-draft discontinued. Documented within 3GPP	draft-bakker-sipping-3gpp-ims-xml-body-handling
521024	**(IETF) (RFC 6544)**	C1-IETF	CP-080794	Keith Drage	CP#56 completed	RFC 6544 (was draft-ietf-mmusic-ice-tcp)
521025	**(IETF)**	C1-IETF	CP-080794	Roland Jesske	Submitted to IESG for publication	draft-ietf-salud-alert-info-urns

Rel-7 work on IMS protocol fulfilled a useful purpose in separating all minor IMS enhancements needing progress. Rel-8 WID has an identical scope (with the removal of 24.930).

IMS was defined in Rel-5 to support IP Multimedia services and provided the basis for IP Multimedia support. Rel-6 and Rel-7 further improvements were made. Rel-8 identified new capabilities and there is still significant IETF ongoing work that should be documented in relation to its impact on IMS.

This work aligned protocol between 3GPP Stage 3 IMS and IETF, reviewed IETF provided SIP capabilities, and documented whether these capabilities are supported in the IMS or not.

In addition, minor technical enhancements to IMS, not of sufficient significance to be normally covered by a work item, were covered by this work item.

Petitioners' Exhibit 1003, p. 185
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.12 Interworking between User-to-User Signalling (UUS) and SIP (UUSIW) UID_380014 (open IETF)

Resources: C1,C3,IETF

References

Document	Title/Contents
	WID(s)
CP-070782	C1 WID on UUS interworking
	Impacted Specifications
TS 29.163	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3 - C1
TS 24.229	Combining Circuit Switched (CS) and IP Multimedia Subsystem (IMS) services; Stage 3 - C1
TS 24.279	Interworking between the IP Multimedia (IM) Core Network (CN) subsystem and Circuit Switched (CS) networks - C3
	New Dedicated Specifications/Reports
-	-

Supporting Individual Members: Huawei, Infineon, LG Electronics, Deutsche Telekom, Ericsson.

UID	Name	Resource	Hyperlink	Rapporteur	Notes	TS_TR
380015	**CT1 part**	C1	CP-070782	Huawei	CP#42 completed	24.279, 24.229
521026	**(IETF)**	C1-IETF,C3-IETF	CP-070782	Roland Jesske	Submitted to IESG for publication	draft-ietf-cuss-sip-uui
551001	**(IETF)**	C1-IETF,C3-IETF	CP-070782	Keith Drage	Submitted to IESG for publication	draft-ietf-cuss-sip-uui-isdn
380016	**CT3 part**	C3	CP-070782	Huawei	CP#43 completed	29.163

SA1 identified the requirement of MGCF (Media Gateway Control Function) interworking between UUS and SIP. This MGCF interworking makes possible the CSI (CAMEL Subscription Information) capability exchange between UEs that use CSI and UEs that use IMS with IMS origination and CSI termination.

The purpose of CSI capability exchange is to enrich communication for CSI termination. So the user of CSI capable UE can expect same user experience in case remote party is IMS capable UE.

Hence, Stage 3 should properly cover the MGCF interworking to enable transportation of CSI capability information and the CSI capability exchange for IMS originated sessions leading to CSI session termination.

This work aligns the agreed Stages1 and 2 with Stage 3 along with the provision of relevant Stage 3 capabilities and functionalities to elaborate the MGCF interworking as defined in TS 22.228 and the functional involvement of the CSI capability exchange defined in TS 23.279.

TS 22.228 requires IMS support interoperability of UUS service with the PSTN/ISDN and vice versa. This was applied from TISPAN Stage 1.

Stage 2 requirement of CSI capability exchange and MGCF interworking between UUS1 and SIP is part of TS 23.279.

This work:

- implements the MGCF interworking between UUS and corresponding SIP as defined in Stage 1 requirements (CT3 related part);
- includes UUS into SIP header (CT3 and CT1 common part);
- includes CSI capability exchange feature in CT1 as defined in Stage 2 (CT1 related part)

NOTE 1: This work only covers UUS1 implicit aspects of UUS interworking

NOTE 2: Extensions to SIP should be developed in accordance with 3GPP agreements with IETF, see RFC 3113.

Petitioners' Exhibit 1003, p. 186
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.13 Support of Overlap signalling (Overlap) UID_380018

Resources: C3,C1,C4

References

Document	Title/Contents
	WID(s)
CP-070731	C3 WID on Support of Overlap within the common IMS
	Impacted Specifications
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3 - C1
TS 29.163	Interworking between the IP Multimedia (IM) Core Network (CN) subsystem and Circuit Switched (CS) networks - C3
TS 29.228	IP Multimedia (IM) Subsystem Cx and Dx Interfaces; Signalling flows and message contents - C4
TS 29.229	Cx and Dx interfaces based on the Diameter protocol; Protocol details
	New Dedicated Specifications/Reports
-	-

Supporting Individual Members: Deutsche Telekom, T-Mobile, Huawei, Alcatel-Lucent, British Telecom, Telecom Italia, Nortel Networks.

UID	Name	Resource	Hyperlink	TS_TR
380018	**Support of Overlap signalling**	C3,C1,C4	CP-070731	-
380019	**Stage 3 Overlap (CT1)**	C1	CP-070731	24.229
380020	**Stage 3 Overlap (CT3)**	C3	CP-070731	29.163
380120	**Stage 3 Overlap (CT4)**	C4	CP-070731	29.228, 29.229

As part of the agreement of moving common IMS work from ETSI TISPAN to 3GPP, there is a need to ensure that work on Overlap Signalling in TISPAN is continued within 3GPP. Within TISPAN the feasibility study WI3111 (TR 183 056) evaluates overlap related procedures, some of which may be needed for IMS to support Overlap Signalling.

This work specifies a method inside IMS for supporting Overlap Signalling originating from networks using Overlap Signalling. The solution is based on requirements from SA1 and architectural input from SA2.

Petitioners' Exhibit 1003, p. 187
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.14 AS/MRFC stage 2 and 3 work (MRFC_TS) UID_380035

Resources: C1

References

Document	Title/Contents
WID(s)	
CP-070784	WID on Media Server Control using the IP Multimedia (IM) Core Network (CN) system (AS/MRFC stage 2/3)
Impacted Specifications	
TS 23.218	IP Multimedia (IM) session handling; IM call model; Stage 2
TS 24.147	Conferencing using the IP Multimedia (IM) Core Network (CN) subsystem; Stage 3
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3
TS 24.247	Messaging service using the IP Multimedia (IM) Core Network (CN) subsystem; Stage 3
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Hewlett-Packard, Comverse Network Systems, IAESI, Huawei.

UID	Name	Resource	Hyperlink	Notes	TS_TR
380035	**AS/MRFC Stage 2 and 3**	C1	CP-070784	-	-
380135	**AS/MRFC Stage 2**	C1	CP-070784	CP#42 completed	23.218
380235	**AS/MRFC Stage 3**	C1	CP-070784	CP#42 completed	24.229, 24.147, 24.247
521027	**(IETF) AS/MRFC Stage 2 and 3**	C1-IETF	CP-070784	CP#56 RFC 6505 completed	RFC 6505 (was draft-ietf-mediactrl-mixer-control-package)

This work was triggered by the CT1 Study UID_7048 (MRFC).

The SIP signalling used between an AS and an MRFC (Media Resource Function Controller) is specified but not the format of the media commands/instructions and results/events used for controlling a Media Resource Function.

TR 24.880 (Study on AS-MRFC media server control protocol UID_7048) studied requirements, options and alternatives for Media Server Control (MSC) of a Media Resource Function and made recommendations for MSC specification.

CT1 produced stage 2 and stage 3 by following the recommendations from TR 24.880:

- Create Cr reference point that can be used for both delegation and protocol models, and would support the functions of both the Cr and Sr interfaces;
- Use VoiceXML 2.1 standard or VoiceXML 3.0 working draft (the decision to be taken depending on availability of the VoiceXML 3.0 working draft);
- Use RFC 4240 and draft-ietf-mediactrl-vxml needs to be specified;
- Specify AS/MRFC conferencing split and a corresponding media conference policy that can be used by a media server control method;
- Use SCXML or CCXML profile together with the delegation model;
- For the protocol model, to align requirements with and to specify the use of IETF mediactrl protocol. If this work is not available in Rel-8 then use an existing protocol such as MSCML (RFC 4722).

Petitioners' Exhibit 1003, p. 188
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.15 IMS Restoration Procedures (IMS_RP) UID_400012

Resources: C4,C1

References

Document	Title/Contents
	WID(s)
CP-080447	WID on IMS Restoration Procedures
	Impacted Specifications
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3 - C1 [Added new information elements and detailed behaviour]
TS 29.228	IP Multimedia (IM) Subsystem Cx and Dx Interfaces; Signalling flows and message contents - C4 [Updated ABNF command]
TS 29.229	Cx and Dx interfaces based on the Diameter protocol; Protocol details - C4 [Defined new AVPs]
TS 29.230	Diameter applications; 3GPP specific codes and identifiers - C4 [Updated procedures of network elements handling SIP signalling]
	New Dedicated Specifications/Reports
TS 23.380	IMS Restoration Procedures - C4

Supporting Individual Members: Ericsson, Vodafone, France Telecom, Huawei, Nortel, Hewlett-Packard, ZTE, Alcatel-Lucent.

UID	Name	Resource	Hyperlink	TS_TR
400012	**IMS Restoration Procedures**	C4,C1	CP-080447	-
400026	**IMS Restoration Procedures**	C4	CP-080447	23.380, 29.228, 29.229, 29.230, 23.008
400027	**IMS Restoration Procedures**	C1	CP-080447	24.229

This work is triggered by TR 23.820 Study on Restoration Procedures (FS_IMS_RP) UID_350018.

This work specifies the procedures recommended in TR 23.820, e.g. covering the S-CSCF service interruption scenario.

7.16 IMS Application Server Service Data Descriptions for AS interoperability (IMS_ASIO) UID_410003

Resources: C4

References

Document	Title/Contents
	WID(s)
CP-080451	WID on IMS Application Server Service Data Descriptions for AS interoperability
	Impacted Specifications
TS 29.328	IP Multimedia Subsystem (IMS) Sh interface; Signalling flows and message contents
TS 29.329	Sh interface based on the Diameter protocol; Protocol details
	New Dedicated Specifications/Reports
TS 29.364	IP Multimedia Subsystem (IMS) Application Server (AS) service data descriptions for AS interoperability

Supporting Individual Members: Alcatel-Lucent, Verizon Wireless, Nortel Networks, Nokia-Siemens Networks, ZTE.

UID	Name	Resource	Hyperlink	TS_TR
410003	**IMS Application Server Service Data Descriptions for AS interoperability**	C4	CP-080451	29.328, 29.329, 29.364

This work is triggered by TR 29.864 Study on IMS Application Server (AS) service data descriptions for AS interoperability UID_360030 (FS_IMS_ASIO).

Application data for IMS is defined as being 'Transparent'. Transparency in this case refers to the fact that the HSS, and the Sh interface, do not semantically understand the data just syntactically how to deal with its entirety. ASs are free to

Petitioners' Exhibit 1003, p. 189
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

store data without an openly distributed definition of the stored content, however, because the data is transparent (the format is not standardized) it is potentially an issue for one AS to make use of data defined for another AS (e.g. the ASs are supplied by different vendors).

Standardizing the data formats facilitates interoperation among ASs supplied by the same, or different, vendors. These AS vendors may be primary and secondary suppliers of the same Service Provider (SP) within a SP's IMS network. This is especially true of mature services, such as the features provided in basic voice subscriptions, and is likely to be true of any future services that achieve a wide deployment.

There has already been work incorporated into 3GPP from TISPAN that point towards the need to define common data. The UE may update a service setting (e.g. a forwarded to number) in an AS via the Ut interface. The AS may store this information in transparent data in the HSS, but unless the data is defined it cannot be shared with other ASs.

Some benefits of standardizing the data formats for services:

1 Multi-vendor AS support.

Today's telecom SPs regularly use two or more vendors to provide identical capabilities. Standardization has facilitated this, as products must conform to the defined interfaces. Service providers use this to build competition among vendors and to build business contingencies. The AS market, especially for high penetration services, is expected to follow a similar path.

2 Data Synchronization

In defining IMS centralized services, interworking between the HLR/HSS and the Telephony Application Server may occur to exchange data that is administered in the CS domain and IMS. The definition of IMS AS service data descriptions facilitates this exchange.

3 Feature Interaction

Advertising and defining data for each application is expected to increase communication regarding features within applications. This will make the integration of complex features more likely to succeed, as the information is available to examine for interactions.

4 User re-homing and load balancing

To facilitate re-homing of users to application servers and load balancing, the definition of IMS AS service data descriptions increases the opportunity for hosting services on alternative ASs.

This work standardized the necessary components of an AS subscriber data definition by using the methods proposed in TR 29.864. These procedures enable applications to define, extend and publish data definitions.

Redefine the OMA XDM XML based data of the AS providing Presence, IM, etc. is out of the scope of this work.

Petitioners' Exhibit 1003, p. 190
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

8 WLAN interworking with a 3GPP system (I-WLAN)

Interworking WLAN (I-WLAN): A WLAN that interworks with a 3GPP system (TR 21.905).

WLAN Wireless Local Area Network

8.1 I-WLAN Network Selection Principle (IWLANNSP) UID_340030

Resources: S1,C1,C6

References

Document	Title/Contents
WID(s)	
SP-060932	S1 WID on I-WLAN NSP
CP-080217	C1,C6 WID on I-WLAN NSP
Impacted Specifications	
TS 22.234	Requirements on 3GPP system to Wireless Local Area Network (WLAN) interworking - S1 (Added NSP requirements to I-WLAN Network Selection)
TS 24.234	3GPP system to Wireless Local Area Network (WLAN) interworking; WLAN User Equipment (WLAN UE) to network protocols; Stage 3 - C1 (Add NSP requirements to I-WLAN Network Selection)
TS 31.102	Characteristics of the Universal Subscriber Identity Module (USIM) application - C6 (Added provisioning files)
TS 31.111	Universal Subscriber Identity Module (USIM) Application Toolkit (USAT) - C6 (Added steering of roaming procedures)
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: O2, RIM, Gemalto, Softbank Mobile.

UID	Name	Resource	Hyperlink	TS_TR
340030	**I-WLAN Network Selection Principle (NSP)**	S1,C1,C6	SP-060932	-
390024	**Stage 1 for I-WLAN NSP**	S1	SP-060932	22.234
390025	**Stage 3 for I-WLAN NSP**	C1	CP-080217	24.234
390125	**Stage 3 for I-WLAN NSP**	C6	CP-080217	31.102, 31.111

SA1 aligned the requirements for the selection of I-WLAN access in TS 22.234 (Requirements for WLAN Interworking) to the ones applicable to PLMN network selection in TS 22.011 (Service accessibility).
Due to changes of the network selection mechanism in TS 22.011, the following SA1,CT1 alignment was needed:

- Automatic PLMN selection procedure by WLAN UE (TS 22.234, TS 24.234);
- Manual PLMN Selection Mode Procedure by WLAN UE (TS 22.234, TS 24.234);
- Operator management of network preferences for I-WLAN (TS 22.234);

MMI aspects considered: Identification and manual choice of PLMNs by I-WLAN UE.

Petitioners' Exhibit 1003, p. 191
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

8.2 Mobility between 3GPP-WLAN Interworking and 3GPP Systems (IWLAN_Mob) UID_370049

Resources: S2,C1

References

Document	Title/Contents
	WID(s)
SP-070701	S2 WID on Mobility between 3GPP-WLAN Interworking and 3GPP Systems
CP-080320	WID on CT1 aspects of mobility between 3GPP WLAN Interworking and 3GPP Systems
	Impacted Specifications
TS 24.303	Mobility management based on Dual-Stack Mobile IPv6; Stage 3 - C1
	New Dedicated Specifications/Reports
TS 23.327	Mobility between 3GPP-WLAN interworking and 3GPP systems - S2
TS 24.327	Mobility between 3GPP WLAN Interworking and 3GPP Systems; GPRS and 3GPP I-WLAN Aspects; stage 3 - C1

Supporting Individual Members: Orange, China Mobile, Telenor, Nokia Siemens Networks, Nokia, Ericsson, Airvana, Marvell, Qualcomm, Bridgewater.

UID	Name	Resource	Hyperlink	TS_TR
370049	**Mobility between 3GPP-WLAN Interworking and 3GPP Systems**	S2,C1	SP-070701	-
380045	**Stage 2: I-WLAN Mobility**	S2	SP-070701	new 23.327
400013	**CT1 aspects of I-WLAN Mobility**	C1	CP-080320	24.303, new 24.327

This work is linked to SAE for support of non-3GPP accesses (UID_350027).

TS 23.234 (3GPP system to WLAN interworking; System description) provides the possibility to offer access to IP services via WLAN (and other compatible IP access technologies) by interworking with Rel-6 3GPP systems.
As defined in Rel-6 TR 22.934, service continuity (scenario 4) and seamless services (scenario 5) at a change of the access network (between I-WLAN and GPRS) are desirable enhancements to improve the user experience.

The work was based on architectural/functional/procedural definitions described in TS 23.234 (3GPP system to WLAN interworking; System description) and TS 23.060 (GPRS; Service description; Stage 2).
Synergies and smooth migration to SAE was considered.

New SA2 TS 23.327 specifies the stage 2 system description for providing mobility between 3GPP-Wireless Local Area Network Interworking (I-WLAN) and 3GPP Systems. It defines a technical solution based on the working principles of DS-MIPv6 with necessary enhancement of the I-WLAN architecture for supporting mobility and roaming between 3GPP-WLAN Interworking system and 3GPP Systems so that ongoing 3GPP PS based services can be maintained with minimal impact on the end-user's perceived quality on the services at a change of the access network (between I-WLAN and 3GPP Access Systems.
TS 23.327 includes both non-roaming and roaming scenarios and covers all aspects, including mobility between 3GPP Systems and I-WLAN with access authentication and charging.

CT1 part of work is linked to SAE for support of non-3GPP accesses (UID_350027) particularly to Stage 3 for Inter-system mobility between E-UTRAN and non 3GPP accesses (UID_380030). CT1 produced the specifications for the H1 reference point and associated procedures used for the mobility between I-WLAN and 3GPP legacy systems. On Service Aspects, minimum interruptions are expected to the applications running on UE during the change between 3GPP and I-WLAN systems. Collection of accounting information when the UE changes accesses shall be specified with maximum re-use of existing 3GPP charging specifications. The service continuity across the access systems shall not compromise the security mechanisms of the individual access system.

New CT1 TS 24.327 specifies Stage 3 referencing where appropriate TS 24.303 Mobility management based on Dual-Stack Mobile IPv6; Stage 3.

8.2.1 Conformance Test Aspects – Mobility between 3GPP WLAN Interworking and 3GPP Systems UID_460006

Resources: R5

Petitioners' Exhibit 1003, p. 192
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Supporting Individual Members: Orange, Qualcomm, ZTE, TeliaSonera.

UID	Name	Hyperlink	Status_Report	Notes	TS_TR
460006	**Conformance Test Aspects – Mobility between 3GPP WLAN Interworking and 3GPP Systems**	RP-091349	RP-100740	RP#49 completed. Testing for Rel-8 UID_400013 CT1 aspects of mobility between 3GPP WLAN Interworking and 3GPP Systems (24.327)	34.108, 34.123-1, 34.123-2, 34.123-3

Petitioners' Exhibit 1003, p. 193
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

9 Pan-European in-vehicle emergency call (eCall)

UID	Name	Resource	Hyperlink	Notes
330005	eCall Data Transfer	S1,C1	SP-060678	Linked to SA4 Feature UID_34042 (eCall_Phase2)
360015	Study on Transferring of emergency call data – in-band modem solution	S4	SP-060935	Spin-off WID UID_34042 (eCall_Phase2)
34042	eCall data transfer Phase 2: Comparison of alternative in-band modem solutions and standardization of one in-band modem solution	S4	SP-070756	Triggered by Study UID_360015 (eCALLIBMS). Linked to SA1 Feature UID_330005 (EData)
450001	eCall Conformance Testing	G3new	GP-091098	Testing for Rel-8 eCall_Phase2 (UID_34042) and EData (UID_330005)
450023	Conformance Test Aspects – non-modem procedures of eCall sessions in UTRA	R5	RP-090952	Testing for Rel-8 eCall_Phase2 (UID_34042) and Edata (UID_330005)

9.1 eCall Data Transfer (EData) UID_330005

Resources: S1,C1

References

Document	Title/Contents
WID(s)	
SP-060678	S1 WID on eCall Data Transfer – Requirements
CP-080316	C1 WID on Transfer of data during an emergency call (EData)
Impacted Specifications	
TS 22.101	Service principles
TS 22.105	Services and service capabilities
TS 24.008	Mobile radio interface Layer 3 specification; Core network protocols; Stage 3
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Airbiquity, T-Mobile, Vodafone, Wavecom

UID	Name	Resource	Hyperlink	TS_TR
330005	eCall Data Transfer	S1,C1	SP-060678	-
370081	**eData Requirements**	S1	SP-060678	22.101, 22.105
400014	**Transfer of data during an emergency call**	C1	CP-080316	24.008

This work is linked to SA4 Study on "eCall data transfer Phase 2: Comparison of alternative in-band modem solutions and standardization of one in-band modem solution" (eCall_Phase2) UID_34042

This WID identifies the necessary requirements, from SA1 Rel-7 TR 22.967 (Transferring of emergency call data) and ETSI MSG agreed documents, for the transmission of a Minimum Set of Data (MSD), i.e. 140 bytes maximum, from the In Vehicle System (IVS) to a Public Safety Answering Point (PSAP). As explained in the document 1609/6/EN WP125 on EU's Article 29 Working Party, the Minimum Set of Data (MSD) consists of the following (i) time of incident, (ii) precise location including direction of driving, (iii) vehicle identification, (iv) eCall qualifier giving the severity of the incident (as a minimum, as indication if eCall has been manually or automatically triggered), (v) information about a possible service provider.

As part of the EU Commission eSafety initiative, ETSI MSG was requested to standardize the transmission of a MSD sent from a suitably equipped vehicle to a PSAP. The intention (of eCall) is to supplement TS12 emergency voice calls with emergency related data from a vehicle e.g. accurate location information, that will enable the emergency services to reach accident victims more rapidly, with the potential to save more lives.

SA1 TR 22.967 examined the issues associated with the transmission of emergency call data from a vehicle to a PSAP. In order to progress work in other 3GPP groups supporting the EU Commission's proposed pan-European eCall service, this work identifies (only) those requirements necessary for the transmission of the MSD from the IVS to a PSAP.

SA1 added in TS 22.101 the requirements for supporting the transfer of data during an emergency call.

Petitioners' Exhibit 1003, p. 194
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

SA4 and SA1 have agreed to send the data will by using an in-band modem.

SA4 TR 26.967 indicates that unmodified CTM as standardized can not fulfil all the eCall requirements; i.e. applying the proposed robust Pull-Protocol on application layer, transmits the MSD (Minimum Set of incident Data) of 140 bytes in 29 sec instead of the required 4 sec. Unmodified CTM as standardized also does not include a transport layer acknowledgement. This is not necessarily a disadvantage; TR 26.967 shows that a flexible half-duplex application layer protocol can simply be added.

To fulfil some of the SA1 requirements, CT1 needed to modify the mobility management and the emergency call set up.

CT1 TS 24.008 includes the Stage 3 enhancements to mobility management and call control procedures.

Petitioners' Exhibit 1003, p. 195
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

9.2 Study on Transferring of emergency call data – in-band modem solution (eCALLIBMS) UID_360015

Resources: S4

References

Document	Title/Contents
WID(s)	
SP-060935	SID on Transferring of emergency call data – in-band modem solution
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 26.967	eCall data transfer; In-band modem solution

Supporting Individual Members: Airbiquity, T-Mobile, Vodafone, Wavecom.

As part of the EU Commission eSafety initiative, ETSI MSG were requested to standardize the transmission of a Minimum Set of Data (MSD) sent from a suitably equipped vehicle to a Public Safety Answering Point (PSAP). The intention (of eCall) is to supplement E112 and 112 (TS12) emergency voice calls with emergency related data from a vehicle e.g. accurate location information, that should enable emergency services to reach faster accident victims, with the potential to save more lives annually. GSME Position Paper on eCall investigated SMS, UUS (User to User Signalling), USSD (Unstructured Supplementary Service Data), GSM CS data, DTMF and in-band modem solutions. In-band modem solution resulted as the preferred option.

SA1 Rel-7 TR 22.967 (Transferring of emergency call data) examined the transmission of emergency call data from a vehicle to a PSAP. SA1 set requirements for adding data component to E112 and 112 (TS12) emergency calls and eCall MSD (data) transfer requirements necessary for the transmission of the MSD (140 bytes maximum), from the In Vehicle System (IVS) to a PSAP.

For eCall, SA4 has studied the in-band modem solution and any necessary interface to the ME. Because eCall is a European regional requirement, it shall not impact the global circulation of terminals. SA4 investigated the suitability of existing 3GPP in-band solutions satisfying the requirements for eCall (e.g. Cellular Text telephony Modem - CTM). In case no existing solution is suitable, an alternative in-band solution for eCall should be specified.

SA4 TR 26.967 concludes that unmodified CTM cannot fulfil all eCall requirements, i.e. applying the proposed robust Pull-Protocol on application layer, transmits the MSD of 140 bytes in 29 seconds instead of the required 4 seconds. Unmodified CTM also does not include a transport layer acknowledgement.

Spin-off implementation work UID_34042 (eCall_Phase2).

Petitioners' Exhibit 1003, p. 196
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

9.3 eCall data transfer Phase 2: Comparison of alternative in-band modem solutions and standardization of one in-band modem solution (eCall_Phase2) UID_34042

Resources: S4

References

Document	Title/Contents
	WID(s)
SP-070756	WID on eCall data transfer Phase 2: Comparison of alternative in-band modem solutions and standardization of one in-band modem solution
	Impacted Specifications
TS 26.226	Cellular text telephone modem; General description
	New Dedicated Specifications/Reports
TS 26.267	eCall data transfer; In-band modem solution; General description
TS 26.268	eCall data transfer; In-band modem solution; ANSI-C reference code
TS 26.269	eCall data transfer; In-band modem solution; Conformance testing
TR 26.967	eCall data transfer; In-band modem solution [Characterizes the performance under various radio and network conditions]
TR 26.969	eCall data transfer; In-band modem solution; Characterization report

Supporting Individual Members:

UID	Name	Resource	Hyperlink	TS_TR
34042	**eCall data transfer Phase 2: Comparison of alternative in-band modem solutions and standardization of one in-band modem solution**	S4	SP-070756	26.226 new (26.267, 26.268, 26.269, 26.967, 26.969)

This work was triggered by Study UID_360015 (eCALLIBMS).

This work is linked to SA1 Feature UID_330005 (EData)

As part of the EU Commission eSafety initiative, ETSI MSG were requested to standardize the transmission of a Minimum Set of Data (MSD) sent from a suitably equipped vehicle to a Public Safety Answering Point (PSAP). eCall will supplement E112 and 112 (TS12) emergency voice calls with emergency related data from a vehicle, e.g. accurate location information, enabling emergency services to reach accident victims more rapidly. GSME has investigated numerous options and identified that the GSME preferred option be based on an in-band modem solution.

Consideration of in-band modem solutions in Phase 1 was limited to existing 3GPP standards, i.e. CTM (Cellular Text telephony Modem), a data delivery technology developed for text telephony.
As agreed at SA4#45 (subsequently confirmed by 3GPP TSG SA, ETSI TC MSG and the European Commission), unmodified CTM as standardized does not fulfil all the eCall requirements. Further, SA, MSG and the EC all agreed that 3GPP should proceed "as soon as possible" with the evaluation of alternative in-band modem data transfer solutions and the standardization of one in-band modem solution for eCall.

SA4 examined alternative in-band modem solutions (in-band modem and any necessary interface to the ME) for eCall, and subsequently standardized the best ranked solution fulfilling the requirements. Comparison criteria were developed and compared to the performance of each proposed in-band modem solution.

SA4 TR 26.967 indicates that unmodified CTM as standardized can not fulfil all the eCall requirements; i.e. applying the proposed robust Pull-Protocol on application layer, transmits the MSD (Minimum Set of incident Data) of 140 bytes in 29 sec instead of the required 4 sec. Unmodified CTM as standardized also does not include a transport layer acknowledgement. This is not necessarily a disadvantage; TR 26.967 shows that a flexible half-duplex application layer protocol can simply be added.

Petitioners' Exhibit 1003, p. 197
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

9.4 eCall Conformance Testing UID_450001

Resources: G3new

References

Document	Title/Contents
WID(s)	
GP-091098	WID on eCall Conformance Testing
Impacted Specifications	
TS 51.010-1, 51.010-2	
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members:Ericsson, Qualcomm

UID	Name	Resource	Hyperlink	Notes	TS_TR
450001	eCall Conformance Testing	G3new	GP-091098	GP#47 completed. GP#43 WID approved. Testing for Rel-8 eCall_Phase2 (UID_34042) and EData (UID_330005)	51.010-1, 51.010-2

Testing for Rel-8 eCall_Phase2 (UID_34042) and EData (UID_330005)

The eCall in-band modem is a modulation protocol to transfer data over the mobile voice channel. It is specified in TS 26.267 and TS 26.268, and a corresponding conformance specification is contained in TS 26.269.

Non-modem procedures required for eCalls have been specified in TS 22.101 while protocol support for eCall is defined in TS 24.008. This work developed conformance test cases to verify protocol behaviour for activites such as registration for eCall, connection establishment for eCall and behaviour during eCall inacitivity period

This work introduces conformance testing for non-modem procedures of eCall sessions in the GERAN conformance test specifications.

9.5 Conformance Test Aspects - non-modem procedures of eCall sessions in UTRA UID_450023

Resources: R5

References

Document	Title/Contents
WID(s)	
RP-090952	WID on Conformance Test Aspects - non-modem procedures of eCall sessions in UTRA
Impacted Specifications	
TS 34.108	Common test environments for User Equipment (UE); Conformance testing
TS 34.123-1	User Equipment (UE) conformance specification; Part 1: Protocol conformance specification
TS 34.123-2	User Equipment (UE) conformance specification; Part 2: Implementation conformance statement (ICS) specification
TS 34.123-3	User Equipment (UE) conformance specification; Part 3: Abstract test suites (ATSs)
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members:

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
450023	Conformance Test Aspects – non-modem procedures of eCall sessions in UTRA	R5	RP-090952	RP-100489	34.108, 34.123-1, 34.123-2, 34.123-3

Testing for Rel-8 eCall_Phase2 (UID_34042) and Edata (UID_330005)

The pan-European in-vehicle emergency call, "eCall" is an emergency call generated either manually by the vehicle occupants or automatically via activation of in-vehicle sensors after an accident. Various solutions for eCall were evaluated by SA4 during eCall Phase 1 and eCall Phase 2. A candidate proposal from eCall Phase 2 was selected by

Petitioners' Exhibit 1003, p. 198
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

SA4 and approved by SA plenary #43 (March 2009). The SA specifications are TS 22.101, TS 26.267 and TS 26.268 while the protocol related aspects of eCall are defined in TS 24.008 and 3GPP TS 31.102. The in-band modem test specification is in TS 26.269.

The eCall modem specification was also approved as an ETSI eCall in-band modem standard and adopted by the European Commission and CEN as the Pan-European eCall Standard.

When activated, the in-vehicle eCall device establishes an emergency call carrying both voice and data directly to the most appropriate Public Safety Answering Point (PSAP). The voice call enables the vehicle occupants to communicate with the PSAP operator. At any time during the call, a Minimum Set of Data (MSD) can be sent to the PSAP operator receiving the voice call.

Aside from the in-band modem component specified in TS 26.267 and TS 26.268, full support of eCall sessions requires that the UE perform non-modem related procedures. Therefore, there is a need for conformance testing for eCall by developping test cases for non-modem related protocols as required. The following are some of the non-modem procedures related to eCall:

1. In eCall only mode, blocking of calls to numbers other than to PSAP, test and reconfiguration numbers
2. In eCall only mode, ability to set up calls to PSAP, test number and reconfiguration numbers
3. In eCall only mode, non-execution of mobility management procedures when the terminal changes location areas and non-execution of periodic location update procedure

The eCall in-band modem is a modulation protocol to transfer data over the mobile voice channel. It is specified in TS 26.267 and TS 26.268, and a corresponding conformance specification is contained in TS 26.269.

Non-modem procedures required for eCalls have also been specified in TS 22.101, TS 24.008 and TS 31.102. This work developed conformance test cases to address the non-modem aspects of eCall sessions.

Petitioners' Exhibit 1003, p. 199
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10 SA1 Features

10.1 Enhancements for Voice Group Call Service (VGCS) Applications (EVA) UID_7042

Resources: S1,C1,C4,G2

References

Document	Title/Contents
WID(s)	
SP-070904	S1 WID on Enhancements for Voice Group Call Service (VGCS) Applications (EVA)
SP-070653	S1 WID on VGCS/VBS and GPRS Interactions
CP-060260	C1 WID on Enhancements for VGCS Applications
GP-071855	G2 WID on Enhancements for VGCS Applications
Impacted Specifications	
TS 42.068	Voice Group Call Service (VGCS); Stage 1 - SA1
TS 42.069	Voice Broadcast Service (VBS); Stage 1 - SA1
TS 43.068	Voice Group Call Service (VGCS); Stage 2 - CT1
TS 44.068	Group Call Control (GCC) protocol - CT1
TS 29.002	Mobile Application Part (MAP) specification - CT4
TS 48.008	Stage 3 enhancements for the transfer of application specific data - G2
TS 44.018	Stage 3 enhancements for the transfer of application specific data - G2
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Nortel Networks, Nokia Siemens Networks, Huawei, Vodafone.

UID	Name	Resource	Hyperlink	TS_TR
7042	**Enhancements for Voice Group Call Service (VGCS) Applications (EVA)**	-	SP-070904	
320021	SA1 aspects of EVA	S1	SP-070904	42.068
370019	VGCS/VBS and GPRS Interactions	S1	SP-070653	42.068, 42.069
320019	CT1 aspects of EVA	C1	CP-060260	43.068, 44.068
320020	CT4 aspects of EVA	C4	CP-060260	29.002
52148	GERAN2 aspects of EVA	G2	GP-071855	44.018, 48.008

Enhancements for VGCS Applications (EVA) Stage 1:

SA1 work under WID SP-070904 provides additional optional Voice Group Call Service (VGCS) functions to allow for the support of VGCS applications in railway and public networks, including:

- Transfer of railways application-specific control information, requiring short round trip delay. Railways requirement is for the transfer of shunting commands from the chief shunter to group members, to be acknowledged by the train cab driver.
- A means to request dispatchers to rejoin a group call. Railways requirement is for a simple solution (e.g. pressing a single button, and without the requestor having to leave the group call). Use of a point-to-point call for contacting the dispatcher is not acceptable because too many MMI actions would be needed.
- *Listener identity information – useful for public authority application (e.g. a police chief wants to know who is listening in order to assign tasks to group members) and railway networks (e.g. for dispatchers to identify if members are listening). - not fulfilled by G2 - see GP-071855*

This service provides the ability to:

- Send and receive a small amount of data between group members, including dispatchers;
- Send an indication/ small amount of data from service subscribers to the network;
- Transfer critical data within a short time period (500ms) without impacting voice quality of the group call;
- *Gather information on the identities of current listeners, which should not be older than a specified time interval, and to inform dispatchers on the identities of current listeners. Also, this information may be provided to service subscribers. - not fulfilled by G2 - see GP-071855*

GERAN2 added in existing TS 48.008 and TS 44.018 additional optional VGCS functions meeting the above purposes. The intent was to have a future-proof solution that can be used to meet potential future application needs.

Petitioners' Exhibit 1003, p. 200
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

VGCS/VBS and GPRS Interactions:

SA1 work under WID SP-070653 covers the VGCS/VBS (Voice Group Call Service/Voice Broadcast Service) and GPRS interactions.
Requirements for use of VGCS/VBS in public networks for communication of public authority officials have been defined already.

The improvements of the VGCS/VBS service functionality cover the following aspects:

- When a Class B MS is engaging in a GPRS data session and a VGCS/VBS (emergency) call is coming, the GPRS data session may be immediately aborted and the VGCS/VBS call will be accepted.
- Incoming call's priority information is now provided to the GPRS application, so the GPRS application can choose to interrupt the GPRS data session and accept the incoming call or not based on this priority information.

Petitioners' Exhibit 1003, p. 201
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10.2 Personal Network Management (PNM) UID_31081

Resources: S1,C1,S3

References

Document	Title/Contents
	WID(s)
SP-080327	S1 WID on Personal Network Management (PNM)
CP-080065	C1,C4 WID on Personal Network Management
	Impacted Specifications
TS 22.259	Service requirements for Personal Network Management (PNM); Stage 1 - S1
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3 - C1
	New Dedicated Specifications/Reports
TS 23.259	Personal Network Management (PNM); Procedures and information flows - C1
TS 24.259	Personal Network Management (PNM); Stage 3 - C4

Supporting Individual Members: Vodafone, NTT DoCoMo, NEC, Toshiba, Panasonic, Telcordia Technologies, Huawei.

UID	Name	Resource	Hyperlink	TS_TR
31081	**Personal Network Management**	S1,C1,S3	SP-080327	-
7012	**Stage 1 for PNM**	S1	SP-080327	22.259
350050	**Stage 2 for PNM**	C1	CP-080065	23.259
350041	**Stage 3 for PNM**	C1,C4	CP-080065	-
350001	CT1 aspects of Stage 3 PNM	C1	CP-080065	24.259, 24.229
350002	CT4 aspects of Stage 3 PNM	C4	CP-080065	-

The purpose of this WI is to define a Personal Network (PN) and a Personal Area Network (PAN) within the scope of All IP Based Network (AIPN).

AIPN has been studied some time ago and TR 22.978 was approved at 3GPP SP#27. In the context of this feasibility study, requirements on prospective PNs and PANs were discussed and considered for progress even beneficial for deployment in a mixed CS/PS domain, independent from AIPN or its successor EPS.

This Work Item was established to address such requirements and cater for creation of respective specifications.

*"**Personal Network:** A Personal Network, in the context of AIPN, consists of more than one device (terminal or server provided by the AIPN operator) under the control of one user providing access to the AIPN. These devices are interconnected by the AIPN such that the user perceives a continuous secure connection regardless of their relative locations. The user controls the PN using facilities provided by the AIPN."*

Why this feature: Already now, many subscriber own more than one terminal and subscription, e.g. ordinary handset for telephony, car phone, PDA for emails when on the move, data card with laptop for work when in semi-stationary mode. Although those devices mainly taken for particular usage, many are able to support more than one sort of services, e.g. telephony is supported by all but the data card. Customers may not carry always their full set of "gadgets", but still want to be reachable. Management for the user by setting forwarding options, switch on and off terminals, providing partners with multiple addresses is not very customer friendly. The Personal network will provide the efficient means for the customer to manage their terminals.

*"**Personal Area Network:** A Personal Area Network (PAN), in the context of AIPN consists of more than one device (terminal) controlled by, and physically close to, the same user (person). All the devices within a PAN use the same USIM. These devices are connected together using internal PAN means. The user obtains services from the AIPN using his multiple devices which all access the users USIM through the PAN to gain access to the AIPN. The user controls the PAN directly."*

Why this feature: Complimentary to the Personal Network, customers use devices which are capable to support certain services, but neither they are equipped with USIM nor with the radio access means, e.g. a PDA or laptop might be better suited to play a video stream with reasonable quality that a 3G phone with very limited screen size. Current interconnection means between auxiliary devices and 3G terminals are very much of a proprietary nature and come with security constrains, e.g. for setting up a session via an auxiliary device.

Further advanced features on PAN, initially planned to be part of Release 8, will finally be included in a later release.

Petitioners' Exhibit 1003, p. 202
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10.2.1 Key establishment between a UICC hosting device and a remote device (PNM) UID_340010

Resources: S3

References

Document	Title/Contents
WID(s)	
SP-060839	S3 WID on Key establishment between a UICC hosting device and a remote device
Impacted Specifications	
TS 33.259	Key establishment between a UICC hosting device and a remote device - S3
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: 3, Ericsson, Nokia, Rogers Wireless, Vodafone.

UID	Name	Resource	Hyperlink	TS_TR
31081	**Personal Network Management**	-	SP-080327	-
340010	**Key establishment between a UICC hosting device and a remote device**	S3	SP-060839	33.259

This work was moved from Rel-7 to Rel-8 Feature => BB as per SA3/SA WID in SP-060839, keeping the same UID

TS 22.259 describes the service requirements for the Personal Network Management (PNM). PNM allows the user to manage his Personal Network Elements (PNEs), Personal Networks (PNs) and Personal Area Networks (PANs).

TS 22.259 describes PNM use cases requiring secure links established among locally connected devices of a PAN. One example is when a video service is terminating in a PNE (e.g. a laptop) of a PAN and the service is routed through the PNE holding the (U)SIM (i.e. the UE), the local link between the two devices needs to be secured.

This calls for mechanisms to establish a shared key between the UICC hosting device and other PNEs in the PAN. The UICC hosting device may have a (U)SIM that is not able to support secure interaction between the UICC and remote entities, also these devices should have a way to securely communicate with remote entities.

In a PAN there may reside devices with communication capabilities that do not hold a (U)SIM. For interoperability reasons, it is beneficial, if the means to provision a UICC hosting device and a remote device with a shared secret are as agnostic as possible to the nature of the remote device.

This work defines how to provision a shared key between a UICC hosting device and a remote device via a local interface. Authorisation (e.g. determining which terminal can securely connect to which device) was studied as well.

Establishment of a shared key between a UICC hosting device and a remote device allows operators to provide a wide range of sensitive applications that require a secure local interface to protect the data exchanged between the UICC hosting device and remote devices.

Petitioners' Exhibit 1003, p. 203
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10.3 IP Interconnection of Services (IPinterc) UID_380060

UID	Name	Acronym	Resource	Hyperlink
380060	**IP Interconnection of Services**	IPinterc	S1,S2,S5,C3	SP-080565
380061	**Stage 1 for IPinterc**	IPinterc	S1	SP-080565
7005	**System enhancements for interconnection interfaces between two IMSs**	IMS_NNI	S2,S5,C3	SP-080554
360024	Stage 2 for IMS_NNI	IMS_NNI	S2	SP-080554
360011	IMS inter-operator service interconnection interface	FBI2-IOPSI	C3	CP-080578
330011	Charging harmonization for NGN between 3GPP and ATIS-TMOC	FBI2-TISP2-CH	S5	SP-060545

10.3.1 Stage 1 for IP Interconnection of Services UID_380061

Resources: S1

References

Document	Title/Contents
WID(s)	
SP-070871	S1 WID on Stage 1 Specification of Requirements for IP Interconnection of Services
Impacted Specifications	
TS 22.228	Service requirements for the Internet Protocol (IP) multimedia core network subsystem (IMS); Stage 1 (IMS Interconnection)
TS 22.101	Service aspects; Service principles (CS Services Interconnection)
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Telefonica O2 Europe; Telecom Italia, BT, Sprint, Vodafone.

UID	Name	Acronym	Resource	Hyperlink	TS_TR
380060	**IP Interconnection of Services**	IPinterc	S1,S2,S5,C3	SP-080565	-
380061	**Stage 1 for IPinterc**	IPinterc	S1	SP-080565	22.101, 22.228

Stage 1 covers IMS_NNI (UID_360024), SIP_Nc (UID_360026), CS-IBCF (UID_400008).

Linked work items:

IMS_NNI	Inter-IMS Network to Network Interface (UID_7005)
SIP_Nc	Support of (G)MSC-S – (G)MSC-S Nc Interface based on the SIP-I protocol (UID_360025)
CS-IBCF	CS-IBCF and CS-TrGW definition in 3GPP specifications (UID_400008)

Support IP inter-connect for MSC Server and IMS as proposed by external bodies (e.g. GSMA, ETSI).

Service Aspects: Define interoperability requirements of IP based services to ensure transparency to the end user.

Petitioners' Exhibit 1003, p. 204
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10.3.2 System enhancements for interconnection interfaces between two IMSs (IMS_NNI) UID_7005

Resources: S2,C3

References

Document	Title/Contents
WID(s)	
SP-080554	WID on System enhancements for interconnection interfaces between two IM CN subsystem networks (IMS-NNI)
CP-080054	WID on IMS inter-operator service interconnection interface
Impacted Specifications	
TS 23.002	Network architecture
TS 23.228	IP Multimedia Subsystem (IMS); Stage 2
New Dedicated Specifications/Reports	
TR 29.865	Inter-IMS network to network interface - C3
TS 29.165	Inter-IMS Network to Network Interface (NNI) - C3

Supporting Individual Members: Ericsson, Orange, Telecom Italia, Telenor, TeliaSonera, Alcatel-Lucent; Nokia Siemens Networks; Huawei.

UID	Name	Acronym	Resource	Hyperlink	TS_TR
380060	**IP Interconnection of Services**	IPinterc	S1,S2,S5,C3	SP-080565	-
7005	**System enhancements for interconnection interfaces between two IMSs**	IMS_NNI	S2,S5,C3	SP-080554	-
360024	Stage 2 for IMS_NNI	IMS_NNI	S2	SP-080554	23.002, 23.228
360011	IMS inter-operator service interconnection interface	FBI2-IOPSI	C3	CP-080578	29.865, 29.165

IMS enables supporting basic voice over IP calls as well as other multimedia services (e.g. video calls). These services require a well defined Inter-IMS Network-to-Network Interface (II-NNI) supporting interoperability between IMS networks. Standardized II-NNI ease IMS networks comply with national / international regulations on interoperability.

II-NNI signalling profile provides a standard reference for service interconnection between two IMS networks.

Stage 1 for IMS_NNI is covered by the SA1 Feature IPinterc UID_380060 in TS 22.228 and TS 22.101.

SA2 provided the necessary architectural enhancements in TS 23.002 and TS 23.228 (specified signalling profiles of those interfaces and ensured the alignment with ITU-T Q.3401 (NNI interface).

CT3 provided II-NNI signalling on Ici and Izi reference points between IMS networks for end-to-end service interoperability. The work addressed control plane signalling (3GPP profile of SIP and SDP protocols) and other interconnection aspects e.g. common basic communication procedures, SIP headers used at II-NNI, security, Numbering/naming/addressing and charging information of SIP signalling; covered by a set of 3GPP specifications.

CT3 goal was not to define new protocols or new profiles of existing protocols, but to identify protocols and profiles produced elsewhere in 3GPP applicable to these interfaces. As such, any recommendation in TR 29.865 for protocol change or additional profiling was taken to the WG owning it for documentation in the base specification. Furthermore the CT3 work addressed issues related to the user plane (Izi). Security functionalities and Charging information needed at the interconnection between two IMS networks were investigated.

CT3 TR 29.865 collected all implications of control and user plane on II-NNI interconnection, including:

- Definition of II-NNI based on the existing 3GPP IMS profile;
- Integration, if required, in existing 3GPP specifications;

Based on TR 29.865 conclusions, a new CT3 TS 29.165 specifies the II-NNI interconnection.

Petitioners' Exhibit 1003, p. 205
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10.3.2 SA5 Charging harmonization for NGN between 3GPP and ATIS-TMOC UID_330011

Resources: S5

References

Document	Title/Contents
WID(s)	
SP-060545	WID on SA5 Charging harmonization for NGN between 3GPP and ATIS-TMOC
Impacted Specifications	
TS 32.297	Telecommunication management; Charging management; Charging Data Record (CDR) file format and transfer
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Amdocs, Orange, Lucent Technologies, Ericsson, Huawei, Cingular.

UID	Name	Acronym	Resource	Hyperlink	TS_TR
380060	**IP Interconnection of Services**	IPinterc	S1,S2,S5,C3	SP-080565	-
7005	**System enhancements for interconnection interfaces between two IMSs**	IMS_NNI	S2,S5,C3	SP-080554	-
330011	Charging harmonization for NGN between 3GPP and ATIS-TMOC	FBI2-TISP2-CH	S5	SP-060545	32.297

The standardization of the NGN is addressed by a number of SDOs. (e.g. ETSI TISPAN, ITU-T and ATIS-TMOC). External standards organizations were defining NGN session control using IMS as a platform. This embeds IMS as the framework for advanced services for many types of operators.

ITU-T SG4 identified harmonization possibilities between ATIS TMOC and 3GPP for the NGN charging, and they were requested to make an effort to harmonize their standards. To accomplish harmonization the charging architecture incorporates an optional solution to the existing 3GPP solution, namely:

- ATIS-TMOC's protocol (IPDR/SP IPDR/F) is adopted as an alternative protocol on the Bx reference point.

Petitioners' Exhibit 1003, p. 206
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10.4 Support of (G)MSC-S – (G)MSC-S Nc Interface based on the SIP-I protocol (SIP_Nc) UID_360025

Resources: C4,C3,S1

References

Document	Title/Contents
WID(s)	
CP-080282	WID on Support of (G)MSC-S – (G)MSC-S Nc Interface based on the SIP-I protocol
Impacted Specifications	
TS 23.153	Out of band transcoder control; Stage 2 [CT4 - allow for a 3GPP SIP-I based codec negotiation with RTP-based bearer]
TS 23.172	Technical realization of Circuit Switched (CS) multimedia service; UDI/RDI fallback and service modification; Stage 2 [CT3 - SIP-I procedures with SCUDIF]
TS 23.202	Circuit switched data bearer services [CT3 - Stage 2 SIP-I impacts on CSD]
TS 23.205	Bearer-independent circuit-switched core network; Stage 2 [CT4 - reflect that content is normative if using a BICC-based Nc interface. Add reference to new Stage 2 for SIP-I based Nc Interface.]
TS 29.007	General requirements on interworking between the Public Land Mobile Network (PLMN) and the Integrated Services Digital Network (ISDN) or Public Switched Telephone Network (PSTN) [CT3 - Stage 3 SIP-I impacts on CSD]
TS 29.163	Interworking between the IP Multimedia (IM) Core Network (CN) subsystem and Circuit Switched (CS) networks CT3 - include 3GPP SIP-I as a valid protocol for interworking between IMS and CS networks]
TS 29.232	Media Gateway Controller (MGC) - Media Gateway (MGW) interface; Stage 3 [CT4 - add new procedures on Mc interface supporting RTP-based bearer on the Nb interface]
TS 29.332	Media Gateway Control Function (MGCF) – IM Media Gateway; Mn Interface [CT4 - reflect impact for terminations used for SIP-I based Nc interface]
TS 29.414	Core network Nb data transport and transport signalling [CT3 - impact for Bearer Multiplexing. IPBCP is not applicable to SIP-I]
New Dedicated Specifications/Reports	
TS 23.231	SIP-I based circuit-switched core network; Stage 2 [CT4 - SIP-I based Nc Interface; contains call flows, scenarios and procedures]
TS 29.231	Application of SIP-I Protocols to Circuit Switched (CS) core network architecture; Stage 3 [CT4 - Stage 3 SIP-I based Nc profile definition; contains also the codec negotiation mechanism]
TS 29.235	Interworking between SIP-I based circuit-switched core network and other networks [CT3 - Specify 3GPP SIP-I interworking with BICC, ISUP, external SIP-I networks]

Supporting Individual Members: Vodafone, Nokia Siemens Networks, Alcatel-Lucent, Ericsson, Nortel, Huawei, TeliaSonera, T-Mobile.

Stage 1 for SIP_Nc is covered by the SA1 Feature IPinterc UID_380060 in TS 22.228 and TS 22.101.

As the industry trend moves from Voice over TDM to Voice over IP, the majority of networks (fixed telephony, enterprise, IMS) are moving towards SIP-based signalling. 3GPP has defined in Rel-7 an interworking scenario for external SIP-I interworking into the bearer independent Circuit Switched network.

In order to avoid the use of a heavyweight interworking function (BICC to external SIP-I) and to provide commonality of products between wireless and wireline networks, this work provides the implementation of SIP-I on the Nc Interface as an alternative protocol to Bearer Independent Call Control (BICC). This provides the additional benefits such as:

- Provides a standardised SIP-I based Nc Interface improving network interconnections by reducing potential signalling interworking to external SIP-I networks;
- Eases interworking for IP-Interconnect and converges SIP-I signalling across the industry, wireless and wireline;
- Standardises end-to-end service between mobile subscribers that may be located in different networks, e.g. support of codec negotiation over SIP-I based IP transit network to enable OoBTC/TrFO;
- Provides migration of PLMN towards common NGN based SIP-I signalling;

CT3, CT4 provided Stage 2 and Stage 3 defining related procedures and a SIP-I profile to be used on the Nc Interface as an alternative to the existing BICC definition. This work has used CT4 Rel-7 TR 29.802 as feasibility basis and CT4's TS 23.205 and TS 23.153 for input to requirements and architecture of the bearer-independent CS core network to provide the following:

- Support for interworking SIP-I on the Nc interface with an external SIP-I based signalling network.

Petitioners' Exhibit 1003, p. 207
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Support for interworking SIP-I on the Nc interface with a BICC-based Nc interface.
- Support for interworking SIP-I on the Nc Interface with the 3GPP IMS.
- Support for Interworking SIP-I on the Nc interface with an ISUP based signalling network.
- Definition of a SIP-I Profile on the Nc Interface in order to provide the requirements to fulfil 3GPP CS mobile core network telephony.
- Support for RTP-based bearer on the user plane when utilising SIP-I on the Nc Interface, and provide support on the Mc Interface to support this bearer on the Nb Interface.
- The functional capabilities that currently exist for a 3GPP BICC implementation (e.g. OoBTC/TrFO, SCUDIF, CSD, etc.) on the Nc Interface.

NOTE: The interworking scenario 3GPP IMS – external SIP-I networks is not within the scope of this WI.

Petitioners' Exhibit 1003, p. 208
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10.5 Earthquake and Tsunami Warning System Requirements and Solutions (ETWS) UID_370051

Resources: S1,S2,C1,C4,G2

References

Document	Title/Contents
WID(s)	
SP-070815	S1 WID on Earthquake and Tsunami Warning System Requirements and Solutions (ETWS)
CP-080951	C4 WID on Earthquake and Tsunami Warning System
SP-090154	GERAN2 LS to TSG SA, CT1, RAN2
Impacted Specifications	
TS 23.041	Technical realization of Cell Broadcast Service (CBS) - C1
TS 44.018	Mobile radio interface layer 3 specification; Radio Resource Control (RRC) protocol
TS 44.060	General Packet Radio Service (GPRS); Mobile Station (MS) - Base Station System (BSS) interface; Radio Link Control / Medium Access Control (RLC/MAC) protocol
New Dedicated Specifications/Reports	
TR 23.828	Earthquake and Tsunami Warning System (ETWS); Requirements and solutions; Solution placeholder - S2
TS 22.168	Earthquake and Tsunami Warning System (ETWS) requirements - S1
TS 23.041	General Packet Radio Service (GPRS) enhancements for E-UTRAN access - S2
TS 29.168	Cell Broadcast Centre interfaces with the Evolved Packet Core; Stage 3 - C4

Supporting Individual Members: NTT DoCoMo, OKI, Panasonic, Sharp, Softbank, Toshiba, eMobile, NEC, Qualcomm.

UID	Name	Resource	Hyperlink	TS_TR
370051	**Earthquake and Tsunami Warning System**	S1,S2,CP,G2	SP-070815	-
370052	**Stage 1 for ETWS**	S1	SP-070815	22.168
380056	**SA2 aspects of ETWS**	S2	SP-070815	23.828, 23.401
400015	**CT1 aspects of ETWS**	C1	CP-080951	23.041
410021	**CT4 aspects of ETWS**	C4	CP-080951	29.168
430045	**ETWS primary notification message definition in GERAN**	G2	SP-090154	44.018, 44.060

ETWS introduces a means to deliver Warning Notification simultaneously to many mobile users who should evacuate from approaching Earthquake or Tsunami. A mobile user receiving a Warning Notification finds out that a nearby threat is approaching or happened already and is able to determine where and when to evacuate. Mobile phones are the closest media for people. This system helps people in disaster situations.

This service needs quick and optimized information delivery. Currently it is not possible to predict an Earthquake is imminent. This work specifies:

- Requirements for ETWS;
- Functional requirements;
- Defines the system architecture and functions of ETWS;
- Roaming aspects for terminals (e.g. impact on inbound roaming terminals);

SA1 TR 22.968 (Study on requirements for a Public Warning System (PWS) service) UID_320025, shows that the requirements for PWS and the expected timelines for deployment differ in each region. In Japan Earthquake Early Warning system is required urgently to help mitigate human and social damages. Therefore this work is a "Regional" specific part of PWS for Japan implementing the most urgent aspects. To avoid possible conflict with ongoing generic work on PWS, this part of the system is called ETWS.

ETWS is a subset of PWS and as such does not exclude or conflict with the ongoing work on PWS.

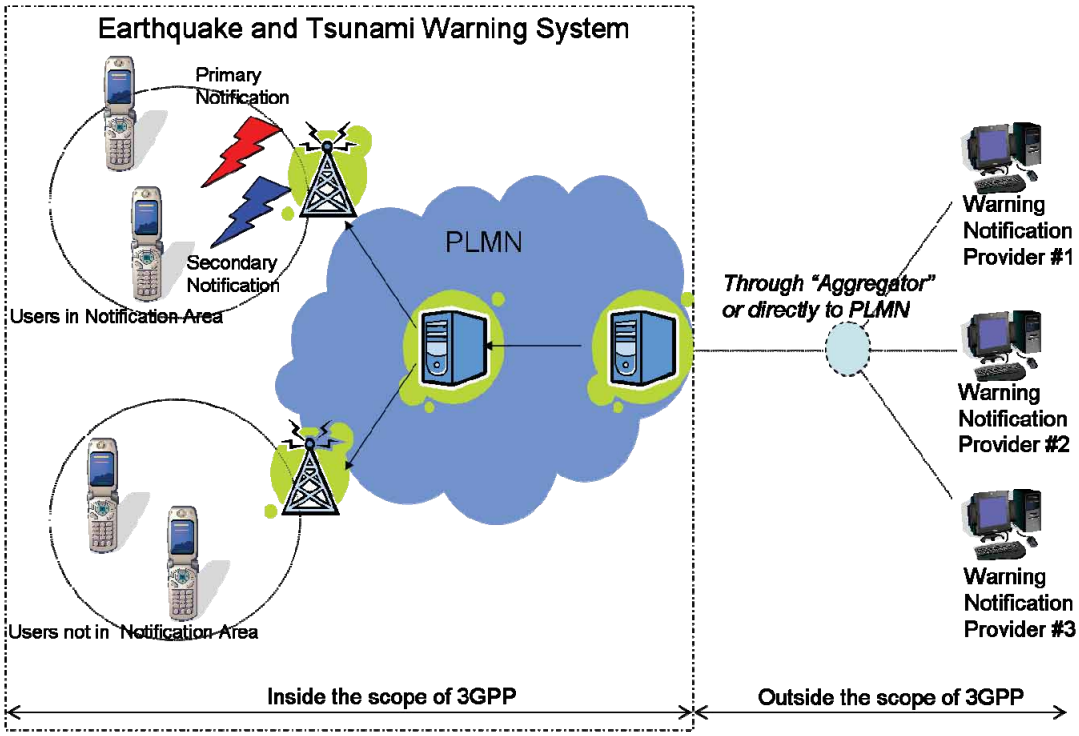
As this service is applicable to emergency situations, an effort was made to define a service that can be provided over existing mobile networks in the near term. The impacts on power consumption, current specifications and existing networks by the introduction of this service have been minimized. Support of this service is optional.

The work took into account related work in other bodies. Despite the only current regulatory requirement is coming from Japan, solutions for GERAN are also within the scope of ETWS.

Petitioners' Exhibit 1003, p. 209
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Simple mechanisms within existing mobile networks based on available approaches (e.g. CBS and MBMS for GERAN/UTRAN and eMBMS for E-UTRAN) have been preferred.

The table below from TS 22.168 shows what is within the 3GPP scope of ETWS.



Following the decision in TSG SP# 43 to incorporate support of ETWS over GERAN in Rel-8, TSG GERAN have approved a complete set of Rel-8 CRs (to TS 44.018 and 44.060) introducing ETWS:

- solution covers sending primary notification in idle/dedicated/packet idle/packet transfer/dual transfer modes;
- it is based on CT1 CR to TS 23.041, defining the primary notification message;
- due to this definition of the primary notification in TS 23.041, the security issues with duplicate detection identified in RAN2 do not affect GERAN.

10.5.1 Conformance Test Aspects – UMTS Earthquake and Tsunami Warning System FDD UID_440011

Resources: R5

References

Document	Title/Contents
WID(s)	
RP-090467	WID on Conformance Test Aspects – UMTS Earthquake and Tsunami Warning System (ETWS) FDD
Impacted Specifications	
TS 34.108	Common test environments for User Equipment (UE); Conformance testing
TS 34.123-1	User Equipment (UE) conformance specification; Part 1: Protocol conformance specification
TS 34.123-2	User Equipment (UE) conformance specification; Part 2: Implementation conformance statement (ICS) specification
TS 34.123-3	User Equipment (UE) conformance specification; Part 3: Abstract test suites (ATSs)
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: NTT DoCoMo, Panasonic, Fujitsu, NEC, Nokia, Qualcomm, Sony Ericsson

Testing for Rel-8 ETWS UID_370051.

UID	Name	Resource	Hyperlink	Status_Report	TS_TR

Petitioners' Exhibit 1003, p. 210
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

440011	**Conformance Test Aspects – UMTS Earthquake and Tsunami Warning System (ETWS) FDD**	R5	RP-090467	RP-100068	34.108, 34.123-1, 34.123-2

Petitioners' Exhibit 1003, p. 211
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10.6 In Case of Emergency (ICE) numbers storage and easy access on UICC UID_380059

Resources: S1,C6

References

Document	Title/Contents
WID(s)	
SP-070944	S1 WID on ICE – In Case of Emergency
Impacted Specifications	
TS 22.101	Service aspects; Service principles - S1 [Added A.x Requirements for "In Case of Emergency" (ICE) information]
TS 22.030	Man-Machine Interface (MMI) of the User Equipment (UE) - S1 [Added 6.x In Case of Emergency information access procedure]
TS 31.102	Characteristics of the Universal Subscriber Identity Module (USIM) application- C6 [Added EF-ICE (In Case of Emergency Dialling Numbers)
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Vodafone, Vodafone D2, SwissCom, T-Mobile, AT&T, Gemalto, RIM.

UID	Name	Resource	Hyperlink	TS_TR
380059	**In Case of Emergency numbers storage and easy access on UICC**	S1,C6	SP-070944	-
380159	**Stage 1 for ICE**	S1	SP-070944	22.030, 22.101
380259	**CT6 aspects of ICE**	C6	SP-070944	31.102

The In Case of Emergency (ICE) program is used to enable first responders, such as paramedics, fire-fighters, police officers, to identify victims and contact their next of kin to obtain important medical information.

In some countries 80% or more people carry a mobile phone, and the police or paramedics often use them to identify victims at road traffic accidents or other incidents. The idea of ICE is that everyone should put an emergency contact name and number into his/her mobile phone under the headword "ICE". This would give the emergency services personnel a standard place to look for contacts.

While this contact list has been introduced by some operators on a proprietary mobile phone dependent way, a standardised solution is not available, making the use for "first responders" difficult, if not impossible.

This work defines the UE capability to store one or more ICE information on the UICC which the subscriber can optionally configure. Provision is made for direct and unambiguous read access from UE to the ICE information stored on the UICC.

The MMI is modified to provide unambiguous identification of ICE information and easy read access. Under control of the subscriber, the ICE information can be made accessible even when the UE/UICC security features have been enabled (e.g. keypad is locked).

The following table provides an example of ICE information stored on the UICC (extract from TS 22.101):

Table: "ICE information" example

ICE information type	ICE information type value	ICE information value 1	ICE information value 2
Phone Number	"Contact in case of emergency"	My Wife	+33645661234
Phone Number	"Contact in case of emergency"	Family Smith	+33645654321
Phone Number	"Contact in case of emergency"	My Family doctor: Dr. Jones	+336432341111
Free Format	"Medical Information"	My blood type is A+, I am allergic to etc.	N/A
Free Format	"Home Postal Address"	15 rue de la Paix, Paris, France	N/A
Free Format	"Language"	French	N/A
Free Format	"Travel Information"	London, from 3rd July. to 29th July, 2008	N/A

NOTE: ICE Graphics was not included in Rel-8.

Petitioners' Exhibit 1003, p. 212
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10.7 Local Charging Zone Requirements (LCZR) UID_330006

Resources: S1

References

Document	Title/Contents
WID(s)	
SP-060482	S1 WID on Local Charging Zone Requirements
Impacted Specifications	
TS 22.115	Service aspects; Charging and billing
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: China Mobile, Huawei, ZTE, Alcatel.

UID	Name	Acronym	Resource	Hyperlink	TS_TR
330006	**Local Charging Zone Requirements**	LCZR	S1	SP-060482	22.115

In a large scale network, different tariffs apply to HPLMN subscribers when they are in different parts of the network. It is expected that the users are aware of where they are and decide whether to originate/accept a service.

The Local Charging Zone (LCZ) concept has been introduced to represent the part of the network that applies the same tariff for a group of users and believed much simpler and more generic (e.g. applicable to both UTRAN and GERAN) than the concept of SoLSA (Support of Localised Service Area) which is currently applied to GERAN only.
To obtain a solution quickly and for simplification reasons, the impacts on Core Network should be avoided if possible.

This work defines the concept of LCZ and specifies the related requirements for e.g.:

- Relationship between LCZs;
- Indication of the LCZ to users;
- User's decision of whether to accept/originate a service;
- Priority of LCZs (FFD);

Differentiated charging can be achieved via the already-existing cell-based charging mechanism.

Stage 1 completed.

Petitioners' Exhibit 1003, p. 213
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10.8 Customized Alerting Tone (CAT) service UID_340029

Resources: S1,C1,C3,C4

References

Document	Title/Contents
	WID(s)
SP-070122	S1 WID on Support of Customised Alerting Tone Service
SP-070880	S1 WID on TISPAN Customized Multimedia Information Services (TISCMI-R8)
CP-080496	C1 WID on IMS CAT Supplementary Service
	Impacted Specifications
TS 23.014	Support of Dual Tone Multi-Frequency (DTMF) signalling - C1
TS 23.205	Bearer-independent circuit-switched core network - C4
TS 23.231	SIP-I based circuit-switched core network - C4
TS 24.008	Mobile radio interface Layer 3 specification; Core network protocols; Stage 3 - C1
TS 29.002	Mobile Application Part (MAP) specification - C4
TS 29.163	Interworking between the IP Multimedia (IM) Core Network (CN) subsystem and Circuit Switched (CS) networks - C3
	New Dedicated Specifications/Reports
TS 22.182	Customized Alerting Tone (CAT) requirements; Stage 1 - S1
TS 24.182	IP Multimedia Subsystem (IMS) Customized Alerting Tones (CAT) - C1

Supporting Individual Members: China Mobile, Ericsson, Huawei, NEC, Comverse, Lucent

UID	Name	Resource	Hyperlink	TS_TR
340029	**Customized Alerting Tone (CAT) Service**	S1,C1,C3,C4	SP-070122	-
370028	**Stage 1 for CAT**	S1	SP-070122	22.182
370029	**TISPAN requirements for customized multimedia information services**	S1	SP-070880	22.182
390014	**IMS CAT Supplementary Service**	C1	CP-080496	24.182
390071	**CAT solution for voice and video call in CS domain**	C3	CP-080496	29.163
410010	**CAT Service in 3GPP CS domain**	C4	CP-080445	23.205, 23.231, 29.002
410015	**CAT Service in 3GPP CS domain**	C1	CP-080445	24.008, 23.014

Stage 1 for CAT (SP-070122):

The Customized Alerting Tone Service (CAT service) is an operator specific service by which an operator enables the subscriber to customize the alerting tone which is played to the calling party. CAT service should not negatively affect the conversation between calling and called parties. The caller can experience favourite songs, multi-media clips or other CAT instead of the traditional ringing tones.

As there are many methods to realize the basic functions of CAT in CS domain and IMS, standardization work was needed especially for roaming and interworking support. Furthermore, more and more additional features of CAT are expected by the subscribers, e.g. a user may be able to easily subscribe to the same alerting tone at the same time as he/she is hearing it by for instance pressing a key.

Following TR 22.982 (Study of Customized Alerting Tone requirements) this work specifies the CAT service in 3GPP.

Multiple domains roaming/interworking and interaction with other services such as IMS based services, Supplementary Services, Charging and User profile have also been specified based on the same study TR 22.982.

TISPAN requirements for customized multimedia information services (SP-070880):

This WID adds in 3GPP TS 22.182 the TISPAN CAT requirements developed by TISPAN for Fixed NGN in WID 1040 for "Customized Terminating Multimedia Information Services", needed to implement the core IMS specification in light of the Common IMS concept.

CT1, CT3 work on IMS CAT Supplementary Service (CP-080496)

Linked work items:

- 3GPP2 Input to Common IMS
- UID_380078 Study on the Architecture of IMS based Customized Alerting Tone

Petitioners' Exhibit 1003, p. 214
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

During the joint workshop on common IMS in Jan 2008, 3GPP and 3GPP2 agreed on principles to incorporate parts of 3GPP2 MMD/IMS related specifications into 3GPP within the Rel-8 timeframe.

CT1 TS 24.182 and CT3 TS 29.163 specify Stage 3 for IMS CAT Supplementary Service in 3GPP2's X.P0055 (MMD Supplementary Services), the service requirements in TS 22.182 and the recommendations in TR 23.872.

CT4, CT1 work on Support of Customized Alerting Tone (CAT) Service in 3GPP CS domain

Linked work item

- UID_360031 Study on Customized Alerting Tone (CAT) solution for voice and video call in CS domain

SA1 TS 22.182 specifies the requirements for supporting CAT Service both in CS domain and in IMS domain, and CT4 TR 29.882 has studied providing audio and multimedia customized alerting tone in CS domain (UID_360031).

This work defines essential functional requirement of GMSC Server switch architecture on the network functions and the interfaces impacted by the provision of CAT Service in CS domain:

- Essential behaviour of the originating VMSC Server to enable both-way through-connect the bearer a multimedia call during the alerting phase.
- Enhancement on the Nc signalling protocol to support the transport of the calling party UE CAT capability (multiple H.245 call negotiations, transmission of DTMFs during multimedia call through the H.245 UserInputIndication message)
- Enhancement on the NAS Signalling to enable the calling party UE to indicate its CAT capability
- Enhancement on the NAS Signalling to enable the originating VMSC Server to indicate the calling party UE start of the multimedia call setup during the alerting phase
- Enabling the transmission of DTMFs during multimedia call through the H.245 UserInputIndication message for CAT stop and CAT copy
- ATI from GMSC to HLR-A for retrieval of the calling party UE CAT capability

Impacted specifications CT4 (TS 23.205, TS 23.231, TS 29.002) and CT1 (TS 24.008, TS 23.014).

Petitioners' Exhibit 1003, p. 215
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10.9 Service-Level Interworking for Messaging Services (MESSIW) UID_340031

Resources: S1,S2,C3,C1

References

Document	Title/Contents
WID(s)	
SP-070816	S1,S2 WID on Support of Service-Level Interworking for Messaging Services
CP-080575	C3 WID on Support of Service-Level Interworking for Messaging Services - Stage 3
Impacted Specifications	
TS 22.105	Services and service capabilities - S1
TS 22.340	IP Multimedia Subsystem (IMS) messaging; Stage 1 - S1
TS 23.204	Support of Short Message Service (SMS) over generic 3GPP Internet Protocol (IP) access; Stage 2 - S2
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3 - C1
TS 24.341	Support of SMS over IP networks; Stage 3 - C1 [Interaction with service level interworking at the IP-SM-GW. Cover interaction with service level interworking, Add reference to new stage 3 TS]
New Dedicated Specifications/Reports	
TR 23.811	Service level interworking for messaging services; Stage 2 - S2
TS 29.311	Service Level Interworking for Messaging Services; Stage 3 - C3

Supporting Individual Members: Huawei, Comverse, China Mobile, BT, Ericsson, Telecom Italia, Orange, RIM, ZTE.

UID	Name	Resource	Hyperlink	TS_TR
340031	**Service-Level Interworking for Messaging Services**	S1,S2,C3,C1	SP-070816	-
350047	**Stage 1 for MESSIW**	S1	SP-070816	22.105, 22.340
350048	**Stage 2 for MESSIW**	S2	SP-070816	23.811, 23.204
400016	**Stage 3 for MESSIW**	C3	CP-080773	29.311
400017	**Stage 3 for MESSIW**	C1	CP-080773	24.229

There is interest in service-level interworking for messaging services, e.g. between Short Message (SM) and existing Instant Messaging (IM) services. Other types of messaging interworking need also to be considered.

This work 1st defines the scenarios for service-level interworking between:

- SMS and IM services;
- Interworking scenarios as requested by OMA in SP-060851;

In a 2nd step, it implements the solution(s) fulfilling the required service-level interworking scenarios and requirements.

This work considered with priority the following aspects:

- Provide a consistent service experience to the user when service-level interworking takes place;
- Determine the scenarios where this service-level interworking is applicable;
- Provide requirements for suitable security mechanisms for interworked messages (e.g. stop certain messages from being interworked);
- Provide the service-level interworking authorization;
- Avoid overlap with OMA;
- Provide appropriate mechanisms to apply charging principles for interworking;
- Provide requirements to support service-level interworking;
- Consider interaction with existing functionality in TS 23.040 (Technical realization of Short Message Service);

SA2 TR 23.811 concluded that the two Alternative Architectures for the service-level interworking are identical in the terminating cases and only differ in the originating case. Alternative 1 is using iFCs to route the Instant Messages to the IP-SM-GW, while Alternative 2 goes through BGCF in order to reach IP-SM-GW. TR 23.811 recommends to include Alternative 1 in SA2 TS 23.204. The architecture and flows have been added to TS 23.204 and TR 23.811 was not updated anymore.

SA2 added the service-level interworking via CR to TS 23.204.

Petitioners' Exhibit 1003, p. 216
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CT3 work enhances the relevant 3GPP protocols to support the requirements in TS 23.204 including:

- Procedures to implement service level interworking between SM and IM guaranteeing that existing SMS and IM services are not impacted;
- Enhancement of the IP-SM-GW as an Application Server to support service selection, authorization and mapping between SM and IM protocols;
- Interaction between service level interworking and transport layer interworking;

CT3 new TS 29.331 contains Stage3 supporting this feature under 3GPP IMS architecture.

10.10 Multimedia Priority Service (PRIOR) UID_340044

Resources: S1,C1,C4

References

Document	Title/Contents
WID(s)	
SP-060780	S1 WID on Multimedia Priority Service Requirements
CP-070576	C1 WID on Multimedia Priority Service
Impacted Specifications	
TS 23.008	Organization of subscriber data - C4
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3 [CT1 - use Resource-Priority header and associated RFCs in IMS SIP]
TS 29.228	IP Multimedia (IM) Subsystem Cx and Dx interfaces; Signalling flows and message contents - C4
TS 29.229	Cx and Dx interfaces based on the Diameter protocol; Protocol details - C4
New Dedicated Specifications/Reports	
TS 22.153	Multimedia Priority Service - S1

Supporting Individual Members: Lucent, Cingular, Telcordia, NCS, T-Mobile, Nortel Networks.

UID	Name	Resource	Hyperlink	TS_TR
340044	**Multimedia Priority Service**	S1,C1,C3,C4	SP-060780	-
320023	**Service Requirements for PRIOR**	S1	SP-060780	22.153
340012	**Stage 3 for PRIOR**	C1	CP-070576	24.229
370021	**Stage 3 for PRIOR**	C4	CP-070576	23.008, 29.228, 29.229

The response to emergency situations (e.g. floods, hurricanes, earthquakes, terrorist attacks) depends on the communication capabilities of public networks. In most cases, emergency responders use private radio systems to aid in the logistics of providing critically needed restoration services. However, certain government and emergency management officials and other authorised users have to rely on public network services when the communication capability of the serving network may be impaired, for example due to congestion or partial network infrastructure outages, perhaps due to a direct or indirect result of the emergency situation.

Multimedia Priority Service, supported by the 3GPP system set of services and features, is one element creating the ability to deliver calls or complete sessions of a high priority nature from mobile to mobile networks, mobile-to-fixed networks, and fixed-to-mobile networks.

The scope of this work is to specify those requirements of MPS necessary to provide an end-to-end service and to interwork with external networks where needed. Service interactions with external networks are considered within the scope of this work, although these interactions may be specified in other standards.

This work defines prioritized service provision for Packet (e.g. IP) based multimedia services including data, video, audio and text transmission capabilities. It is based on the results of the Rel-7 TR 22.953 (Multimedia priority service feasibility study). The Circuit Switched counterpart was described in the Rel-6 TR 22.952 (Priority service guide).

The Multimedia Priority Service is intended to be utilised for both Voice and Data in PS domain and IMS. Interaction with other services/capabilities (e.g. VCC, POC) was considered.

SA1 new TS 22.153 contains Stage 1 for Multimedia Priority Service. No Stage 2 impact was identified by SA2.

CT1,CT4 have specified the protocols for the use of the Multimedia Priority Service (see table above).

Petitioners' Exhibit 1003, p. 217
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10.11 Open Service Access (OSA8) UID_360010

Resources: S1,C5

References

Document	Title/Contents
WID(s)	
SP-070692	S1 WID on OSA Stage 1
CP-080429	C5 WID on OSA Stage 2/3 enhancements
Impacted Specifications	
TS 22.127	Service requirement for the Open Services Access (OSA); Stage 1 (SA1)
TS 23.198	Open Service Access (OSA); Stage 2 (CT5)
-	**Stage 3 Specifications**
TS 29.198-01	OSA API; Part 1: Overview
TS 29.198-02	OSA API; Part 2: Common data definitions
TS 29.198-03	OSA API; Part 3: Framework
TS 29.198-04-1	OSA API; Part 4: Call control; Subpart 1: Call control common definitions
TS 29.198-04-2	OSA API; Part 4: Call control; Subpart 2: Generic call control SCF
TS 29.198-04-3	OSA API; Part 4: Call control; Subpart 3: Multi-party call control SCF
TS 29.198-04-4	OSA API; Part 4: Call control; Subpart 4: Multimedia call control SCF
TS 29.198-04-5	OSA API; Part 5: Call control; Subpart 5: Conference call control SCF
TS 29.198-05	OSA API; Part 5: User interaction SCF
TS 29.198-06	OSA API; Part 6: Mobility SCF
TS 29.198-07	OSA API; Part 7: Terminal capabilities SCF
TS 29.198-08	OSA API; Part 8: Data session control SCF
TS 29.198-11	OSA API; Part 11: Account management SCF
TS 29.198-12	OSA API; Part 12: Charging SCF
TS 29.198-13	OSA API; Part 13: Policy management SCF
TS 29.198-14	OSA API; Part 14: Presence and Availability Management (PAM) SCF
TS 29.198-15	OSA API; Part 15: Multi-media Messaging (MM) SCF
TS 29.198-16	OSA API; Part 16: Service broker SCF
TS 29.199-01	OSA; Parlay X web services; Part 1: Common
TS 29.199-02	OSA; Parlay X web services; Part 2: Third party call
TS 29.199-03	OSA; Parlay X web services; Part 3: Call notification
TS 29.199-04	OSA; Parlay X web services; Part 4: Short messaging
TS 29.199-05	OSA; Parlay X web services; Part 5: Multimedia messaging
TS 29.199-06	OSA; Parlay X web services; Part 6: Payment
TS 29.199-07	OSA; Parlay X web services; Part 7: Account management
TS 29.199-08	OSA; Parlay X web services; Part 8: Terminal status
TS 29.199-09	OSA; Parlay X web services; Part 9: Terminal location
TS 29.199-10	OSA; Parlay X web services; Part 10: Call handling
TS 29.199-11	OSA; Parlay X web services; Part 11: Audio call
TS 29.199-12	OSA; Parlay X web services; Part 12: Multimedia conference
TS 29.199-13	OSA; Parlay X web services; Part 13: Address list management
TS 29.199-14	OSA; Parlay X web services; Part 14: Presence
TS 29.199-15	OSA; Parlay X web services; Part 15: Message broadcast
TS 29.199-16	OSA; Parlay X web services; Part 16: Geocoding
TS 29.199-17	OSA; Parlay X web services; Part 17: Application-driven Quality of Service (QoS)
TS 29.199-18	OSA; Parlay X web services; Part 18: Device capabilities and configuration
TS 29.199-19	OSA; Parlay X web services; Part 19: Multimedia streaming control
TS 29.199-20	OSA; Parlay X web services; Part 20: Multimedia multicast session management
TR 29.998-06-1	OSA API Mapping; Part 6: User location - user status service mapping; Subpart 1: Mapping to MAP
TR 29.998-06-2	OSA API Mapping; Part 6: User location - user status service mapping; Subpart 2: Mapping to SIP
New Dedicated Specifications/Reports	
-	**Stage 3 Specifications**
TS 29.198-10	OSA API; Connectivity manager SCF
TS 29.199-21	OSA; Parlay X web services; Content management
TS 29.199-22	OSA; Parlay X web services; Policy

Supporting Individual Members: France Telecom, Orange, Ericsson, ETRI, Telenor, Telecom Italia, Sprint, BT

UID	Name	Resource	Hyperlink	TS_TR
360010	**OSA Rel-8**	S1,C5	SP-070692	-
360004	**OSA Stage 1 - Service Requirements**	S1	-	22.127
370034	**OSA Stage 1 - NGN Service Requirement**	S1	SP-070692	22.127
360005	**OSA Stage 2/3 enhancements**	C5	CP-080429	23.198, 29.198, 29.199
370013	Parlay-X Content Management web service (store/manage meta-data)	C5	CP-080429	29.199-21

Petitioners' Exhibit 1003, p. 218
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

370014	Parlay-X Policy web service	C5	CP-080429	29.199-22
370015	Parlay-X Terminal status web service	C5	CP-080429	29.199-08
380054	Presence alignment with OMA and IETF (22.127 CR 0092 S1-071764)	C5	CP-080429	29.199-14/13
390067	Framework Enterprise Operator (Service Subscription function)	C5	CP-080429	29.198-03
390068	Mobility Emergency Location	C5	CP-080429	29.198-06
390069	Connectivity Manager SCF	C5	CP-080429	29.198-10
390070	PAM Presence Agent	C5	CP-080429	29.198-14

The Open Service Access (OSA) enables service application developers to make use of network functionality through open, standardised, secure, extensible and scalable interfaces. Applications see the network functionality offered to them as a set of Service Capability Features (SCFs) in the OSA API. These SCFs provide access to the network capabilities on which the application developers can rely when designing their applications. The OSA API enable network service capabilities in an abstract, network-agnostic way to the application developers independent of:

- where or how these network capabilities are implemented in the network and
- of vendor specific solutions and programming languages.

Interest in web services for telecommunications networks is increasing, with several initiatives in other groups such as OMA OWSER, ETSI TISPAN. Developers require easy access to functionality provided by telecommunications networks in order to use them successfully in a combinational manner, e.g. as part of an SOA. As such, the existing APIs for Parlay-X web services need to be evolved and expanded in order to ensure Parlay-X APIs provide the necessary functionality for developers and Operators to exploit the capabilities of their networks.

OSA APIs (29.198-family)

- The OSA specifications define a set of APIs that enables operator and 3rd party applications to make use of network functionality through a set of open, standardized interfaces.
- The specifications are derived from a UML model of the OSA API. Using the latest document and code generation techniques, the detailed technical description documents, the IDL code, WSDL code and Java API are all produced from a single source UML model. This ensures alignment between all versions, all formats of the API.

OSA Web Services (29.199-family)

- Access to Service Capability Features is realised by using modern state of the art access technologies, like distributed object oriented technique and Web Services technologies. WSDL description of the interfaces are attached to the technical specifications.

Current web service specifications provided by the Parlay/OSA APIs in Rel-7 provide limited support for new functionalities implemented by IMS. In order to provide sufficient functionality for 3rd party developers that wish to develop within the web services framework, the existing functionality needs to be extended in order to support a greater level of control and diversity in web service applications.

Responsibility for Parlay / OSA Stage 1 was divided between 3GPP SA1 and ETSI TISPAN, whilst Stage 2/3 responsibility rested within the JWG (3GPP CT5, ETSI TISPAN and the Parlay group).
TISPAN requirements for NGN R2 are aligned with 3GPP R7 requirements.

SA1 TS 22.127 captures in context of Common IMS, the Rel-8 requirements for exposure of IMS enabling services and capabilities, such as MM Telephony, Presence, Group&List mgmt/XDM, and IMS Messaging over an open Parlay-X/webservices interface to consumer applications. In addition, the work identifies and defines new requirements for exposure of services and capabilities over an open Parlay-X/webservices interface to consumer applications. Appropriate coordination was set up to avoid overlap with proper groups (e.g. TISPAN WG1).

CT5 Stage 2/3 WID (CP-080252) was updated to include the new functionality added in SA1's OSA Stage 1 TS 22.127 on ETSI TISPAN OSA transfer to 3GPP CT5.

TSG#40 (June 2008) decided to move the maintenance of the OSA specifications (R99 to Rel-8), the remaining Rel-8 work and any new OSA work beyond Rel-8 to OMA.

As CT5 was disbanded before the target date for Rel-8 Stage 3 freezing, not all the SA1 requirements could be supported by the corresponding CT5 Stage 2/3 specifications. This creates a discrepancy/misalignment between the current (June 2008) 3GPP OSA Rel-8 Stage 1 vs. Stage 2/3.

Petitioners' Exhibit 1003, p. 219
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CT5 has documented this delta in the updated WID in CP-080429 as follows:

Work Item	Complete	Specification
370013 Parlay-X Content Management web service (store/manage meta-data)	100%	29.199-21
370014 Parlay-X Policy web service	100%	29.199-22
370015 Parlay-X Terminal status web service	100%	29.199-08
380054 Presence alignment with OMA and IETF (22.127 CR 0092 S1-071764)	100%	29.199-14/13
390067 Framework Enterprise Operator (Service Subscription function)	100%	29.198-03
390068 Mobility Emergency Location	100%	29.198-06
390069 Connectivity Manager SCF	100%	29.198-10
390070 PAM Presence Agent	100%	29.198-14
370012 Ensure Parlay-X composable with identity management frameworks, in particular Liberty Alliance	0%	existing 29.199-xy
370016 Identify communication format used by a particular application	0%	existing 29.199-xy
380047 Security on User Profile Management - reuse GUP API (22.127 CR 0084 S1-071794)	0%	PXWS Framework
380048 Privacy on Subscriber Identity (Liberty Alliance, OASIS) (22.127 CR 0085 S1-071835)	0%	PXWS Framework
380049 Topology Hiding (22.127 CR 0086 S1-071838)	0%	PXWS Framework
380050 Subscriber event notification (22.127 CR 0087 S1-071836)	0%	PXWS Framework
380051 Event notification (22.127 CR 0088 S1-071762)	0%	PXWS Framework
380052 Access policy (22.127 CR 0089 S1-071763)	0%	PXWS Framework
380053 API usage accounting (22.127 CR 0090 S1-071792)	0%	PXWS Framework
380055 Service identification (22.127 CR 0095 S1-071837)	0%	existing 29.199-xy

Petitioners' Exhibit 1003, p. 220
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10.12 Paging Permission with Access Control (PPACR) UID_360032

Resources: S1,C1,R2

References

Document	Title/Contents
WID(s)	
SP-070501	WID on Paging Permission with Access Control Requirements (PPACR)
CP-070783	WID on Paging Permission with Access Control Requirements for CT1 (PPACR-CT1)
Impacted Specifications	
TS 22.011	Service accessibility - S1 CR#0094 PPAC requirement, CR#0119 PPAC restriction to UTRAN
TS 24.008	Mobile radio interface Layer 3 specification; Core network protocols; Stage 3 - C1
TS 23.122	Non-Access-Stratum (NAS) functions related to Mobile Station (MS) in idle mode - C1
TS 25.331	Radio Resource Control (RRC); Protocol specification - R4 CR#3276 Introduction of PPAC, CR#3313 Early Implementation of PPAC
New Dedicated Specifications/Reports	
TS 24.301	Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3 - C1

Supporting Individual Members: NEC, NTT DoCoMo, Samsung, Sharp, Softbank Mobile, Telecom Italia, Toshiba.

UID	Name	Resource	Hyperlink	TS_TR
360032	**Paging Permission with Access Control (PPACR)**	S1,C1	SP-070501	-
370084	**Stage 1 for PPACR**	S1	SP-070501	22.011
380017	**Stage 3 for PPACR (CT1)**	C1	CP-070783	24.008, 23.122, 24.301

This work is based on TR 22.908 Study on Paging Permission with Access Control (FS_PPAC) UID_330016.

Paging Permission with Access Control Requirements (PPACR) work solves three issues caused by the current access control mechanism not allowing reaching UEs for which access class restriction was applied:

- **Priority Service**
  There is a priority communication service which is produced to an authorized user (e.g. government) by using priority mechanisms such as special access class (i.e. access classes 11 to 15) allocation and high priority level allocation of eMLPP. However there is an issue in the congestion situation (e.g. caused by earthquake) that the authorized user cannot access to the corresponded user when access class barring is applied to the corresponded user.

- **Emergency service**
  User sets up an emergency call and it is unfortunately released. At the condition, emergency agencies (e.g. police) would like to call back the user. However in the current specification, it is impossible to call back if access control restriction has been applied to the user.

- **Communication between UEs in the same area where access control is performed**
  There is an area where access control is performed. In order to allow all the users in the area to setup calls, broadcasting access class numbers are changed at an interval of some seconds. For example, in an interval UEs with access class 0 can perform setup and UEs with access classes 1-9 cannot do setup, in another interval UEs with access class 1 can do setup and UEs with access classes 0, 2-9 cannot do setup. However there is an issue that communication between UE with an access class number and UE with another access class number cannot be established in the area. The communication helps users in the emergency situation, e.g. a mother call to her child to know where he/she is.

This work adds to TS 22.011 functional requirements and information flow for Paging Permission with access control.

CT1 work on PPACR

As it is identified by SA1, there are cases even during access control, the successful terminated call establishment is expected such as priority communication service originated from the authorized user to the user who camps in congested area, emergency service call back, and communication between user UEs in the same area where access

Petitioners' Exhibit 1003, p. 221
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

control is performed. In this case, a network operator performs an access class control, and the access class of originating UE is unbarred and terminating UE is barred.

The current access control mechanism does not allow UEs to respond and establish terminating calls; therefore, it is required to provide the enhanced mechanism to solve this issue.

CT1 specified the Stage3 capabilities and functionalities to meet the requirement defined in SA1 TS 22.011.

The PPAC related capabilities are the permission for UE to respond the paging request while access control operation. UE may make access attempts for mobile terminated call control and terminated message control (e.g., SMS) as an optional procedure of access control.

PPAC is intended to be utilized for the CS/PS domain.

10.12.1 Conformance Test Aspects – Paging Permission with Access Control UID_490017

Resources: R5

UID	Name	Hyperlink	Status_Report	Notes	TS_TR
490017	**Conformance Test Aspects – Paging Permission with Access Control (PPAC)**	RP-100806	RP-101074	RP#50 completed	UTRA 34.108, 34.123-1, 34.123-2, 34.123-3

Paging Permission with Access Control (PPAC) is a mandatory function in the Rel-8 that improves Mobile Communications, during congestion in emergency situations, such as earthquakes.
In networks congested during an emergency situation with all but essential users barred, the implementation of PPAC would extend the number of use cases to allow: additional combinations of calls between authorized and non authorized users and calls between non authorized users. This feature allows the users to respond to a paging request even when under access class barring.

This work introduces conformance testing of Paging Permission with Access Control for the signalling Layer 3 aspects.

Petitioners' Exhibit 1003, p. 222
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10.13 Charging for multi-phases services (CHRGMPH) UID_380063

Resources: S1

References

Document	Title/Contents
WID(s)	
SP-080053	WID on Charging for multi-phases services (CHRGMPH)
Impacted Specifications	
TS 22.115	Charging at service delivery CR#0037 Charging for two-phases services, CR#0040 Correction of charging requirement for multi-phase services
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Telecom Italia, T-Mobile, Deutsche Telekom, Vodafone, Huawei, China Mobile.

UID	Name	Acronym	Resource	Hyperlink	TS_TR
380063	**Charging for multi-phases services**	CHRGMPH	S1	SP-080053	22.115
380070	**Stage 1 for CHRGMPH**	CHRGMPH-s1	S1	SP-080053	22.115

Several services are characterized by an initial period between the service selection and the service provision. Such period starts when the call is taken up by the Service Centre and finishes when the service is really delivered to the end-user. In several cases, the price is charged to the caller only at the provision of the requested service while the latency period is not charged or is correlated to a different tariff. More generally, multiple service phases could occur at different tariffs.

As an example, the services with voice navigation selection in voice band are characterized by the presence of an initial period of interactivity free for the caller: such period starts when the call is taken up by the Service Centre and ends up when the caller makes the choice of the requested service, using a contents' menu (e.g. a voice navigation system).

Such interactive activity may be realized either with an automatic answering machine or with a human operator through live conversation.

This applies to the case where the IMS network is directly connected to the Service Provider (SP), as well as to the interconnection between IMS networks when the SP is not directly connected to the IMS serving network.

In general, charging such a service, it is required to trigger:

1. Start of the first phase of the service, where the network resources are allocated but the real service is not yet provided (a first tariff may apply);
2. End of this first phase of the service / Start of the subsequent phase of the service, where the real service is provided to the user (a second tariff may apply). Multiple service phases may occur in sequence.
3. End of last period of the service;

This work adds via CR to TS 22.115 charging requirements for point 2 above. These requirements apply to the charging among operators and SPs when the SP is directly connected to the IMS serving network, and between operators in case of interconnection when the SP is not directly connected to the IMS serving network.

The solution allows operators to get appropriate information (e.g. using CDR) of the first interactive phase and the subsequent phases of the service provision.

Petitioners' Exhibit 1003, p. 223
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

11 SA3 Features

11.1 Lawful Interception in the 3GPP Rel-8 (LI8) UID_350015

Resources: S3

References

Document	Title/Contents
WID(s)	
SP-070238	WID on Lawful Interception in the 3GPP Rel-8
Impacted Specifications	
TS 33.106	Lawful interception requirements
TS 33.107	3G security; Lawful interception architecture and functions
TS 33.108	3G security; Handover interface for Lawful Interception (LI)
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: BMWi(DE), Nortel, Nokia, Alcatel-Lucent, BT Group, Telefonica O2, HO(UK), PIDS, Ericsson, Cingular, ESTS, BfV(DE), KPN, Siemens Networks.

UID	Name	Acronym	Resource	Hyperlink	TS_TR
350015	Lawful Interception in the 3GPP Rel-8	LI8	S3	SP-070238	33.106, 33.107, 33.108

SAE, MBMS, IMS conferencing and WLAN had been studied for possible Lawful Interception (LI) systemsThis work enhances the LI for Rel-8 architecture and services with focus on enabling LI in EPS; but it also added features such as enabling LI in IMS-based conferencing services.

Petitioners' Exhibit 1003, p. 224
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

11.2 Generic Bootstrapping Architecture Push Function (GBAPush) UID_390046

Resources: S3,C1,C4

References

Document	Title/Contents
WID(s)	
SP-080133	S3 WID on Generic Bootstrapping Architecture Push Function (GBAPush)
Impacted Specifications	
TS 24.109	Bootstrapping interface (Ub) and network application function interface (Ua); Protocol details - CT1
TS 29.109	Generic Authentication Architecture (GAA); Zh and Zn Interfaces based on the Diameter protocol; Stage 3 -CT4
New Dedicated Specifications/Reports	
TS 33.223	Generic Authentication Architecture (GAA); Generic Bootstrapping Architecture (GBA) Push function - SA3
TS 33.224	Generic Authentication Architecture (GAA); Generic push layer **- was moved to Rel-9**

Supporting Individual Members: Ericsson, Huawei, Nokia, Nokia Siemens Networks.

UID	Name	Resource	Hyperlink	TS_TR
390046	**Generic Bootstrapping Architecture Push Function**	S3,C1,C4	SP-080133	-
390146	**SA3 part of GBAPush (33.223)**	S3	SP-080133	33.223
390246	**CT1 part of GBAPush**	C1	CP-090112	24.109
390346	**CT4 part of GBAPush**	C4	CP-090112	29.109

Generic Authentication Architecture (GAA) cannot be used in scenarios where there is no return channel from UE to the network, e.g. broadcast scenarios or when setting up a feedback channel should be avoided or is undesired.
This means that there is a need to establish the GAA master key in a unidirectional manner.
OMA has indicated that such a feature could be used in their services as well.

Primarily this work specifies the GAA Push functionality enabling UE and home network to establish a security association, i.e. a GBA based shared secret, triggered (pushed) by the network.
This feature addresses the fact that GAA cannot be used in scenarios with no return channel from UE to the network.
This security association can be used to establish a second security association between the serving network and UE.
GAA Push functionality should have no or minimal impact on GAA core architecture and functionality.

Secondarily this work provides a "generic push layer" where a generic protection mechanism is specified for the messages that are pushed by the network for which the protection is based on GAA push functionality.

SA3 specified GBA Push in a new TS 33.223 (Push function).

CT1 TS 24.109 and CT4 TS 29.109 made Stage 3 changes required to support GBA Push in Upa interface.

Petitioners' Exhibit 1003, p. 225
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

12 SA4 Features

12.1 Requirements and Test methods for Wideband Terminals (RETEM_WB_T) UID_34045

Resources: S4

References

Document	Title/Contents
WID(s)	
SP-080004	WID on Requirements and Test methods for Wideband Terminals
Impacted Specifications	
TS 26.131	Terminal acoustic characteristics for telephony; Requirements
TS 26.132	Speech and video telephony terminal acoustic test specification
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Orange, France Telecom, T-Mobile International, Vodafone, Ericsson, Nokia.

UID	Name	Resource	Hyperlink	TS_TR
34045	**Requirements and Test methods for Wideband Terminals**	S4	SP-080004	26.131, 26.132

Recognizing the advantages brought by WideBand (WB) speech to the voice quality of conversational services, 3GPP has been working for long time on this. To obtain a genuine wideband speech quality, the whole communication chain has to be considered. AMR-WB codec is a high-quality WB speech compression solution for speech transmission over 3GPP radio access and core networks but this quality could be strongly altered if the terminal is not well designed from the acoustic point of view. 3GPP has already conducted work on this issue. Requirements (TS 26.131) and test methods (TS 26.132) for narrow-band and WB terminals were already specified by SA4.

Terminal performance strongly impacts the quality as really perceived by the end-user. Subjective tests have shown that terminal acoustic design impacts the end-user perceived quality as much as the codec itself. Some requirements set in current TS 26.131 do not guarantee obtaining the optimal WB quality.

Some examples of improvements:

- A handset with sensitivity/frequency response curve considered as acceptable regarding limits in TS 26.131 cannot sufficiently render real effective WB sound to the user if its response curve is in the lower part of the defined mask. As a result the difference with narrow-band rendering could be too reduced to justify WB voice services.
- Measurement of the distortion that is done only for one frequency is not sufficient for WB speech.

Without reconsidering such points especially with respect to high-quality WB voice requirements, some terminals would use WB codecs and be declared as WB, without sufficient improvement of acoustic and analogue part.
For the end-user, difference with "normal" terminal would not justify transition to WB telephony.
In some cases extension of frequency without correct study could even induce lower perceived quality especially with respect to narrow band voice obtained with AMR over a well acoustically designed narrow band terminal.

This work enhances TS 26.131 requirements and TS 26.132 test methods, originally narrow band terminals standards including partial update for WB terminals, to ensure adequate perceived quality for WB speech services and interoperability between terminals (for handset, headset and hands-free).

Petitioners' Exhibit 1003, p. 226
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

12.2 Extending PSS and MBMS User Services for optimized Mobile TV UID_34043

Resources: S4

References

Document	Title/Contents
WID(s)	
SP-070757	WID on Extending PSS and MBMS User Services for optimized Mobile TV
Impacted Specifications	
TS 26.234	Transparent end-to-end Packet-switched Streaming Service (PSS); Protocols and codecs
TS 26.346	Multimedia Broadcast/Multicast Service (MBMS); Protocols and codecs
TS 26.946	Multimedia Broadcast/Multicast Service (MBMS) user service guidelines
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Ericsson, Apple, Vidiator, Nokia, Digital Fountain, RealNetworks.

UID	Name	Resource	Acronym	Hyperlink	TS_TR
34043	**Extending PSS and MBMS User Services for optimized Mobile TV**	S4	PSS_MBMS_OMTV	SP-070757	26.234, 26.346, 26.946

Mobile TV is an important service for MBMS in particular for E-UTRAN access, covered in SA1 TS 22.246 clause 5.1.

Packet Switching Streaming (PSS) enabler was enhanced in Rel-7 allowing fast content switching and start up.
Rel-7 PSS offers Mobile TV with sufficiently fast channel switching performance even on unicast.
PSS and MBMS User Services (MBMSUSE) are foreseen to be used in combination for offering best possible experience to mobile end-user in a network resource efficient way. Therefore, SA4 sees PSS and MBMSUSE as a single entity to be optimized for Mobile TV which includes also downloaded content e.g. to realize Push TV services.
Objectives to extend PSS and MBMSUSE for Mobile TV:

- Tune-in time reduction for MBMS based services;
- Fast Channel Switching for FEC protected channels;
- Guidelines/Improvements PSS to MBMSUSE (and vice versa) channel switching;
- General improvements and additions for MBMSUSE and PSS;
- Time-shifting of live PSS offerings;
- Recording file format in the client;
- Support for more advanced Audiovisual Codecs;
- Server file formats.

Petitioners' Exhibit 1003, p. 227
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

12.3 Encoding formats, transport formats and media description signalling for interworking, QoE, and other enhancements to MTSI-MHI UID_400028

Resources: S4,C3,C4

References

Document	Title/Contents
	WID(s)
SP-080443	S4 Feature WID on Encoding formats, transport formats and media description signalling for interworking, QoE, and other enhancements to MTSI-MHI (MTSI_eMHI)
	Impacted Specifications
-	See below
	New Dedicated Specifications/Reports
-	See below

Supporting Individual Members: Ericsson, Qualcomm, Nokia, France Telecom, Orange, Telecom Italia, T-Mobile International, Samsung, Huawei.

UID	Name	Resource	Hyperlink	TS_TR
400028	**Encoding formats, transport formats and media description signalling for interworking, QoE, and other enhancements to MTSI-MHI**	-	SP-080443	-
34041	**MTSI Video - Dynamic Rate Adaptation/Signalling of Image Size**	S4	SP-080246	26.114
400018	**CT3 part of Enhancement of interworking between MTSI and CS networks**	C3	CP-080774	29.163
400020	**CT4 part of Enhancement of interworking between MTSI and CS networks**	C4	CP-080774	29.332

This Feature has the following Building Blocks:

- MTSI Video: Dynamic Rate Adaptation/Signalling of Image Size (MTSIV_DRASIS) UID_34041
- CT-wide WID on Enhancement of interworking between MTSI and CS networks UID_400019, 400018, 400020)

Rel-7 TS 26.114 defined Media Handling and Interaction (MHI) procedures for Multimedia Telephony Service for IMS (MTSI), enabling telephony-grade services over QoS controlled bearers. Due to Rel-7 closure only a minimum set of requirements could be completed.

In the Common IMS work, it has been decided that codecs are not included and that 3GPP is responsible for ensuring that necessary procedures are defined so that inter-working with other systems is ensured.

SA4 and CT1 realized that the session media configuration in TS 26.114 is suboptimal for many interworking scenarios and for call scenarios requiring forking.

MTSI terminals are deployed and need to interoperate with the existing base of CS 3GPP terminals.
For MTSI video, this requires interworking with the deployed base of 3GPP H.324M video telephony terminals.

Interworking between PS and CS conversational video services introduces challenges that can result in increase of end-to-end latency and/or degradation of video quality. In order to enable good inter-working, MTSI should include features and tool-sets capable of allowing the service to interwork efficiently with CS video telephony terminals.

For these reasons SA4 TS 26.114 MTSI-MHI was enhanced to:

- Introduce higher bit rate, profiles and/or levels for video coding.
- Introduce coding support for generic signal types including non-speech signals (e.g. ring-back signals and music-on-hold).
- Implement necessary media functionality for interworking to ensure that a 3GPP service can interoperate with other similar services, applications and clients defined by 3GPP or other bodies. This includes all media handling aspects e.g.: encoding / transport formats and session description signalling. Most important interworking scenarios:
  - CS/PS voice and/or video telephony services defined by 3GPP (CS GERAN; CS UTRAN and CSoHS).
  - Video interworking with 3G-324M
    - define new SDP attribute(s) to enhance interworking between MTSI video and H.324M terminals;
    - provide guidance on usage of defined SDP attribute(s) by terminals and interworking gateways;
    - provide guidance on usage of RTCP AVPF messages (e.g., Picture Loss Indication and Codec Control Messages) in interworking gateways.

Petitioners' Exhibit 1003, p. 228
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

  - CS/PS voice, video and/or Multimedia Telephony services defined by ETSI.
  - VoIP and/or Multimedia Telephony services defined in ITU, 3GPP2, PacketCable, etc.
- Improve session media configuration for inter-working with other networks, applications and clients.
- Introduce support for service performance monitoring.

Backwards compatibility with Rel-7 was ensured. User experience and service efficiency was enhanced. Interoperability with other similar services was improved.

Interworking was enhanced in close cooperation with CT1, CT3, CT4, TISPAN, etc.

MTSI Video - Dynamic Rate Adaptation/Signalling of Image Size (MTSIV_DRASIS) UID_34041

Resources: S4

References

Document	Title/Contents
WID(s)	
SP-080246	S4 BB WID on MTSI Video: Dynamic Rate Adaptation/Signalling of Image Size
Impacted Specifications	
TS 26.114	IP Multimedia Subsystem (IMS); Multimedia telephony; Media handling and interaction (SA4)
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: T-Mobile International, China Mobile, Samsung, Qualcomm, Research in Motion.

UID	Name	Acronym	Hyperlink	TS_TR
34041	**MTSI Video - Dynamic Rate Adaptation/Signalling of Image Size**	MTSI_eMHI-DRASIS	SP-080246	26.114

Dynamic Rate Adaptation

MTSI specifies the PS version of CS conversational services. Compared to existing CS conversational services, MTSI provides the flexibility that enables a more feature rich and greater quality user experience. Additionally, the use of shared wireless resources in MTSI (compared to the use of dedicated resources in CS) can enable operators to simultaneously address the competing requirements of providing good user experience while at the same time making efficient use of available wireless resources.

In order to achieve this, MTSI should include features and tool-sets capable of allowing the service to adapt dynamically to the changing network and user conditions (e.g., mechanisms to enable the sending terminal to adapt its media transmission to changing congestion conditions and user link conditions using end-to-end terminal feedback and/or network-based feedback, etc.). This would ensure maintenance of acceptable user experience across diverse channel and network conditions.

SA4 developed advanced functionality optimizing MTSI in TS 26.114. Dynamic video rate adaptation for MTSI enhances procedures ensuring that acceptable user experience can be achieved while improving service efficiency. It addressed:

- Identification of operating conditions which would benefit from dynamic video rate adaptation;
- Providing guidance on the use of dynamic video rate adaptation for the identified operating conditions;
- Specification of end to end dynamic video rate adaptation signalling mechanisms;
- Specification of associated SDP parameters;
- Providing guidance on the use of various feedback mechanisms (e.g. end-to-end or network based) for improving service efficiency.

Signalling of Image Size

Information on width and height of video is not directly exchanged. Determining width and height of video, based only on existing information set in SDP offer, allows only pre-defined size either too small or too large for typical UE LCD, which necessitates significant resizing of decoded video. From this inefficiency, video quality and spectral efficiency can be reduced.

Therefore, enhancement of MTSI session initiation procedure is necessary to reduce the gap between the size of encoded video and the decoded, resized, and displayed video. In addition, the enhanced session initiation procedure shall be flexible enough to evolve with the progress in the network, video and VLSI technology.

Petitioners' Exhibit 1003, p. 229
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

This work enhances the existing MTSI session initiation procedure with additional negotiation step of width and height of video, and definition of additional size between the current minimum and the maximum size to allow more graceful quality/bit-rate trade-off.

- Define a new SDP attribute for the width and height of video
- Define new sizes between QCIF(176x144) and QVGA(320x240)
- Incorporate new SDP attribute into MTSI session initiation procedure

Enhancement of interworking between MTSI and Circuit Switched networks (MTSI_eMHI) **UID_400018**

Resources: C3,C4

References

Document	Title/Contents
	WID(s)
CP-080774	CT WID on Enhancement of interworking between MTSI and Circuit Switched networks
	Impacted Specifications
TS 29.163	Interworking between the IP Multimedia (IM) Core Network (CN) subsystem and Circuit Switched (CS) networks [CT3 - Add functionality for inter-working enhancement between the 3G-324M and MTSI]
TS 29.332	Media Gateway Control Function (MGCF) - IM Media Gateway (IM-MGW); Mn interface [CT4 - Add functionality for inter-working enhancement between the 3G-324M and MTSI]
	New Dedicated Specifications/Reports
-	-

Supporting Individual Members: Huawei, China Mobile, Ericsson, Qualcomm, Telecom Italia.

UID	Name	Resource	Hyperlink	TS_TR
400018	**CT3 part of Enhancement of interworking between MTSI and CS networks**	C3	CP-080774	29.163
400020	**CT4 part of Enhancement of interworking between MTSI and CS networks**	C4	CP-080774	29.332

This work enhances the relevant protocols addressing video inter-working between the 3G-324M and MTSI including:

- Usage of the enhancement SDP attribute(s) in the inter-working gateways;
- Procedures to use RTCP AVPF messages (e.g. possibly Picture Loss Indication and Codec Control Messages) in the inter-working gateways;

Petitioners' Exhibit 1003, p. 230
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

13 SA5 Features

13.1 Operations, Administration, Maintenance and Provisioning (OAM&P)

Resources: S5

UID	Name	Acronym	Resource	Hyperlink
340063	**OAM&P 8**	OAM8	S5,C1,C4	-
340064	**Network Infrastructure Management**	OAM8-NIM	S5	-
35051	Telecom Management Methodology	OAM8	S5	SP-070296
35053	Advanced Alarming on Itf-N	OAM8	S5	SP-070492
35056	CN CS Bearer Transport Network (BTN) relative NRM	OAM8	S5	SP-070300
390016	Alignment with eTOM and M.3060 architectural concepts	OAM8	S5	SP-080068
400030	IRP SOAP Solution Sets	OAM8	S5	SP-090148
450052	Create missing specifications for IRP XML definitions	OAM8	S5	SP-090553
340065	**Performance Management**	OAM8-PM	S5	-
35061	IP bearer network Performance measurement definitions	OAM8	S5	SP-070301
360001	HSUPA performance measurements	OAM8	S5	SP-070835
360002	Key Performance Indicators (KPIs) for UMTS and GSM	OAM8	S5	SP-070299
340066	**Trace Management**	OAM8-Trace	S5,C1,C4	-
11067	Service Level Tracing in IMS	OAM8-Trace	C1	CP-080315
400022	Service Level Tracing in IMS	OAM8-Trace	C4	CP-080315
350016	**Charging Management small Enhancements**	CH8	S5	-
350038	**Online charging correlation**	CH8	S5	SP-070077
360003	**SMS online charging**	CH8	S5	SP-070293
410045	**Introduce Online Charging from SMS-SC into the SMS Charging Specifications**	CH8	S5	SP-080463

Petitioners' Exhibit 1003, p. 231
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

13.1.1 Telecom Management Methodology UID_35051

Resources: S5

References

Document	Title/Contents
	WID(s)
SP-070296	WID on Telecom Management Methodology
	Impacted Specifications
TS 32.150	Telecommunication management; Integration Reference Point (IRP) Concept and definitions
TS 32.151	Telecommunication management; Integration Reference Point (IRP) Information Service (IS) template
TS 32.152	Telecommunication management; Integration Reference Point (IRP) Information Service (IS) Unified Modelling Language (UML) repertoire
TS 32.154	Telecommunication management; Backward and Forward Compatibility (BFC); Concept and definitions
	New Dedicated Specifications/Reports
TS 32.153	Telecommunication management; Integration Reference Point (IRP) technology specific templates, rules and guidelines
TS 32.155	Telecommunication management; Requirements template

UID	Name	Acronym	Resource	Hyperlink	rapporteur	TS_TR
340063	**OAM&P 8**	OAM8	-	-	-	-
340064	**Network Infrastructure Management**	OAM8-NIM	S5	-	-	-
35051	Telecom Management Methodology	OAM8	S5	SP-070296	Ericsson	32.155, 32.153

Telecom Management (TM) capabilities and functions evolve continuously because for example, new functions are added to manage new kind of nodes introduced into the network, more efficient functions and capabilities are introduced, new technologies are added, old technologies are not longer used. There is a constant need to enhance and further develop the methodology for the evolved TM area.

To spread the way of working for TM, the methodology developed by 3GPP is promoted outside 3GPP. The use of the same or similar methodology to develop management capabilities for the various networks would facilitate the integration of these systems and networks where telecom is a part of. Therefore there are some dependencies on external bodies, e.g. 3GPP2, ITU-T and ETSI that are using a methodology that is common to 3GPP. The needs from these external bodies have to be taken into account. SA5 developed jointly with ITU-T and ETSI methodology for:

- Requirements;
- Information Services;
- Solution Sets (technologies).

Methodology for XML technology was started in Rel-7 and needs to be completed.

SOAP technology was introduced in Rel-7 and the methodology how to use it needs to be developed, so that the same issues do not occur as for XML. It is still not clear how vendor specific extensions shall be done for XML.

Petitioners' Exhibit 1003, p. 232
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

13.1.2 Advanced Alarming on Itf-N UID_35053

Resources: S5

References

Document	Title/Contents
	WID(s)
SP-070492	WID on Advanced Alarming on Itf-N
	Impacted Specifications
-	-
	New Dedicated Specifications/Reports
TS 32.121	Telecommunication management; Advanced Alarm Management (AAM) Integration Reference Point (IRP); Requirements
TS 32.122	Telecommunication management; Advanced Alarm Management (AAM) Integration Reference Point (IRP); Information Service (IS)
TS 32.123	Telecommunication management; Advanced Alarm Management (AAM) Integration Reference Point (IRP); Common Object Request Broker Architecture (CORBA) Solution Set (SS)

UID	Name	Acronym	Resource	Hyperlink	rapporteur	TS_TR
340063	**OAM&P 8**	OAM8	-	-	-	-
340064	**Network Infrastructure Management**	OAM8-NIM	S5	-	-	-
35053	Advanced Alarming on Itf-N	OAM8	S5	SP-070492	Nokia Siemens Networks	32.121, 32.122, 32.123

The current definitions of Information Object Classes (IOCs) and their notifications in case of alarms and changes related to them put a high burden on both, the IRP managers and IRP agents. In alarm situations the number of notifications to be sent across the Itf-N can be very high, but often the information/data contained in the notifications does not justify their transmission. It is also possible that one error results in several alarm notifications and/or additional notifications indicating state or attribute value changes.

TS 32.121, TS 32.122 and TS 32.123:

- Define requirements and methods to improve the information content of alarms (e.g. to help identify the root cause of an alarm and the instances affected by it), thereby contributing to reduce the time-to-repair.
- Define configurable rules for advanced alarm filtering and reducing the number of alarms by applying such advanced alarm filtering.

Petitioners' Exhibit 1003, p. 233
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

13.1.3 CN CS Bearer Transport Network (BTN) relative NRM UID_35056

Resources: S5

References

Document	Title/Contents
WID(s)	
SP-070300	WID on CN CS Bearer Transport Network (BTN) relative NRM
Impacted Specifications	
TS 32.632	Telecommunication management; Configuration Management (CM); Core Network Resources Integration Reference Point (IRP): Network Resource Model (NRM)
TS 32.633	Telecommunication management; Configuration Management (CM); Core network resources Integration Reference Point (IRP): Common Object Request Broker Architecture (CORBA) Solution Set (SS)
TS 32.635	Telecommunication management; Configuration Management (CM); Core network resources Integration Reference Point (IRP): Bulk CM eXtensible Markup Language (XML) file format definition
New Dedicated Specifications/Reports	
-	-

UID	Name	Acronym	Resource	Hyperlink	rapporteur	TS_TR
340063	**OAM&P 8**	OAM8	-	-	-	-
340064	**Network Infrastructure Management**	OAM8-NIM	S5	-	-	-
35056	CN CS Bearer Transport Network (BTN) relative NRM	OAM8	S5	SP-070300	China Mobile	32.632, 32.633, 32.635

Circuit is a logic link between two exchange network nodes which bear the user data such as voice, e.g. 64K slot of one 2M E1. Traffic route represents the route via which bearer flow to a specific destination.

To learn the detailed circuit connection relationship between network nodes and traffic route configuration status of the CN CS bearer transport network related NRM needs to be defined, such as circuit, traffic route, etc.

This work

- Defined Bearer Transport Network (BTN) related NRM applicable to CN CS of UMTS;
- Added BTN relative NRM definition of the CN CS to TS 32.63x-series Configuration Management (CM); Core network resources IRP;

Petitioners' Exhibit 1003, p. 234
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

13.1.4 Alignment with eTOM and M.3060 architectural concepts UID_390016

Resources: S5

References

Document	Title/Contents
WID(s)	
SP-080068	WID on Alignment with eTOM and M.3060 architectural concepts
Impacted Specifications	
TS 32.101	Telecommunication management; Principles and high level requirements (Update Telecom Operation Map references)
TS 32.102	Telecommunication management; Architecture (Update of ITU-T TMN NGNM architectural concepts)
New Dedicated Specifications/Reports	
-	-

UID	Name	Acronym	Resource	Hyperlink	rapporteur	TS_TR
340063	**OAM&P 8**	OAM8	-	-	-	-
340064	**Network Infrastructure Management**	OAM8-NIM	S5	-	-	-
390016	Alignment with eTOM and M.3060 architectural concepts	OAM8	S5	SP-080068	TeliaSonera	32.101/2, 32-series

The PLMN Management architecture is based on ITU-T TMN Recommendation M.3010 and early work of TMForum addressing common working procedures in Telecom called "Telecom Operations Map" (TOM).

TMForum has developed the extended TOM (eTOM), superseding TOM and now widely adopted among operators. ITU-T has published a new set of TMN documents incorporating requirements for the management of Next Generation Networks (NGN), a Service-Oriented Architecture and alignment with the updated business process views from eTOM. Valuable new concepts were added to better support network services, business processes and to reduce operational costs.

The 3GPP TM specifications need to adopt the development of the telecom operators market and the challenges the new services will have on management of the networks. The prime approach of the 3G TM work was to reuse functions, methods and interfaces already defined (or being defined) that were suitable to the management needs of a PLMN.

The fundamental reused platforms have been updated and the SA5 specifications need to be updated accordingly.

The TMN NGN architecture includes a new business process view, based on eTOM. The goal of NGN is to provide the capabilities to make possible the creation, deployment and management of all kind of services. To achieve this it is necessary to decouple and make independent the service creation/deployment infrastructure from the transport infrastructure.

New reference points enabling more run-time flexibility were added. The BML layer is obsolete. A new management layered architecture is introduced. Significant redefinitions of basic concepts as management function blocks, WSF is absorbed into OSF and NEF.

The new concepts need alignment between 3GPP TM and ITU-T TMN NGN, ETSI TISPAN NGN OSS standards.

Petitioners' Exhibit 1003, p. 235
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

13.1.5 IRP SOAP Solution Set UID_400030

Resources: S5

References

Document	Title/Contents
	WID(s)
SP-080276	WID on SOAP Solution Set
	Impacted Specifications
TS	32.111-1, 32.111-2, 32.111-3, 32.111-5, 32.307, 32.317, 32.341, 32.342, 32.343, 32.345, 32.361, 32.362, 32.363, 32.365, 32.411, 32.412, 32.413, 32.415, 32.611, 32.612, 32.613, 32.615, 32.625
	New Dedicated Specifications/Reports
TS 32.111-7	Alarm IRP SOAP SS
TS 32.617	Bulk CM IRP SOAP SS
TS 32.417	Performance Management (PM) IRP SOAP SS
TS 32.367	Entry Point (EP) IRP SOAP SS
TS 32.347	File Transfer (FT) IRP SOAP SS

UID	Name	Hyperlink	rapporteur	TS_TR
340063	**OAM&P 8**	-	-	-
340064	**Network Infrastructure Management**	-	-	-
400030	IRP SOAP Solution Sets	SP-090148	Ericsson	32.111-7, 32.617, 32.417, 32.367, 32.347, 32.111-1, 32.111-2, 32.111-3, 32.111-5, 32.307, 32.317, 32.341, 32.342, 32.343, 32.345, 32.361, 32.362, 32.363, 32.365, 32.411, 32.412, 32.413, 32.415, 32.611, 32.612, 32.613, 32.615, 32.625

Currently the SA5 IRP specifications are mainly using one type of Solution Set (SS), namely CORBA.
The CMIP SS technology has been discontinued after Rel-6.

SA5 has defined SOAP SSs for the Interface IRPs (such as Basic CM IRP in 32.60x) supporting Subscription Management NRM IRP (TS 32.17x), but SOAP SSs are missing for other IRPs e.g. Alarm IRP (TS 32.111-x).

Both SA5 TR 32.809 (Feasibility Study of XML-based (SOAP/HTTP) IRP Solution Sets) and TR 32.818 (Study on 3GPP SA5 / MTOSI XML harmonization) recommended the use of SOAP/XML-based SSs to support all IRPs.

This work provides SOAP SS for **ALL** IRPs not having it, excluding Subscription Management IRP.
ALL means all Rel-7 and all new Rel-8 IRPs such as E-UTRAN NRM IRP.

It is unlikely that all SOAP SSs identified in the WID (see table above) can be produced within the Rel-8 time frame.

Petitioners' Exhibit 1003, p. 236
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

13.1.6 Create missing specifications for IRP XML definitions UID_450052

Resources: S5

References

Document	Title/Contents
	WID(s)
SP-090553	WID on Create missing specifications for IRP XML definitions
	Impacted Specifications
TS 32.150	Telecommunication management; Integration Reference Point (IRP) Concept and definitions
TS 32.153	Telecommunication management; Integration Reference Point (IRP) technology specific templates, rules and guidelines
TS 32.335	Telecommunication management; Notification Log (NL) Integration Reference Point (IRP); eXtensible Markup Language (XML) solution definitions
	New Dedicated Specifications/Reports
TS 32.125	Telecommunication management; Advanced Alarm Management (AAM) Integration Reference Point (IRP); XML definitions
TS 32.355	Telecommunication management; Communication Surveillance (CS) Integration Reference Point (IRP) ; XML definitions
TS 32.505	Telecommunication management; Self-Configuration of Network Elements Integration Reference Point (IRP) ; XML definitions
TS 32.535	Telecommunication management; Software management Integration Reference Point (IRP) ; XML definitions

UID	Name	Hyperlink	rapporteur	TS_TR
340063	**OAM&P 8**	-	-	-
340064	**Network Infrastructure Management**	-	-	-
450052	Create missing specifications for IRP XML definitions	SP-090553	ZTE	new (32.125, 32.355, 32.505, 32.535), 32.150, 32.153, 32.335

This work item creates the missing XML definitions specifications for the following IRPs: Advanced Alarm Management, Communication Surveillance, Self-Configuration of Network Elements, Software Management.
These definitions are required for implementation of Rel-8 Notification Log IRP (TS 32.33x-series).
It is not possible to log the notifications generated by Rel-8 implementations of these IRPs.
Furthermore, they are needed in the specification of SOAP Solution Sets for these IRPs. Without them it is not possible to complete the Rel-9 WI "IRP SOAP Solution Sets continuation from Rel-8 (OAM9) (UID_440065)".

Petitioners' Exhibit 1003, p. 237
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

13.1.7 IP bearer network Performance measurement definition UID_35061

Resources: S5

References

Document	Title/Contents
WID(s)	
SP-070301	WID on IP bearer network Performance measurement definition
Impacted Specifications	
TS 32.321	Telecommunication management; Test management Integration Reference Point (IRP); Requirements
TS 32.322	Telecommunication management; Test management Integration Reference Point (IRP); Information Service
TS 32.323	Telecommunication management; Test management Integration Reference Point (IRP); CORBA Solution Set
TS 32.325	Telecommunication management; Test management Integration Reference Point (IRP); XML definitions
New Dedicated Specifications/Reports	
-	-

UID	Name	Acronym	Resource	Hyperlink	rapporteur	TS_TR
340063	**OAM&P 8**	OAM8	-	-	-	-
340065	**Performance Management**	OAM8-PM	S5	-	-	-
35061	IP bearer network Performance measurement definitions	OAM8	S5	SP-070301	China Mobile	32.321, 32.322, 32.323, 32.325

Standardizing performance measurements can bring a unified criterion for operators to evaluate the performance of networks provided by different vendors. With the evolution of RAN and All-IP Networks, it is very important to measure the performance of an IP network between any two among RNCs, SGSNs, GGSNs, MGWs and MSC Servers. At present, 3GPP does not have performance measurements for this.

This work widens the scope of TS 32.32x TestIRP by adding 3GPP support of IP network performance measurements either by reference to existing measurements from other SDOs or by initiating an effort in those SDOs to include the counters that SA5 has identified in this WI. IP performance mainly deals with the time delay, jitter, packet loss etc between any two NEs.

Some IP network performance measurements methods defined elsewhere (ITU-T, IETF) can be used as reference.

Petitioners' Exhibit 1003, p. 238
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

13.1.8 HSUPA performance measurements UID_360001

Resources: S5

References

Document	Title/Contents
WID(s)	
SP-070835	WID on HSUPA performance measurements
Impacted Specifications	
TS 32.405	Telecommunication management; Performance Management (PM); Performance measurements Universal Terrestrial Radio Access Network (UTRAN)
New Dedicated Specifications/Reports	
-	-

UID	Name	Acronym	Resource	Hyperlink	rapporteur	TS_TR
340063	**OAM&P 8**	OAM8	-	-	-	-
340065	**Performance Management**	OAM8-PM	S5	-	-	-
360001	HSUPA performance measurements	OAM8	S5	SP-070835	China Mobile	32.405

High Speed Uplink Packet Access (HSUPA) is a UMTS/WCDMA uplink evolution standardized by 3GPP in Rel-6. HSUPA boosts the UMTS/WCDMA uplink data rate up to 5.8Mbps. To realize HSUPA, the overall UE/UTRAN MAC architecture, includes a new MAC-es/MAC-e entity which controls access to the E-DCH. A new connection from MAC-d to MAC-es/MAC-e is added to the architecture, as well as a connection between MAC-es/MAC-e and the MAC Control SAP.

HSUPA performance measurements are different from R99 HSDPA and DCH.

This work adds to TS 32.405 performance measurements for HSUPA FDD and TDD modes (e.g. E-DCH successful and failure assignment, E-DCH normal and abnormal release, serving cell change, soft and hard handover etc.

Petitioners' Exhibit 1003, p. 239
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

13.1.9 Key Performance Indicators (KPIs) for UMTS/GERAN UID_360002

Resources: S5

References

Document	Title/Contents
WID(s)	
SP-070299	WID on Key Performance Indicator (KPI) for UMTS/GERAN
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TS 32.410	Telecommunication management; Key Performance Indicators (KPI) for UMTS and GSM

UID	Name	Acronym	Resource	Hyperlink	rapporteur	TS_TR
340063	**OAM&P 8**	OAM8	-	-	-	-
340065	**Performance Management**	OAM8-PM	S5	-	-	-
360002	Key Performance Indicators (KPIs) for UMTS and GSM	OAM8	S5	SP-070299	China Mobile	32.410

KPIs are very important for operators to monitor their network. Currently, vendors and / or operators define their KPIs in proprietary ways which adds a big overhead on the evaluation of network performance and leads to an unfair rating of different vendors and/or operators. Hence KPIs should be standardized by 3GPP.

KPIs and definition of performance measurements are in the scope of network Performance Management (PM). Currently, performance measurements related to UMTS have been specified in 3GPP as follows:

- TS 52.402 Performance Management (PM); Performance measurements – GSM
- TS 32.404 Performance Management (PM); Performance measurements - Definitions and template
- TS 32.405 Performance Management (PM); Performance measurements UTRAN
- TS 32.406 Performance Management (PM); Performance measurements Core Network PS domain
- TS 32.407 Performance Management (PM); Performance measurements Core Network CS domain
- TS 32.408 Performance Management (PM); Performance measurements Teleservice
- TS 32.409 Performance Management (PM); Performance measurements IP Multimedia Subsystem (IMS)

SA5 TR 32.814 UTRAN and GERAN Key Performance Indicators (KPIs) served as basis for this work.

Petitioners' Exhibit 1003, p. 240
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

13.1.10 Service Level Tracing in IMS (OAM8-Trace) UID_11067

Resources: C1,C4,IETF

References

Document	Title/Contents
WID(s)	
CP-080315	WID on Service Level Tracing in IMS
Impacted Specifications	
TS 24.229	Internet Protocol (IP) multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3 - CT1
TS 29.228	IP Multimedia (IM) Subsystem Cx and Dx Interfaces; Signalling flows and message contents - CT4
TS 29.229	Cx and Dx interfaces based on the Diameter protocol; Protocol details - CT4
New Dedicated Specifications/Reports	
TS 24.323	Trace Management Object (MO) - CT1

UID	Name	Resource	Hyperlink	Notes	TS_TR
340066	**Trace Management**	-	-	-	-
11067	CT1 part	C1	CP-080315	CP#42 completed	24.323, 24.229
521028	(IETF)	C1-IETF	CP-080315	CP#58 Removed from Rel-8, Rel-9 and Rel-10 (Not completed internet-draft)	Rel-11 remains draft-dawes-dispatch-debug
531003	(IETF)	C1-IETF	CP-080315	CP#54 Draft removed from 3GPP documentation, covered by draft-dawes-sipping-debug	draft-dawes-sipping-debug-event
400022	CT4 part	C4	CP-080315	CP#42 completed	29.228, 29.229
400021	Deleted - CT3 part	C3	CP-080315	CP#42 stopped (No CT3-impact)	-

This work is linked to SA5 Stage 2 Trace Management (OAM8-Trace) UID_340066, Stage 1 being defined by OMA. The CT WGs Stage 3 work was removed from Rel-7 and is now continued in Rel-8. This work could not proceed without substantial contribution from IETF.

Subscriber and Equipment Trace provide very detailed information at call level on one or more specific mobile(s) or subscribers. This data is an additional source of information to performance measurements and allows going further in monitoring and optimization operations.

Service Level Tracing (SLT) improves and simplifies end-to-end service diagnostics and enhances the operator's ability to manage complex services. SLT is aimed at end-to-end service-level diagnostics, rather than per node tracing.
By definition, SLT is the ability to capture and log all relevant information at each component within a service chain, associated with a specific service that is initiated either by an end-user or a component (see OMA-RD-OSPE-V1_0-20050614-C.pdf).

The following tasks for CT WGs were defined in SA5 Rel-7 Trace Management WID:

- CT1 on trace activation/deactivation over SIP between IMS entities;
- CT4 on trace activation/deactivation over Cx;
- CT1, CT3, and CT4 on End-to-end tracing for IMS;

This work updates the above mentioned interface protocols to include the procedures defined in SA5 TS 32.422 "Trace control and configuration management". Protocol updates are needed for both trace activations, Signalling Based (SBA) and Management Based (MBA), and conveying SLT indication.

Petitioners' Exhibit 1003, p. 241
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

13.2 Charging Management

Resources: S5

13.2.1 Online charging correlation UID_350038

References

Document	Title/Contents
	WID(s)
SP-070077	WID on Online charging correlation
	Impacted Specifications
TS 32.296	Telecommunication management; Charging management; Online Charging System (OCS): Applications and interfaces (Update the OCS architecture, Add online charging correlation functions, Add message flows to describe online correlation)
	New Dedicated Specifications/Reports
-	-

UID	Name	Acronym	Resource	Hyperlink	rapporteur	TS_TR
350038	**Online charging correlation**	CH8	S5	SP-070077	Orange	32.296

TS 32.240 (Charging architecture and principles) provides the possibility to aggregate and correlate charging information produced by different domains (e.g. IMS, PS) and different sources (e.g. x-CSCF, GGSN, etc.).
This intra-domain and inter-domain correlation is specified only for offline charging but not for online charging.

The Online Charging System (OCS) which performs event/session based charging, credit control and rating features collects charging events at the bearer, IMS and service levels.
By controlling the network and application usage separately, the OCS is not able to apply special charging handling to one charging level against the other (e.g. zero rate bearer usage when an IMS session is active). On the other hand, when multiple services are rendered simultaneously to the subscriber, the OCS is not able to perform service bundling of these services.

As a consequence, the correlation functionality needs to be defined for online charging. This work:

- Updates the OCS internal architecture to combine the EBCF (Event Based Charging Function) and SBCF (Session Based Charging Function) into a single OCF (Online Charging Function) that performs both event and session based charging. This allows optimizing the handling of correlation;
- Introduces a correlation function within the OCS as part of the OCF which would be implement the service logic for correlation;
- Introduces a context monitoring function that defines a context related to the multiple sessions/services activated by a user simultaneously;

Petitioners' Exhibit 1003, p. 242
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

13.2.2 SMS online charging UID_360003

References

Document	Title/Contents
WID(s)	
SP-070293	WID on SMS online charging
Impacted Specifications	
TS 32.240	Telecommunication management; Charging management; Charging architecture and principles (Introduce SMS as a standalone service into charging architecture)
TS 32.299	Telecommunication management; Charging management; Diameter charging applications (Introduce new SMS specific information necessary to enable the relevant SMS charging models)
New Dedicated Specifications/Reports	
TS 32.274	Telecommunication management; Charging management; Short Message Service (SMS) charging

UID	Name	Acronym	Resource	Hyperlink	rapporteur	TS_TR
360003	**SMS online charging**	CH8	S5	SP-070293	Vodafone	32.240, 32.299, new 32.274

This work is linked to

- SA2 – Support of SMS over IP networks (UID_32081)
- CT4 – Routeing of MT-SMS via the HPLMN (UID_340016)

The above linked work items introduced new nodes into the SMS architecture (IP-SM-GW and SMS Router) which currently are not covered y SA5 charging specifications. Both nodes are located within the home PLMN and therefore direct online charging (not reusing CAMEL) is possible.
This work does not replace existing SMS related charging performed at the MSC and SGSN according to SA5 TS 32.250 (CS domain charging) and TS 32.251 (PS domain charging).

TS 32.274 specifies offline and online charging for SMS, based on functional description in TS 23.040 and SMS over IP in TS 23.204. It does not replace existing offline SMS charging functionality and therefore is in addition to that defined in TS 32.250 (CS domain charging) and TS 32.251 (PS domain charging). TS 32.274 includes offline and online charging architecture and scenarios specific to SMS, as well as mapping of the common 3GPP charging architecture specified in TS 32.240 onto SMS. It further specifies the structure and content of the CDRs for offline charging, and the charging events for online charging. TS 32.274 relates to other 3GPP charging TSs as follows:

- TS 22.115 Requirements that govern the charging work;
- TS 32.240 Common 3GPP charging architecture;
- TS 32.298 Parameters, abstract syntax and encoding rules for the CDRs;
- TS 32.295 Transaction based mechanism for the transfer of CDRs within the network;
- TS 32.297 File based mechanism transferring CDRs from network to operator's billing domain (e.g. the billing system or a mediation device);
- TS 32.299 3GPP Diameter application used for SMS offline and online charging.

Petitioners' Exhibit 1003, p. 243
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

13.2.3 Introduce Online Charging from SMS-SC into the SMS Charging Specifications UID_410045

References

Document	Title/Contents
WID(s)	
SP-080463	WID on Introduce Online Charging from SMS-SC into the SMS Charging Specifications
Impacted Specifications	
TS 32.274	Telecommunication management; Charging management; Short Message Service (SMS) charging
TS 32.299	Telecommunication management; Charging management; Diameter charging applications
New Dedicated Specifications/Reports	
-	-

UID	Name	Acronym	Resource	Hyperlink	rapporteur	TS_TR
410045	**Introduce Online Charging from SMS-SC into the SMS Charging Specifications**	CH8	S5	SP-080463	Acision	32.274, 32.299

Linked work items

UID_32081 SA2 Support of SMS over IP networks
UID_340016 CT4 Routeing of MT-SMS via the HPLMN

The current charging specifications cover online charging from SMS Routers and IP-SM-GW but only offline charging from SMS-SC. Adding online charging from SMS-SC brings the following advantages for:

a) **operators and charging system vendors**: a consistent interface specification for online charging across SMS Routers, IP-SM-GW and SMS-SC;
b) **operators:** reduced cost for SMS online charging adaptations when they decide to follow a multi SMS-SC vendor and/or router policy for example. (Currently more than 6 flavours of vendor-specific extensions to Diameter specifications are in use for online charging of SMS.)
c) **SMS-SC and charging system vendors:** less protocols to implement and maintain for online charging of SMS.

Petitioners' Exhibit 1003, p. 244
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

14 CT Features

14.1 Conferencing enhancements for Mp interface (eMp) UID_380024

Resources: C4

References

Document	Title/Contents
WID(s)	
CP-070868	WID on Conferencing Enhancements to the Mp Interface
Impacted Specifications	
TS 23.333	Multimedia Resource Function Controller (MRFC) - Multimedia Resource Function Processor (MRFP) Mp interface; Procedures descriptions [Stage 2]
TS 29.333	Multimedia Resource Function Controller (MRFC) - Multimedia Resource Function Processor (MRFP) Mp interface; Stage 3
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Huawei, Ericsson, China Mobile, Orange, Vodafone

UID	Name	Resource	Hyperlink	TS_TR
380024	**Conferencing enhancements for Mp interface**	C4	CP-080725	-
380025	**Stage 2 for eMp**	C4	CP-080725	23.333
380026	**Stage 3 for eMp**	C4	CP-080725	29.333

Within the IMS, the Multimedia Resource Function (MRF), through interactions with the User Equipment (UE), Application Server (AS) and Serving Call Session Control Function (S-CSCF), provides e.g. video and audio conference capabilities, and the support of announcements, tones and media streams processing.

MRF is decomposed into two functional entities, i.e. the MRFC and MRFP. The Mp interface between these two functional entities supports the H.248 protocol with the additional support of Multimedia specific H.248 Packages.

This work adds further functionality to the Rel-7 basic function by enhancing the Mp procedures and H.248 Profile.

- The MRFC:
  - Controls the media stream resources in the MRFP
  - Interprets information coming from an AS and S-CSCF (e.g. session identifier) and control MRFP accordingly
  - Generates CDRs

- The MRFP:
  - Controls bearers on the Mb reference point
  - Provides resources to be controlled by the MRFC
  - Mixes incoming media streams (e.g. for multiple parties)
  - Sources media streams (for multimedia announcements)
  - Processes media streams (e.g. media analysis)

Rel-7 Mp interface work implements the basic requirements for the Mp interface applications, including playing tone/announcement, detecting DTMF, ad-hoc audio and video conference, etc.

However, Floor control of conference was moved by TSG CT from Rel-7 to Rel-8. Additionally, although requirements such as Message conference were specified in TS 24.147, TS 24.247 and TS 23.228, the corresponding Mp solutions have not been defined yet. This work includes these missing functionalities to the Mp interface.

To further develop and enhance the use of H.248 protocol between the MRFC and MRFP, the requirements, procedures and H.248 Packages were identified and specified. New H.248 Packages were defined by ITU-T SG 16 and/or CT4. The result produced by external bodies was evaluated taking into account the applicability for the packages.

Petitioners' Exhibit 1003, p. 245
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

This work provides solutions to the following requirements:

- Floor Control requirement of conference service
- Message conference
- Number of Participants in conference

Petitioners' Exhibit 1003, p. 246
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

14.2 Contact Manager for 3GPP UICC applications (eUPHBOOK) UID_320014

Resources: C6

CT6 is responsible within 3GPP for specifications of smart card based network authentication applications such as SIM used in 2G systems, USIM used in 3GPP systems and ISIM excluding security algorithms which are developed by SA3.

References

Document	Title/Contents
WID(s)	
CP-080382	WID on Contact Manager for 3GPP UICC applications
Impacted Specifications	
TS 21.111	USIM and IC card requirements (C6)
New Dedicated Specifications/Reports	
TS 31.220	Characteristics of the Contact Manager for 3GPP UICC applications
TS 31.221	Contact Manager for 3GPP UICC applications - internal interface aspects

Supporting Individual Members: Giesecke & Devrient, T-Mobile, Sagem Orga, Oberthur Technologies, Gemalto, SanDisk, Orange, China Mobile

UID	Name	Acronym	Resource	Hyperlink	TS_TR
320014	**Contact Manager for 3GPP UICC applications**	eUPHBOOK	C6	CP-080382	-
320015	**Requirements for Contact Manager**	eUPHBOOK-St1	C6	CP-080382	21.111
350046	**External interface for eUPHBOOK**	eUPHBOOK-Ext_Spec	C6	CP-080382	new 31.220
370004	**Internal interface for eUPHBOOK**	eUPHBOOK-Int_Spec	C6	CP-080382	new 31.221

Limitations of the current phonebook specified in TS 31.102 are felt by some operators when taking advantage of the larger memory capacity available on UICC. Hence, there is a need for specifying a new (scalable) phonebook.

This work adds a set of features for an enhanced USIM phonebook via CR to TS 21.111.

Two new TSs provide the specification for the Contact Manager:

- TS 31.220 defines the Contact Manager External Interface between Contact Manager Server residing on the UICC and Contact Manager External Client;
- TS 31.221 defines the Contact Manager Internal Interface between Contact Manager Server residing on the UICC and Contact Manager Internal Client;

Petitioners' Exhibit 1003, p. 247
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

15 Improvements of the Radio Interface UID_350040

Resources: RP

UID	Name	Resource	Hyperlink	Status_Report
350040	Rel-8 Improvements of the Radio Interface	RP	-	-
350035	**UMTS 700 MHz FDD**	R4	RP-070127	RP-080260
350034	**UMTS 1500 MHz**	R4	RP-070078	RP-070526
410018	**UMTS 1880 MHz TDD**	R4	RP-080757	RP-090044
380074	**UMTS 2300 MHz TDD LCR**	R4	RP-071016	RP-080517
350037	**Further Improved Minimum Performance Requirements for HSDPA UE (FDD) - Two-Branch Interference Cancellation**	R4	RP-070254	RP-080041
370032	**CS Voice Service over HSPA**	R2	RP-070765	RP-080042
25050	**Conformance Test Aspects – CS Voice Service over HSPA**	R5	RP-080160	RP-080542
370033	**Performance requirements for 15 code reception with 16QAM/QPSK (FDD)**	R4	RP-070824	RP-080043
400055	**Conformance Test Aspects – Performance requirements for 15 code reception with 16QAM/QPSK (FDD)**	R5	RP-080311	RP-080818

15.1 UMTS 700 MHz FDD UID_350035

Resources: R4

References

Document	Title/Contents
WID(s)	
RP-070127	WID on UMTS in 700 MHz bands (FDD)
Impacted Specifications	
TR 25.942	Radio Frequency (RF) system scenarios
TS 25.101	User Equipment (UE) radio transmission and reception (FDD)
TS 25.104	Base Station (BS) radio transmission and reception (FDD)
TS 25.133	Requirements for support of radio resource management (FDD)
TS 25.141	Base Station (BS) conformance testing (FDD)
TS 25.306	UE Radio Access capabilities
TS 25.307	Requirements on User Equipments (UEs) supporting a release-independent frequency band
TS 25.331	Radio Resource Control (RRC); Protocol specification
TS 34.121	Terminal conformance specification, Radio transmission and reception (FDD)
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Cingular Wireless (AT&T), Ericsson, Nokia, Alcatel-Lucent, Qualcomm, Marvell, Motorola.

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
350035	**UMTS 700 MHz FDD**	R4	RP-070127	RP-080260	25.101, 25.104, 25.133, 25.141, 25.331, 25.942, 25.306, 25.307, 34.121

This work updates the UMTS specifications to include support for the 700 MHz bands in the US (ITU Region 2).

This work covers the Upper and Lower 700 MHz bands (FDD) for potential deployment in ITU Region 2 as follows:

Upper 700 MHz band includes the following spectrum blocks:

C Block: 747 MHz – 752 MHz: Down-link (Node B transmit, UE receive)
777 MHz - 782 MHz: Up-link (UE transmit, Node B receive)

D Block: 752 MHz – 762 MHz: Down-link (Node B transmit, UE receive)
782 MHz – 792 MHz: Up-link (UE transmit, Node B receive)

NOTE 1: In these blocks the Node-B transmits in the lower frequency block as this convention has been mandated by the FCC for the public safety spectrum in the Upper 700 MHz band.

Petitioners' Exhibit 1003, p. 248
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Lower 700 MHz band includes the following spectrum blocks:

A Block:	698 MHz – 704 MHz: Up-link (UE transmit, Node B receive)
	728 MHz - 734 MHz: Down-link (Node B transmit, UE receive)
B Block:	704 MHz – 710 MHz: Up-link (UE transmit, Node B receive)
	734 MHz – 740 MHz: Down-link (Node B transmit, UE receive)
C Block:	710 MHz – 716 MHz: Up-link (UE transmit, Node B receive)
	740 MHz – 746 MHz: Down-link (Node B transmit, UE receive)

NOTE 2: In these blocks the conventional duplexing is used with the Node-B transmitting in the upper frequency blocks as this should mitigate interference with base stations in the Upper 700 MHz band.

NOTE 3: GSM specifications used a reversed duplexing direction in the Lower 700 MHz band (GSM 710 band) and this should be corrected in the GSM specifications.

Petitioners' Exhibit 1003, p. 249
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

15.2 UMTS 1500 MHz UID_350034

Resources: R4

References

Document	Title/Contents
WID(s)	
RP-070078	WID on UMTS1500
Impacted Specifications	
TR 25.942	Radio Frequency (RF) system scenarios
TS 25.101	User Equipment (UE) radio transmission and reception (FDD)
TS 25.104	Base Station (BS) radio transmission and reception (FDD)
TS 25.133	Requirements for support of radio resource management (FDD)
TS 25.141	Base Station (BS) conformance testing (FDD)
TS 25.306	UE Radio Access capabilities
TS 25.307	Requirements on User Equipments (UEs) supporting a release-independent frequency band
TS 25.331	Radio Resource Control (RRC); Protocol specification
TS 34.121	Terminal conformance specification, Radio transmission and reception (FDD)
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: eAccess, Fujitsu, Mitsubishi, NEC, NTT DoCoMo, Panasonic, Softbank Mobile.

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
350034	**UMTS 1500 MHz**	R4	RP-070078	RP-070526	25.101, 25.104, 25.133, 25.141, 25.331, 25.942, 25.306, 25.307, 34.121

A WG has been established under the national Information and Communications council in Japan to consider the technical condition of the frequency re-arrangement in 1500 MHz band in order to enhance frequency efficiency. The study included co-existing studies with the following technologies: PDC system (ARIB standard RCR STD-27), DIGITAL MCA system (ARIB standard RCR STD-32), Radio astronomy systems, and Mobile satellite communication service, taking the frequency reframing plan in Japan into account. Therefore, the proponents believe that there is high possibility that IMT-2000 would be introduced in Japan in this band.

The consideration of the evolution and migration to introduce IMT-2000 in the 1500 MHz band being studied in the WG under the national Information and Communications council in Japan could be used as the basis for this work, which would reduce the effort required within 3GPP.

UMTS 1500 for potential deployment in Japan:

- 1427.9 - 1452.9 MHz: Up-link (UE transmit, Node B receive)
- 1475.9 - 1500.9 MHz: Down-link (Node B transmit, UE receive)

Petitioners' Exhibit 1003, p. 250
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

15.3 UMTS 1880 MHz TDD UID_410018

Resources: R4

References

Document	Title/Contents
WID(s)	
RP-080757	WID on UMTS 1880 MHz TDD
Impacted Specifications	
TS 25.102	User Equipment (UE) radio transmission and reception (FDD)
TS 25.105	Base Station (BS) radio transmission and reception (TDD)
TS 25.113	Base station and repeater electromagnetic compatibility (EMC)
TS 25.123	Requirements for support of radio resource management (TDD)
TS 25.142	Base Station (BS) conformance testing (TDD)
TS 25.307	Requirements on User Equipments (UEs) supporting a release-independent frequency band
TS 25.331	Radio Resource Control (RRC); Protocol specification
TS 34.124	Electromagnetic compatibility (EMC) requirements for mobile terminals and ancillary equipment
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: CATT, China Mobile, RITT, Spreadtrum Communications, TD Tech, ZTE

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
410018	**UMTS 1880 MHz TDD**	R4	RP-080757	RP-090044	25.102, 25.105, 25.113, 25.123, 25.142, 34.124, 25.307

In China the band 1880-1920 MHz was allocated to LCR TDD.
This work specifies 1.28Mcps TDD system operation in the band 1880-1920 MHz.

Status report in RP-090044

Petitioners' Exhibit 1003, p. 251
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

15.4 UMTS 2300 MHz TDD LCR UID_380074

Resources: R4

References

Document	Title/Contents
WID(s)	
RP-071016	WID on UMTS 2300MHz TDD
Impacted Specifications	
TS 25.102	User Equipment (UE) radio transmission and reception (TDD)
TS 25.105	Base Station (BS) radio transmission and reception (TDD)
TS 25.113	Base station and repeater electromagnetic compatibility (EMC)
TS 25.123	Requirements for support of radio resource management (TDD)
TS 25.142	Base Station (BS) conformance testing (TDD)
TS 25.306	UE Radio Access capabilities
TS 25.331	Radio Resource Control (RRC); Protocol specification
TS 34.122	Terminal conformance specification, Radio transmission and reception (TDD)
TS 34.124	Electromagnetic compatibility (EMC) requirements for mobile terminals and ancillary equipment
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: CATT, China Mobile, Huawei, RITT, Spreadtrum Communications, TD-Tech, ZTE.

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
380074	**UMTS 2300 MHz TDD LCR**	R4	RP-071016	RP-080517	25.102, 25.105, 25.113, 25.123, 25.142, 34.124, 25.306, 25.331, 34.122

In China the band 2300MHz - 2400MHz had been allocated to TD-SCDMA system and has been introduced in CCSA standard. More recently at WRC 07 this band was allocated to the mobile service on a primary basis and identified for IMT. This band was introduced in the 3GPP specifications for LCR TDD.

This work specifies the 1.28Mcps TDD system operation in the band 2300-2400MHz.

Petitioners' Exhibit 1003, p. 252
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

15.5 Further Improved Minimum Performance Requirements for HSDPA UE (FDD) - Two-Branch Interference Cancellation UID_350037

Resources: R4

References

Document	Title/Contents
	WID(s)
RP-070254	WID on Further Improved Minimum Performance Requirements for UMTS/HSDPA UE (FDD): Two-Branch Interference Cancellation
	Impacted Specifications
TS 25.101	User Equipment (UE) radio transmission and reception (FDD)
	New Dedicated Specifications/Reports
-	-

Supporting Individual Members: AT&T, Ericsson, Motorola, Tensorcomm

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
350037	**Further Improved Minimum Performance Requirements for HSDPA UE (FDD) - Two-Branch Interference Cancellation**	R4	RP-070254	RP-080041	25.101

RAN#30 approved a study item on improved minimum performance requirements for UMTS/HSDPA UE (FDD). RAN4 has since assessed feasibility of both one-branch and two-branch interference cancellation/mitigation receivers. These receivers attempt to cancel the interference that arises from users operating outside the serving cell.
This type of interference is also referred to as 'other cell' interference. In past link level evaluations, this type of interference has been modelled as AWGN, and as such can not be cancelled. The study has developed models for this interference in terms of the number of interfering Node Bs to consider, and their powers relative to the total other cell interference power, the latter ratios referred to as Dominant Interferer Proportion (DIP) ratios. DIP ratios have been defined based on three criteria; median values of the corresponding cumulative density functions, weighted average throughput gain, and field data.

Interference aware receivers (referred to as Type 2i and Type 3i) were defined for Type 2 and Type 3 receivers, respectively. HSDPA throughput gains for the Type 3i receiver were found to be significant for DIP ratios based on the weighted average throughput gain and field data at low geometries. For example, the gains for the DIP ratios based on the weighted average ranged from a factor of 1.2 to 2.05 for QPSK H-SET6 PB3, and from 1.2 to 3.02 for VA30 for network geometries of -3 and 0 dB.
System level studies indicated that a Type 3i receiver provided significant gains in coverage ranging from 20-55% depending upon the channel and user location. In addition, the Type 3i receiver is based upon known and mature signal processing techniques, and thus, the complexity is minimized. With two-branch, equalizer-based receivers already available in today's marketplace, it appears quite doable to develop a two-branch equalizer with interference cancellation/mitigation capabilities.

Given the above, it was concluded that two-branch interference cancellation receivers are feasible for HSDPA

Type 3i receiver has been used as the reference receiver for defining the new specification values for TS 25.101.

This work improves the link level performance of various HSDPA downlink channels in the presence of other cell interference thereby improving the spectral efficiency of these services.

Petitioners' Exhibit 1003, p. 253
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

15.6 CS Voice Service over HSPA UID_370032

Resources: R2

References

Document	Title/Contents
WID(s)	
RP-070765	WID on CS Voice Service over HSPA
Impacted Specifications	
TS 25.322	Radio Link Control (RLC) protocol specification
TS 25.323	Packet Data Convergence Protocol (PDCP) specification
TS 25.331	Radio Resource Control (RRC); Protocol specification
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Nokia, Nokia Siemens Networks, Qualcomm, Orange, Telefonica, Huawei, Telecom Italia, AT&T, Telekom Austria, Vodafone.

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
370032	**CS Voice Service over HSPA**	R2	RP-070823	RP-070765	25.323, 25.331, 25.322
25050	**Conformance Test Aspects – CS Voice Service over HSPA**	R5	RP-080160	RP-080542	34.108, 34.123-1, 34.123-2, 34.123-3

During Rel-7 several improvements for running voice service over HSPA were introduced to boost capacity and reduce battery consumption of the devices. As these improvements are not available for CS domain speech running on DCH, this work enables mapping the CS domain speech on HSPA. This as such could be seen not limited to speech only, but in this work item speech case shall be focused on. This approach also provides benefits to the VCC operation.

The reasons to consider running CS speech over HSPA are:

- use of DCH in a cell could be minimized and thus more power and code resources are available for HSDPA use
- setting up of the CS call could be faster as well as when using HSPA for SRB
- availability of the benefits of the features in the WI Continuous Connectivity for Packet Data Users, including DTX/DRX for devices to save battery and reduce interference
- faster set-up of PS services in parallel to CS speech as HSPA is readily on

This work provides a mechanism to map CS services over HSPA channels instead of traditional DCH and covers:

- RRC signalling to map CS service to HSPA
- how to multiplex RAB sub-flows
- avoid specification impact to MAC layer
- ensure interoperability with protocol layers above the RAN

15.6.1 Conformance Test Aspects – CS Voice Service over HSPA UID_25050

Resources: R5

UID	Title	WID	SR	TS-TR
25050	**Conformance Test Aspects – CS Voice Service over HSPA**	RP-080160	RP-080542	34.108, 34.123-1, 34.123-2, 34.123-3

Petitioners' Exhibit 1003, p. 254
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

15.7 Performance requirements for 15 code reception with 16QAM/QPSK (FDD) UID_370033

Resources: R4

References

Document	Title/Contents
WID(s)	
RP-070745	WID on Performance requirements for 15 code reception with 16QAM/QPSK (FDD)
Impacted Specifications	
TS 25.101	User Equipment (UE) radio transmission and reception (FDD)
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Vodafone, Ericsson, Huawei, Interdigital, Nokia, Nokia Siemens Networks, Orange, Qualcomm, Telecom Italia

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
370033	**Performance requirements for 15 code reception with 16QAM/QPSK (FDD)**	R4	RP-070745	RP-080043	25.101
400055	**Conformance Test Aspects – Performance requirements for 15 code reception with 16QAM/QPSK (FDD)**	R5	RP-080311	RP-080818	34.121-1, 34.121-2

It is important for operators to be able to maximise spectrum efficiency in their UMTS networks. Recently 64QAM demodulation requirements with 15 code reception for HSDPA have been progressed in RAN4 with the aim to improve peak rates but also provide some gains in spectrum efficiency.

Since Rel-5 there have been discussions on whether HSDPA demodulation requirements for 15 code reception with 16QAM and QPSK are needed (until Rel-7 this has only been applicable for category 9/10 UEs). Until now it was felt that the use of such a configuration in the UE may be a rare use case, and the work was never completed in 3GPP.

However, on completing the 64QAM and MIMO work item in Rel-7, there is now a gap in demodulation performance requirements between QPSK with 10 codes, 16QAM with 10 codes, and 64QAM with 15 codes. Adding performance requirements for QPSK and 16QAM HSDPA reception with 15 codes allows operators to guarantee that they can maximize the spectrum efficiency performance in their networks by maximizing throughputs particularly in the case when the UE is not in conditions suitable for 64QAM reception. In addition, this allows UEs not supporting 64QAM or MIMO to have the capability to maximize their potential throughput in the cell.

This work introduces performance requirements for QPSK and 16QAM with 15 codes for the HSDPA UE categories 9, 10 and 13 to 16 based on the same reference receiver assumptions as used to derive the enhanced performance requirements Type 2 and Type 3 in Rel-6 and Rel-7 (i.e. LMMSE chip level equalizer with one and two antenna ports). No specific UE implementation is mandated by these enhanced HSDPA requirements.

Status report in RP-080043

15.7.1 Conformance Test Aspects – Performance requirements for 15 code reception with 16QAM/QPSK (FDD) UID_400055

Resources: R5

UID	Title	WID	SR	TS-TR
400055	**Conformance Test Aspects – Performance requirements for 15 code reception with 16QAM/QPSK (FDD)**	RP-080311	RP-080818	34.121-1, 34.121-2

Petitioners' Exhibit 1003, p. 255
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

16 RAN improvements UID_370035

Resources: RP

UID	Name	Resource	Hyperlink	Status_Report
370035	**Rel-8 RAN improvements**	RP	-	-
360013	**Combination of 64QAM and MIMO for HSDPA (FDD)**	R1	RP-070500	RP-080518
410020	Conformance Test Aspects – Combination of 64QAM and MIMO for HSDPA (FDD)	R5	RP-080759	RP-091058
370036	**Improved L2 for uplink**	R2	RP-070717	RP-080265
400056	Conformance Test Aspects – Improved L2 for uplink	R5	RP-080606	RP-090712
440010	Conformance Test Aspects – 1.28 Mcps TDD Improved L2 support for high data rates	R5	RP-090491	RP-100486
370037	**Enhanced Uplink for CELL_FACH State in FDD**	R2	RP-070677	RP-080804
430024	Conformance Test Aspects – Enhanced Uplink for CELL_FACH State in FDD	R5	RP-090152	RP-100483
370038	**Enhanced UE DRX for FDD**	R2	RP-070679	RP-080520
370039	**Enhancements for SRNS Relocation Procedure**	R3	RP-070759	RP-080521
370040	**Enhancements for FDD HSPA Evolution**	R3,R2	RP-080830	RP-080805
380075	**64QAM for 1.28 Mcps TDD HSDPA**	R1	RP-070924	RP-080806
400057	Conformance Test Aspects – 64QAM for 1.28 Mcps TDD HSDPA	R5	RP-080334	RP-090415
380076	**Enhanced CELL_FACH state in 1.28 Mcps TDD**	R2	RP-071038	RP-080807
440009	Conformance Test Aspects – Enhanced CELL_FACH State in LCR TDD	R5	RP-090490	RP-100484
390028	**Continuous Connectivity for packet data users for 1.28 Mcps TDD**	R1	RP-080085	RP-090394
450024	Conformance Test Aspects – Continuous Connectivity for packet data users for 1.28 Mcps TDD	R5	RP-090751	RP-100490
390029	**HSPA VoIP to WCDMA/GSM CS continuity**	R2	RP-080749	RP-090050
390030	**HS-DSCH Serving Cell Change Enhancements**	R2	RP-080227	RP-080811
450026	Conformance Test Aspects – HS-DSCH Serving Cell Change Enhancements	R5	RP-090756	RP-100077
400050	**MIMO for 1.28 Mcps TDD**	R1,R4	RP-080485	RP-090313
450025	Conformance Test Aspects – MIMO for 1.28 Mcps TDD	R5	RP-100120	RP-100660
400052	**Dual-Cell HSDPA operation on adjacent carriers**	R1,R4	RP-080490	RP-080814
420015	Conformance Test Aspects – Dual-Cell HSDPA operation on adjacent carriers	R5	RP-080996	RP-100479
430028	**Conformance Test Aspects – Receiver Type3i**	R5	RP-090010	RP-091066

Petitioners' Exhibit 1003, p. 256
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

16.1 Combination of 64QAM and MIMO for HSDPA (FDD) UID_360013

Resources: R1

References

Document	Title/Contents
WID(s)	
RP-070500	WID on Combination of 64QAM and MIMO for HSDPA (FDD)
Impacted Specifications	
TS 25.101	User Equipment (UE) radio transmission and reception (FDD)
TS 25.104	Base Station (BS) radio transmission and reception (FDD)
TS 25.141	Base Station (BS) conformance testing (FDD)
TS 25.211	Physical channels and mapping of transport channels onto physical channels (FDD)
TS 25.212	Multiplexing and channel coding (FDD)
TS 25.213	Spreading and modulation (FDD)
TS 25.306	UE Radio Access capabilities
TS 25.308	High Speed Downlink Packet Access (HSDPA); Overall description; Stage 2
TS 25.331	Radio Resource Control (RRC); Protocol specification
TS 25.423	UTRAN Iur interface Radio Network Subsystem Application(RNSAP) signalling
TS 25.425	UTRAN Iur interface user plane protocols for Common Transport Channel data stream
TS 25.433	UTRAN Iub interface Node B Application Part (NBAP) signalling
TS 25.435	UTRAN Iub interface use plane protocols for Common Transport Channel data streams
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: AT&T, Ericsson, 3, Qualcomm, TeliaSonera, Telecom Italia

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
360013	**Combination of 64QAM and MIMO for HSDPA (FDD)**	R1	RP-070500	RP-080518	25.308, 25.211, 25.212, 25.213, 25.306, 25.331, 25.433, 25.435, 25.423, 25.425, 25.101, 25.104, 25.141
410020	Conformance Test Aspects – Combination of 64QAM and MIMO for HSDPA (FDD)	R5	RP-080759	RP-091058	34.108, 34.121-1, 34.121-2, 34.123-1, 34.123-2

64QAM use in the downlink is an attractive complement to multi-antenna techniques (MIMO) in the downlink, e.g. in scenarios where deployment of MIMO is not possible.
The combination of 64QAM and MIMO allows for further increased user throughput in favourable radio conditions such as in well tuned outdoor systems or indoor system solutions (cells with isolation).

This work provides support of 64QAM as a downlink modulation scheme for HSDPA in FDD in combination with MIMO for Type II/III UEs, building upon provisions taken together with the introduction of 64QAM support.
This specification includes:

- L1 aspects of 64QAM combined with MIMO
- L2/L3 aspects of 64QAM combined with MIMO
- Iub/Iur support for 64QAM combined with MIMO
- BS and UE requirements for 64QAM combined with MIMO for an agreed set of radio conditions/environments.
- Requirement set point to take the BTS impairments into account

16.1.1 Conformance Test Aspects – Combination of 64QAM and MIMO for HSDPA (FDD) UID_410020

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
410020	Conformance Test Aspects – Combination of 64QAM and MIMO for HSDPA (FDD)	R5	RP-080759	RP-091058	34.108, 34.121-1, 34.121-2, 34.123-1, 34.123-2

Petitioners' Exhibit 1003, p. 257
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

16.2 Improved L2 for uplink UID_370036

Resources: R2

References

Document	Title/Contents
WID(s)	
RP-070717	WID on Improved L2 for uplink
Impacted Specifications	
TS 25.319	Enhanced Uplink, Overall description; stage 2
TS 25.301	Radio Interface Protocol Architecture
TS 25.306	UE Radio Access capabilities
TS 25.321	Medium Access Control (MAC) protocol specification
TS 25.322	Radio Link Control (RLC) protocol specification
TS 25.331	Radio Resource Control (RRC); Protocol specification
TS 25.433	UTRAN Iub interface Node B Application Part (NBAP) signalling
TS 25.435	UTRAN Iub interface use plane protocols for Common Transport Channel data streams
TS 25.423	UTRAN Iur interface Radio Network Subsystem Application(RNSAP) signalling
TS 25.425	UTRAN Iur interface user plane protocols for Common Transport Channel data streams
TS 25.427	UTRAN Iur/Iub interface user plane for DCH data streams
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Ericsson, Nokia Siemens Networks, Nokia, T-Mobile.

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
370036	**Improved L2 for uplink**	R2	RP-070717	RP-080265	25.319, 25.301, 25.306, 25.321, 25.331, 25.433, 25.435, 25.423, 25.425, 25.427
400056	Conformance Test Aspects – Improved L2 for uplink	R5	RP-080606	RP-090712	34.108, 34.123-1, 34.123-2, 34.123-3
440010	Conformance Test Aspects – 1.28 Mcps TDD Improved L2 support for high data rates	R5	RP-090491	RP-100486	34.108, 34.123-1, 34.123-2, 34.123-3

Work linked to UID_370037 Enhanced Uplink for CELL_FACH State in FDD.

Rel-7 Work Item “Improved L2 support for high data rates” achieved the targeted results of having link layer support for high data rates in downlink, a single DL L2 evolution for all performance enhancements and a smooth transition between old and new DL protocol formats. Flexible RLC PDU sizes and MAC segmentation in downlink were introduced in order to reach high data rates and reduce protocol overhead and padding.

The link layer enhancements in the uplink were not covered in Rel-7.

Analogous to downlink, the RLC protocol with fixed PDU size cannot efficiently support high uplink data rates. Large PDUs allow for higher peak-rates, but it can create problems at the cell border when the UE is power-limited.

In addition to supporting high data rates efficiently, flexible RLC PDU sizes allow reduced header overhead and padding. In addition, the flexible RLC PDU sizes allow less PDUs to be transmitted in a TTI, leading to reduced processing load in the terminals and the network equipment.

Support of enhanced CELL_FACH, CELL_PCH and URA_PCH state was included in the L2 DL improvements. Similarly for the uplink the enhanced protocol should support seamless state transitions between CELL_DCH, CELL_FACH, CELL_PCH and URA_PCH. This however may be dependent on potential enhancements to the CELL_FACH UL data transmission.

In addition MAC segmentation reduced the reduces residual HARQ error rate for high data rates and allows efficient operation at power limited scenarios.

Therefore it would be beneficial to adopt future proof solutions that provide support for flexible RLC PDU sizes and MAC segmentation in uplink. The uplink protocol should also provide a single L2 evolution for all performance enhancements.

In order to facilitate easy deployment of the enhanced protocols, as well as backward compatibility, the methods to enhance transition between old and new PDU formats should be evaluated.

Petitioners' Exhibit 1003, p. 258
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

This work provides a solution for link layer protocols in the uplink for Rel-8, which

- introduces support for flexible RLC PDU sizes
- introduces support for MAC segmentation
- allows smooth transition between old and new protocol formats
- supports seamless state transitions between CELL_DCH, CELL_FACH, CELL_PCH and URA_PCH (dependent on potential enhancements to the CELL_FACH UL transmission)

16.2.1 Conformance Test Aspects – Improved L2 for uplink UID_400056

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
400056	Conformance Test Aspects – Improved L2 for uplink	R5	RP-080606	RP-090712	34.108, 34.123-1, 34.123-2, 34.123-3

16.2.2 Conformance Test Aspects – 1.28 Mcps TDD Improved L2 support for high data rates UID_440010

Testing for Rel-7 UID_340039 Improved L2 support for high data rates and Rel-8 UID_370036 Improved L2 for uplink

UID	Name	Resource	Hyperlink	Status_Report	rapporteur	Notes	TS_TR
440010	**Conformance Test Aspects – 1.28 Mcps TDD Improved L2 support for high data rates**	R5	RP-090491	RP-100737	CATT	RP#49 completed. Testing for Rel-7 UID_340039 Improved L2 support for high data rates and Rel-8 UID_370036 Improved L2 for uplink	34.108, 34.123-1, 34.123-2, 34.123-3

Petitioners' Exhibit 1003, p. 259
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

16.3 Enhanced Uplink for CELL_FACH State in FDD UID_370037

Resources: R2

References

Document	Title/Contents
WID(s)	
RP-070677	WID on Enhanced Uplink for CELL_FACH State in FDD
Impacted Specifications	
TS 25.211	Physical channels and mapping of transport channels onto physical channels (FDD)
TS 25.214	Physical layer procedures (FDD)
TS 25.309	FDD Enhanced Uplink, Overall description; stage 2
TS 25.321	Medium Access Control (MAC) protocol specification
TS 25.331	Radio Resource Control (RRC); Protocol specification
TS 25.423	UTRAN Iur interface Radio Network Subsystem Application Part (RNSAP) signalling
TS 25.433	UTRAN Iub interface Node B Application Part (NBAP) signalling
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Nokia Siemens Networks, Nokia, Ericsson, Qualcomm, T-Mobile, Telecom Italia.

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
370037	**Enhanced Uplink for CELL_FACH State in FDD**	R2	RP-070677	RP-080804	25.309, 25.211, 25.214, 25.321, 25.331, 25.423, 25.433
430024	Conformance Test Aspects – Enhanced Uplink for CELL_FACH State in FDD	R5	RP-090152	RP-100483	34.108, 34.121-1, 34.121-2, 34.123-1, 34.123-2, 34.123-3

Work linked to UID_370036 Improved L2 for uplink.

In a modern telecommunication network such as UMTS, the operator aims to offer high Quality of Service to users. QoS is the collective effect of service performances, which determine the degree of satisfaction of a user of a service.

Under the heading of Quality of Experience (QoE) one of the more noticeable points faced by a user is the apparent set-up delay or channel allocation time for various connections as well as stand-by times of battery-operated devices.

Considerations how common channels can be made more efficient to address cases where the usage of CELL_DCH state is not preferred by the network are motivated by high interest on "always on"- type of services like active VoIP clients, PoC, Push email and VPN connections expected to be used via UTRAN, which introduce relatively frequent but small packets to be transmitted between UE and server.

Work to reduce uplink and downlink signalling delays, to overcome the limitations of 3GPP Rel-99 common transport channels, was continued in Rel-7 with the WI “Enhanced CELL_FACH state in FDD”. Reduced downlink signalling delays and higher downlink bit rate in CELL_FACH, CELL_PCH and CELL_URA states were achieved by introducing downlink optimizations of the radio together with Node B based scheduling using HSPA. However, the benefits of this enhancement are limited by the poor uplink counterpart.

Thus the target to modify non-CELL_DCH state operations to reduce uplink and downlink signalling delays is not fully addressed if not investigating packet optimized radio together with Node B based scheduling also for uplink.

The reasons to improve the uplink common channel RACH can be summarised as ease of initiating the data transmission and frequent need of many always-on applications to transmit keep-alive messages:

- Sending an HTTP request takes roughly 500 bytes and it has been observed that this requires over ten Rel-99 random accesses to transmit a complete HTTP request which is too much to be in any way practical and a transition to CELL_DCH is needed. However, moving the UE to the CELL_DCH state before sending any uplink messages introduces significant delay before the actual data download can start.
- A typical VoIP application keep-alive message from the application to the network indicating the server that the application is ready to receive calls is too large to fit on a RACH message easily triggering a state transition to CELL_DCH.
  This is bad for the UE power consumption and is very inefficient for the network resource handling.

This work provides the necessary modifications to random access in the 3GPP specifications by:

Petitioners' Exhibit 1003, p. 260
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Reducing the latency of user and control plane in the IDLE mode, CELL_FACH, Cell_PCH and URA_PCH state
- Increasing the available peak rate for UEs in CELL_FACH state by direct HSUPA access in CELL_FACH state
- Reducing state transition delay from CELL_FACH, CELL_PCH and URA_PCH state to CELL_DCH state

Complexity and backward compatibility were considered as well.

16.3.1 Conformance Test Aspects – Enhanced Uplink for CELL_FACH State in FDD UID_430024

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
430024	Conformance Test Aspects – Enhanced Uplink for CELL_FACH State in FDD	R5	RP-090152	RP-100483	34.108, 34.121-1, 34.121-2, 34.123-1, 34.123-2, 34.123-3

Petitioners' Exhibit 1003, p. 261
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

16.4 Enhanced UE Discontinuous Reception (DRX) for FDD UID_370038

Resources: R2

References

Document	Title/Contents
WID(s)	
RP-070679	WID on Enhanced UE DRX for FDD
Impacted Specifications	
TS 25.306	UE Radio Access capabilities
TS 25.308	High Speed Downlink Packet Access (HSDPA)
TS 25.321	Medium Access Control (MAC) protocol specification
TS 25.331	Radio Resource Control (RRC); Protocol specification
TS 25.423	UTRAN Iur interface Radio Network Subsystem Application(RNSAP) signalling
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Nokia, Nokia Siemens Networks, Qualcomm, LG Electronics, Philips, NXP.

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
370038	**Enhanced UE Discontinuous Reception (DRX) for FDD**	R2	RP-070679	RP-080520	25.306, 25.308, 25.321, 25.331, 25.423

Rel-7 work item "Continuous connectivity for packet data users" UID_20046 (or "Continuous Packet Connectivity"), enhanced the efficiency of radio links when not actively transmitting data in either direction.
This Rel-7 efficiency enhancement can be seen both in the system capacity as well in the UE battery consumption.

Rel-7 did not completely covered the support for frequent transmission of small packets due to IP applications keeping their connection alive by periodically sending a message to the network. Despite this type of application being considered in the WI on Enhanced CELL_FACH, where such packets lead to the UE moving to CELL_FACH state and later being explicitly moved back to the CELL/URA_PCH state, there was little consideration of the actual continuous reception activity in CELL_FACH when the packet exchange is rather infrequent. This causes unnecessary receiver activity before the UE can be moved away form the CELL_FACH state, which leads to reduced UE battery life.
In addition, the signalling load is also further increased if the UE is kept in CELL_FACH for shorter periods.
Therefore, minimizing the signalling needed to move the UE from CELL_FACH state was also considered.

Rel-7 didn't fully covered also taking to limits the discontinuous reception opportunities for the CELL_DCH state.
Rel-7 provides a single DRX cycle that is activated if there is no data transmission to the UE over a given period.
But having just a single DRX cycle does not allow the system to use anything more than very conservatively set DRX cycle lengths.

This work provides enhanced power saving mechanisms for UE and reduces the state transition related signalling load by introducing support for:

- discontinuous reception scheme for CELL_FACH state
- efficient state transition from CELL_FACH to CELL/URA_PCH state
- enhanced DRX method to CELL_DCH state in addition to the one provided in Rel-7.

Complexity and backward compatibility were considered as well.

Petitioners' Exhibit 1003, p. 262
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

16.5 Enhancements for Serving Radio Network Subsystem (SRNS) Relocation Procedure UID_370039

Resources: R3

References

Document	Title/Contents
WID(s)	
RP-070759	WID on Enhancements for SRNS Relocation Procedure
Impacted Specifications	
TS 25.133	Requirements for support of radio resource management (FDD)
TS 25.214	Physical layer procedures (FDD)
TS 25.306	UE Radio Access capabilities
TS 25.308	High Speed Downlink Packet Access (HSDPA); Overall description; Stage 2
TS 25.321	Medium Access Control (MAC) protocol specification
TS 25.331	Radio Resource Control (RRC); Protocol specification
TS 25.423	UTRAN Iur interface Radio Network Subsystem Application Part (RNSAP) signalling
TS 25.433	UTRAN Iub interface Node B Application Part (NBAP) signalling
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Nokia, Nokia Siemens Networks, 3, Huawei, Telecom Italia, Vodafone, T-Mobile.

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
370039	**Enhancements for Serving Radio Network Subsystem (SRNS) Relocation Procedure**	R3	RP-070759	RP-080521	25.306, 25.308, 25.321, 25.331, 25.423, 25.433, 25.214, 25.133

Work linked to UID_370040 Enhancements for FDD HSPA Evolution.

Rel-7 Study “Scope of future FDD HSPA Evolution” TR 25.999 [High Speed Packet Access (HSPA) evolution; Frequency Division Duplex (FDD)] mainly focussed on a deployment scenario compliant with Rel-7 architecture, and resulted in introducing protocol support for this scenario where RNC functionality is merged with the NodeB. Some functions for this scenario were introduced in Rel-7 during this study phase.

Rel-7 didn't completed the mobility improvement in the above scenario where SRNS Relocation happens more frequently.

This work improves the SRNS Relocation procedure such that delay and signalling and processing load are reduced.

Special attention was paid to interworking aspects with previous versions of the affected protocol specifications.

Status report in RP-080521

Petitioners' Exhibit 1003, p. 263
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

16.6 Enhancements for FDD HSPA Evolution UID_370040

Resources: R3,R2

References

Document	Title/Contents
WID(s)	
RP-080830	WID on Enhancements for FDD HSPA Evolution
Impacted Specifications	
TS 25.301	Radio Protocol Interface Architecture
TS 25.346	Introduction of the Multimedia Broadcast Multicast Service (MBMS) in the Radio Access Network (RAN)
TS 25.401	UTRAN overall description
TS 25.413	UTRAN Iu interface RANAP signalling
TS 25.420	UTRAN Iur interface general aspects and principles
TS 25.423	UTRAN Iur interface RNSAP signalling
TS 25.427	UTRAN Iur/Iub interface user plane protocol for DCH data streams
TS 25.433	UTRAN Iub interface Node B Application Part (NBAP) signalling
New Dedicated Specifications/Reports	
TS 25.446	MBMS synchronisation protocol (SYNC)

Supporting Individual Members: Nokia, Nokia Siemens Networks, 3, Vodafone, T-Mobile, Telecom Italia, Huawei.

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
370040	**Enhancements for FDD HSPA Evolution**	R3,R2	RP-080830	RP-080805	25.401, 25.413, 25.420, 25.423, 25.427, 25.433, 25.446, 25.301, 25.346

This work is linked to Rel-7 Study "Scope of future FDD HSPA Evolution" TR 25.999 [High Speed Packet Access (HSPA) evolution; Frequency Division Duplex (FDD)].

TR 25.999 mainly focussed on a deployment scenario compliant with Rel-7 architecture, and resulted in introducing protocol support for this scenario where RNC functionality is merged with the NodeB.
Some functions for this scenario were introduced in Rel-7 during this study phase.

This work improves the support of a deployment scenario where RNC functionality is merged with the NodeB and provides enhancements in the areas of MBMS and RRM by:

- further RRM optimizations
- improved support of MBMS

Petitioners' Exhibit 1003, p. 264
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

16.7 64QAM for 1.28 Mcps TDD HSDPA UID_380075

Resources: R1

References

Document	Title/Contents
WID(s)	
RP-070924	WID on 64QAM for 1.28Mcps TDD HSDPA
Impacted Specifications	
TS 25.102	User Equipment (UE) radio transmission and reception (TDD)
TS 25.105	Base Station (BS) radio transmission and reception (TDD)
TS 25.123	Requirements for support of radio resource management (TDD)
TS 25.142	Base Station (BS) conformance testing (TDD)
TS 25.201	Physical layer - general description
TS 25.221	Physical channels and mapping of transport channels onto physical channels (TDD)
TS 25.222	Multiplexing and channel coding (TDD)
TS 25.223	Spreading and modulation (TDD)
TS 25.224	Physical layer procedures (TDD)
TS 25.306	UE Radio Access capabilities
TS 25.308	High Speed Downlink Packet Access (HSDPA); Overall description; Stage 2
TS 25.321	Medium Access Control (MAC) protocol specification
TS 25.331	Radio Resource Control (RRC); Protocol specification
TS 25.423	UTRAN Iur interface Radio Network Subsystem Application Part (RNSAP) signalling
TS 25.433	UTRAN Iub interface Node B Application Part (NBAP) signalling
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: RITT, CATT, TD-TECH, Spreadtrum Communications.

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
380075	**64QAM for 1.28 Mcps TDD HSDPA**	R1	RP-070924	RP-080806	25.102, 25.105, 25.123, 25.142, 25.201, 25.221, 25.222, 25.223, 25.224, 25.306, 25.308, 25.321, 25.331, 25.423, 25.433
400057	Conformance Test Aspects – 64QAM for 1.28 Mcps TDD HSDPA	R5	RP-080334	RP-090415	34.108, 34.122, 34.123-1, 34.123-2, 34.123-3

This work is linked to Rel-8 Study on Scope of future HSPA Evolution for 1.28 Mcps TDD (UID_370041) TR 25.824 (Scope of HighSpeed Packet Access (HSPA) Evolution for 1.28Mcps TDD).

The use of 64QAM in the downlink is an attractive complement to multi-antenna techniques (MIMO) in the downlink, e.g. in scenarios where deployment of MIMO is not possible.

TR 25.824 shows significant gains provided by 64QAM in scenarios where users can benefit in terms of increased throughput from favourable radio conditions such as in indoor system solutions or well tuned outdoor systems.

This work adds support of 64QAM as a downlink modulation scheme for HSDPA in TDD including specification of:

- L1 aspects of 64QAM
- L2/L3 aspects of 64QAM
- Iub/Iur support for 64QAM
- BS and UE requirements for 64QAM for an agreed set of radio conditions/environments.
- Requirement set point to take the BTS impairments into account

16.7.1 Conformance Test Aspects – 64QAM for 1.28 Mcps TDD HSDPA UID_400057

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
400057	Conformance Test Aspects – 64QAM for 1.28 Mcps TDD HSDPA	R5	RP-080334	RP-090415	34.108, 34.122, 34.123-1, 34.123-2, 34.123-3

Petitioners' Exhibit 1003, p. 265
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

16.8 Enhanced CELL_FACH state in 1.28 Mcps TDD UID_380076

Resources: R2

References

Document	Title/Contents
WID(s)	
RP-071038	WID on Enhanced CELL_FACH state in 1.28 Mcps TDD
Impacted Specifications	
TS 25.123	Requirements for support of radio resource management (TDD)
TS 25.221	Physical channels and mapping of transport channels onto physical channels (TDD)
TS 25.222	Multiplexing and channel coding (TDD)
TS 25.224	Physical Layer Procedures
TS 25.301	Radio interface protocol architecture
TS 25.302	Services provided by the physical layer
TS 25.304	User Equipment (UE) procedures in idle mode and procedures for cell reselection in connected mode
TS 25.306	UE Radio Access capabilities
TS 25.308	High Speed Downlink Packet Access (HSDPA); Overall description; Stage 2
TS 25.321	Medium Access Control (MAC) protocol specification
TS 25.331	Radio Resource Control (RRC); Protocol specification
TS 25.423	UTRAN Iur interface Radio Network Subsystem Application(RNSAP) signalling
TS 25.425	UTRAN Iur interface user plane protocols for Common Transport Channel data streams
TS 25.433	UTRAN Iub interface Node B Application Part (NBAP) signalling
TS 25.435	UTRAN Iub interface use plane protocols for Common Transport Channel data streams
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: ZTE, RITT, CATT, TD-TECH, Spreadtrum Communications.

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
380076	**Enhanced CELL_FACH state in 1.28 Mcps TDD**	R2	RP-071038	RP-080807	25.123, 25.221, 25.222, 25.224, 25.301, 25.302, 25.304, 25.306, 25.308, 25.319, 25.321, 25.331, 25.401, 25.423, 25.425, 25.433, 25.435

This work is linked to:

- Scope of future HSPA Evolution for 1.28Mcps TDD
- Improved L2 for uplink
- Enhanced CELL_FACH state in FDD
- Enhanced Uplink for CELL_FACH State in FDD
- Improved L2 support for high data rates

Rel-8 Study TR 25.824 (Scope of High Speed Packet Access (HSPA) Evolution for 1.28 Mcps TDD) focused on improving the capability and performance of HSPA-based radio networks. Enhancing CELL_FACH state was one of the subjects investigated during this study.

Delay in set up or channel allocation is one important measure of Quality of Service experienced by the subscriber. TR 25.815 shows that the setup delays on PS and CS domain can be significantly reduced by using HSPA for SRBs. Thus, signalling latency when SRBs are mapped on HSPA can meet the target requirements of Rel-7.

In current CELL_FACH state in 1.28Mcps TDD, the signalling delay on FACH and RACH can be seen as one bottle neck compared to signalling speed on HSPA. This can be identified by some "always on" type IMS services, where the UE is typically kept in CELL/URA_PCH state and normally moved to CELL_DCH when DL/UL user plane is activated. The enhancement on signalling bit rates in CELL_FACH state can reduce the signalling delay experienced by the RRC messages when transiting to CELL_DCH.

This work improves the CELL_FACH state by:

- increasing the available peak rate for UEs in CELL_FACH state by utilising HSPA in CELL_FACH state
- reducing the latency of user and control plane in the CELL_FACH, CELL_PCH and URA_PCH state by higher data peak rate
- reducing state transition delay from CELL_FACH, CELL_PCH and URA_PCH state to CELL_DCH state
- allowing lower UE power consumption in CELL_FACH state by discontinuous reception

Petitioners' Exhibit 1003, p. 266
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Complexity and backward compatibility were considered.

16.8.1 Conformance Test Aspects – Enhanced CELL_FACH State in LCR TDD UID_440009

UID	Name	Resource	Hyperlink	Status_Report	rapporteur	Notes	TS_TR
440009	**Conformance Test Aspects – Enhanced CELL_FACH State in LCR TDD**	R5	RP-090490	RP-100735	CATT	RP#49 completed	34.108, 34.123-1, 34.123-2, 34.123-3

Petitioners' Exhibit 1003, p. 267
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

16.9 Continuous Connectivity for packet data users for 1.28Mcps TDD UID_390028

Resources: R1

References

Document	Title/Contents
WID(s)	
RP-080085	WID on Continuous connectivity for packet data users for 1.28Mcps TDD
Impacted Specifications	
TS 25.308	High Speed Downlink Packet Access (HSDPA); Overall description; Stage 2
TS 25.319	Continuous connectivity for packet data users; 1.28Mcps TDD
New Dedicated Specifications/Reports	
TR 25.929	Continuous connectivity for packet data users; 1.28Mcps TDD

Supporting Individual Members: TD-TECH, RITT, ZTE, CATT, Spreadtrum Communications.

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
390028	**Continuous Connectivity for packet data users for 1.28 Mcps TDD**	R1	RP-080085	RP-090394	25.929, 25.308, 25.319

This work is linked to Study TR 25.824 (Scope of High Speed Packet Access (HSPA) Evolution for 1.28 Mcps TDD).

Packet-oriented features like HSDPA and E-DCH in UMTS promote the subscribers' desire for continuous connectivity, where the user stays connected over a long time span with only occasional active periods of data transmission, and avoiding frequent connection termination and re-establishment with its inherent overhead and delay.

This is the perceived mode a subscriber is used to in fixed broadband networks (e.g. DSL) and a precondition to attract users from fixed broadband networks.

For a high number of users in the cell it can be assumed that many users are not transmitting any user data for some time (e.g. for reading during web browsing or in between packets for periodic packet transmission such as VoIP). The corresponding overhead control channels and dedicated channels will significantly limit the number of users that can be efficiently supported.

As completely releasing dedicated channels during periods of temporary traffic inactivity would cause considerable delays for re-establishing data transmission and a corresponding bad user perception, this work intends to reduce the impact of control channels while maintaining the DCH state and allowing a much faster reactivation for temporarily inactive users.

This work aims reducing the code consumption (e.g. overhead of physical control channels or related signalling messages) of packet data users for both real-time (e.g. VoIP) and non real-time services (e.g. for users which have temporarily no data transmission in either uplink or downlink).
Packet data users considered here are using only HS-DSCH/E-DCH channels without UL DPCH and DL DPCH.

The aim is to increase the number of packet data users in the UMTS 1.28Mcps TDD system that can be kept efficiently in CELL_DCH state over a longer time period and that can restart transmission after a period of temporary inactivity with a much shorter delay (for example <100 ms) than would be necessary for re-establishment of a new connection.

Another aim is to reduce UE power consumption in CELL_DCH state over a long period by DTX and DRX.

16.9.1 Conformance Test Aspects – Continuous Connectivity for packet data users for 1.28 Mcps TDD UID_450024

UID	Name	Resource	Hyperlink	Status_Report	rapporteur	Notes	TS_TR
450024	**Conformance Test Aspects – Continuous Connectivity for packet data users for 1.28 Mcps TDD**	R5	RP-090751	RP-100739	ZTE	RP#49 completed	34.108, 34.123-1, 34.123-2, 34.123-3

Petitioners' Exhibit 1003, p. 268
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

16.10 HSPA VoIP to WCDMA/GSM CS continuity UID_390029

Resources: R2

References

Document	Title/Contents
WID(s)	
RP-080749	WID on HSPA VoIP to WCDMA/GSM CS continuity
Impacted Specifications	
TS 25.331	Radio Resource Control (RRC); Protocol specification
TS 25.413	UTRAN Iu interface Radio Access Network Application Part (RANAP) signalling
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Qualcomm, Orange, Telefonica, T-Mobile, Huawei, AT&T, Alcatel-Lucent, Nokia, Nokia Siemens Networks, Vodafone.

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
390029	**HSPA VoIP to WCDMA/GSM CS continuity**	R2	RP-080749	RP-090050	25.331, 25.413

SP#40 had granted SA2 an exception for any necessary changes to SR-VCC specifications as a consequence of the alignment between SR-VCC and HSPA VoIP to WCDMA/GSM CS continuity (see SA2 Liaison in RP-080609).
TSG RAN was informed about the SA2 solution for the SA request (see S2-086123).
This gave a clear direction for further work as SA2 specifications cover also HSPA for the SR-VCC framework.
Hence RAN2 has developed a compatible solution with SA2 thereby avoiding work on diverging alternatives).

A number of enhancements have been introduced in Rel-7 to optimize VoIP services over HSPA.
Support for VoIP service would not be ubiquitous over an operator's entire network from day one.
Therefore there is a need for CS voice to provide continuity of service over an entire network.

This work enhances RAN to allow UTRA-VoIP to WCDMA/GSM CS continuity within the SR-VCC framework defined in TS 23.216. This includes:

- RRC procedure allowing a connected mode UE to switch calls from VoIP to WCDMA CS or directly to GSM CS
- RNC relocation procedure allowing the VoIP call to be transferred to a CS call on UMTS or GSM
- Inform the RNC on UE SR-VCC capability
- Specify abnormal cases such as "handover failure, with the UE returning to the old cell".

16.11 HS-DSCH Serving Cell Change Enhancements UID_390030

Resources: R2

References

Document	Title/Contents
WID(s)	
RP-080227	WID on HS-DSCH Serving Cell Change Enhancements
Impacted Specifications	
TS 25.101	User Equipment (UE) radio transmission and reception (FDD)
TS 25.104	Base Station (BS) radio transmission and reception (FDD)
TS 25.133	Requirements for support of radio resource management (FDD)
TS 25.212	Multiplexing and channel coding (FDD)
TS 25.214	Physical layer procedures (FDD)
TS 25.308	High Speed Downlink Packet Access (HSDPA); Overall description; Stage 2
TS 25.321	Medium Access Control (MAC) protocol specification
TS 25.331	Radio Resource Control (RRC); Protocol specification
TS 25.423	UTRAN Iur interface Radio Network Subsystem Application(RNSAP) signalling
TS 25.433	UTRAN Iub interface Node B Application Part (NBAP) signalling
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Ericsson, Nokia, Nokia Siemens Networks, Qualcomm Europe, 3.

Petitioners' Exhibit 1003, p. 269
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
390030	**HS-DSCH Serving Cell Change Enhancements**	R2	RP-080227	RP-080811	25.101, 25.104, 25.133, 25.212, 25.214, 25.308, 25.321, 25.331, 25.423, 25.433
450026	Conformance Test Aspects – HS-DSCH Serving Cell Change Enhancements	R5	RP-090756	RP-100077	34.108, 34.121-1, 34.121-2, 34.123-1, 34.123-2, 34.123-3

HSPA related features have originally been proposed, optimized and deployed primarily for best effort data delivery. A number of features have been introduced in Rel-6 (F-DPCH) and Rel-7 (CPC) to enable efficient support of real-time services, in particular voice services, over the HSPA related channels. In 2005, 3GPP has also evaluated a proposal to enhance the HS-DSCH serving cell change procedure but could not find consensus that the requirements could not be met with the existing procedures.

Since then, the number of HSDPA deployments has increased significantly enabling more extensive analysis of the serving cell change performance based on actual field data rather than theoretical models. The interest in the transmission of voice bearers (including CS voice) over HS channels has also increased significantly in light of the possible capacity gain and power saving potential. Serving cell change (i.e. mobility) reliability is a critical metric when considering mapping of voice bearers over HS-DSCH. On that basis, a study has been started at RAN#38 to review the reliability of the HS-DSCH serving cell change procedure in the context of real-time services and considering the latest HS-DSCH related features and field experience.

Study on HS-PDSCH serving cell change enhancements (UID_380080 that produced no TR), has concluded that the success rate of the serving cell change procedure is compromised in some difficult scenarios and that enhancements of the serving cell change procedure would make sense to help improve success rate in difficult scenarios.

Candidate schemes for enhancement techniques have been presented and initially discussed in RAN1 and RAN2. These techniques are mostly related to procedures defined by RAN2.

The work specified enhancements to HS-DSCH serving cell change procedure, focusing on modifications needed to:

- Radio protocol procedures and structures
- Iub/Iur protocols
- UE, Base Station and RRM performance requirements

Number of options and impact on UE and network implementations was minimized.

16.11.1 Conformance Test Aspects – HS-DSCH Serving Cell Change Enhancements UID_450026

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
450026	Conformance Test Aspects – HS-DSCH Serving Cell Change Enhancements	R5	RP-090756	RP-100077	34.108, 34.121-1, 34.121-2, 34.123-1, 34.123-2, 34.123-3

Petitioners' Exhibit 1003, p. 270
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

16.12 MIMO for 1.28 Mcps TDD UID_400050

Resources: R1

References

Document	Title/Contents
WID(s)	
RP-080485	WID on MIMO for 1.28Mcps TDD
Impacted Specifications	
TS 25.201	Physical layer - general description
TS 25.102	User Equipment (UE) radio transmission and reception (TDD)
TS 25.105	Base Station (BS) radio transmission and reception (TDD)
TS 25.142	Base Station (BS) Conformance Testing (TDD)
TS 25.221	Physical channels and mapping of transport channels onto physical channels (TDD)
TS 25.222	Multiplexing and channel coding (TDD)
TS 25.223	Spreading and modulation (TDD)
TS 25.224	Physical layer procedures (TDD)
TS 25.306	UE Radio Access capabilities
TS 25.308	High Speed Downlink Packet Access (HSDPA); Overall description; Stage 2
TS 25.321	Medium Access Control (MAC) protocol specification
TS 25.331	Radio Resource Control (RRC); Protocol specification
TS 25.423	UTRAN Iur interface Radio Network Subsystem Application Part (RNSAP) signalling
TS 25.433	UTRAN Iub interface Node B Application Part (NBAP) signalling
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: CATT, RITT, Spreadtrum Communications, TD-TECH, ZTE.

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
400050	**MIMO for 1.28 Mcps TDD**	R1,R4	RP-080485	RP-090313	25.201, 25.221, 25.222, 25.223, 25.224, 25.306, 25.308, 25.321, 25.331, 25.423, 25.433, 25.102, 25.105, 25.142
450025	Conformance Test Aspects – MIMO for 1.28 Mcps TDD	R5	RP-100120	RP-100660	34.108, 34.122, 34.123-1, 34.123-2, 34.123-3

This work is linked to Study TR 25.824 (Scope of High Speed Packet Access (HSPA) Evolution for 1.28 Mcps TDD).

The MIMO technique is introduced to improve the downlink performance of HSPA system.

TR 25.824 shows that MIMO offers significant performance gains with acceptable impact to both UE and UTRAN.

This work improves the system capacity and spectral efficiency by increasing the data throughput in the downlink within the existing carrier. This is achieved by means of deploying multiple antennas at both UE and Node B side. This includes specification of:

- MIMO Physical Layer Aspects
- MIMO Layer 2 and 3 Protocol Aspects
- MIMO UTRAN Iub/Iur Protocol Aspects
- MIMO RF Transmission/Reception, System Performance Requirements and Conformance Testing

16.12.1 Conformance Test Aspects – MIMO for 1.28 Mcps TDD UID_450025

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
450025	Conformance Test Aspects – MIMO for 1.28 Mcps TDD	R5	RP-100120	RP-100660	34.108, 34.122, 34.123-1, 34.123-2, 34.123-3

Petitioners' Exhibit 1003, p. 271
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

16.13 Dual-Cell HSDPA operation on adjacent carriers UID_400052

Resources: R1,R4

References

Document	Title/Contents
WID(s)	
RP-080490	WID on Dual-Cell HSDPA operation on adjacent carriers
Impacted Specifications	
TS 25.101	User Equipment (UE) radio transmission and reception
TS 25.104	Base Station (BS) radio transmission and reception
TS 25.133	Requirements for support of radio resource management
TS 25.211	Physical channels and mapping of transport channels onto physical channels
TS 25.212	Multiplexing and channel coding
TS 25.213	Spreading and modulation
TS 25.214	Physical layer procedures
TS 25.215	Physical layer; Measurements
TS 25.308	High Speed Downlink Packet Access (HSDPA); Overall description; Stage 2
TS 25.321	Medium Access Control (MAC) protocol specification
TS 25.331	Radio Resource Control (RRC); Protocol specification
TS 25.423	UTRAN Iur interface Radio Network Subsystem Application Part (RNSAP) signalling
TS 25.433	UTRAN Iub interface Node B Application Part (NBAP) signalling
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Ericsson, Qualcomm, Huawei, Alcatel-Lucent, 3, TeliaSonera, Orange, Bouygues Telecom, eMobile Softbank Mobile, Telefonica, Vodafone.

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
400052	**Dual-Cell HSDPA operation on adjacent carriers**	R1,R4	RP-080490	RP-080814	25.101, 25.104, 25.133, 25.141, 25.211, 25.212, 25.213, 25.214, 25.215, 25.306, 25.308, 25.321, 25.331, 25.423, 25.433
420015	Conformance Test Aspects – Dual-Cell HSDPA operation on adjacent carriers	R5	RP-080996	RP-100479	34.108, 34.121-1, 34.121-2, 34.123-1, 34.123-2, 34.123-3

This work was triggered by the UID_390032 Study on Dual-Cell HSDPA (withdrawn TR 25.825 v100).

HSPA features are successfully deployed in many networks. HSPA based mobile internet offerings are very popular and data usage is rapidly increasing.

The peak user throughout has been significantly enhanced as part of Rel-7 (MIMO, Higher Order Modulation). Even better and more consistent user experience across the cell and in particular in the outer cell coverage area is desired.

Deployment of additional network resources, such as a second HSPA carrier, creates an opportunity for network resource pooling as a way to enhance the user experience, in particular when the radio conditions are such that existing techniques (e.g. MIMO) can not be used.

The "Study on Dual-Cell HSDPA operation" revealed feasibility, benefits and complexity of combining network radio resources (i.e. cells on adjacent carriers) to address the operators' desire for enhanced user experience and enhanced user experience consistency.

This work specifies dual-cell HSDPA operation for the following scenarios:

- dual cell transmission only applies to HSDPA physical channels
- two cells belong to the same Node-B and are on adjacent carriers
- two cells do not use MIMO to serve UEs configured for dual cell operation
- two cells operate in the same frequency band

16.13.1 Conformance Test Aspects – Dual-Cell HSDPA operation on adjacent carriers UID_420015

UID	Name	Resource	Hyperlink	Status_Report	TS_TR

Petitioners' Exhibit 1003, p. 272
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

420015	Conformance Test Aspects – Dual-Cell HSDPA operation on adjacent carriers	R5	RP-080996	RP-100479	34.108, 34.121-1, 34.121-2, 34.123-1, 34.123-2, 34.123-3

16.14 Conformance Test Aspects – Receiver Type3i UID_430028

Resources: R5

UID	Title	Hyperlink	Status_Report	Notes	TS-TR
430028	**Conformance Test Aspects – Receiver Type3i**	RP-090010	RP-091066	Testing for Receiver Type3i in 25.101 UE radio Tx and Rx FDD	34.108, 34.121-1, 34.121-2

Petitioners' Exhibit 1003, p. 273
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

16.15 3.84 Mcps TDD MBMS over a Single Frequency Network Integrated Mobile Broadcast (MBSFN-DOB)

Resources: R1

UID	Name	Resource	Hyperlink	Status_Report	TS_TR
360008	**3.84 Mcps TDD MBMS over a Single Frequency Network (MBSFN) Integrated Mobile Broadcast**	R1	RP-081124	RP-080218	25.102, 25.105, 25.123, 25.201, 25.221, 25.222, 25.223, 25.224, 25.304, 25.306, 25.331, 25.346, 25.402, 25.433
440008	**Conformance Test Aspects – 3.84 Mcps TDD MBMS over a Single Frequency Network (MBSFN) Integrated Mobile Broadcast**	R5	RP-090583	RP-100070	34.108, 34.122, 34.123-1, 34.123-2, 34.123-3

Supporting Individual Members: Ericsson, 3, LG Electronics, Nokia, Nokia Siemens Networks, TeliaSonera, Telecom Italia.

Impacted Specifications	
TS 25.102	User Equipment (UE) radio transmission and reception (TDD)
TS 25.105	BS radio transmission and reception (TDD) requirements
TS 25.123	Requirements for support of radio resource management (TDD)
TS 25.201	Physical layer - general description
TS 25.221	Physical channels and mapping of transport channels onto physical channels (TDD)
TS 25.222	Multiplexing and channel coding (TDD)
TS 25.223	http://www.3gpp.org/ftp/Specs/html-info/25223.htmSpreading and modulation (TDD)
TS 25.224	Physical layer procedures (TDD)
TS 25.304	User Equipment (UE) procedures in idle mode and procedures for cell reselection in connected mode
TS 25.306	UE Radio Access capabilities definition
TS 25.331	Radio Resource Control (RRC) protocol specification
TS 25.346	Introduction of the Multimedia Broadcast Multicast Service (MBMS) in the Radio Access network (RAN); Stage 2
TS 25.402	Synchronisation in UTRAN Stage 2
TS 25.433	UTRAN Iub interface NBAP signalling

This work is linked to the Rel-7 work items:

UID_340042 MBMS FDD Physical layer Enhancements
UID_340043 MBMS TDD Physical layer Enhancements

Rel-7 Study on Improvement of the Multimedia Broadcast Multicast Service (MBMS) in UTRAN (UID_20051) assessed in TR 25.905 the possibility of transmitting the MBMS service on all available DL resources using an SFN network with an TDD as well as with an FDD channel structure.

TR 25.905 shows that the attainable data rates using a SFN operation for MBMS can be greatly increased with a minimum impact on the physical channel structure, and thus minimum impact on UE receivers.
In order to take full advantage of the attainable data rates however, higher order modulation and receiver performance supporting MBSFN operation is necessary. To allow a smooth migration for existing UMTS networks towards MBSFN, the MBSFN Integrated Mobile Broadcast (IMB) has been proposed for TDD with a chip rate of 3.84Mcps.

This work includes support for MBSFN IMB 3.84Mcps TDD operation including:

- Configuration of a common primary scrambling code
- Receiver support for suitable equaliser technology, i.e. similar to Type-2 and Type-3
- Handling of delay spread in the UE receiver to support reception of MBSFN IMB that supports the assumed deployment scenario
- Ensuring backwards compatibility with the existing UTRA physical layer architectures in existing spectral assignments (legacy UEs should not camp on a dedicated MBSFN IMB carrier)
- Support for 16QAM on S-CCPCH
- Necessary radio protocol enhancements to support MBSFN IMB operation on a DL only MBSFN carrier
- Minimum UE capabilities related to the support of MBSFN IMB reception and the support of simultaneous services on the unicast carrier
- Iub user and control plane protocols to support MBSFN IMB operation
- UE reception performance requirements for applicable bands for the MBSFN IMB transmission
- BTS requirements for 16QAM transmission on S-CCPCH for applicable bands for the MBSFN IMB transmission

The following conditions apply:

Petitioners' Exhibit 1003, p. 274
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- UE mobility requirements and procedures related to the unicast carrier must be met
- No optimizations are done within this work item for single receiver (one local oscillator) UEs, i.e. MBMS data loss may occur during periods where a single receiver UE is receiving on the unicast carrier
- SFN area is limited to the RNC area
- unicast serving RNC does not need to be aware of a UE receiving transmissions from a MBSFN IMB carrier

Petitioners' Exhibit 1003, p. 275
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

17 GERAN Features

17.1 GERAN support for GERAN - 3G Long Term Evolution interworking (GELTE) UID_50583

Resources: GP,G1,C1,G3new

UID	Name	Resource	Hyperlink	Notes	TS_TR
50583	**GERAN support for GERAN - 3G Long Term Evolution interworking**	-	GP-061757	-	44.018, 44.060, 45.002, 45.008, 45.010, 48.008, 48.018, 51.010
51583	**G1 part**	G1	GP-061757	GP#41 completed	43.055, 43.129, 43.246, 45.002, 45.008, 45.010
52583	**G2 part**	G2	GP-061757	GP#41 completed	44.018, 44.060, 48.008, 48.018
53583	**CT1 part**	C1	GP-061757	-	24.008
54583	**Testing**	G3new	GP-061757	GP#52 completed	51.010

Supporting Individual Members: Alcatel, Cingular, Ericsson, Huawei, KPN, LG Electronics, Motorola, Nokia, Nortel Networks, Qualcomm, Research In Motion, Siemens, Telecom Italia, TeliaSonera, T-Mobile.

This work is linked to "3G Long term Evolution" UID_25029 and "System Architecture Evolution" UID_320005.

3GPP approved the above WIs for the evolution of 3GPP radio-access technology towards high-data-rate, low-latency and packet-optimized. Requirements for interworking with GERAN networks are captured in RAN TR 25.913 (Requirements for E-UTRA and E-UTRAN) the relevant being:

Co-existence and interworking with 3GPP RATs

The following requirements are applicable to inter-working between E-UTRA and other 3GPP systems:

a) E-UTRAN Terminals supporting also UTRAN and/or GERAN operation should be able to support measurement of, and handover from and to, both 3GPP UTRA and 3GPP GERAN systems correspondingly with acceptable impact on terminal complexity and network performance.
b) E-UTRAN is required to efficiently support inter-RAT measurements with acceptable impact on terminal complexity and network performance, by e.g. providing UE's with measurement opportunities through downlink and uplink scheduling.
c) Interruption time during handover of real-time services between E-UTRAN and UTRAN is less than 300 ms
d) Interruption time during handover of non real-time services between E-UTRAN and UTRAN should be less than 500 ms
e) Interruption time during handover of real-time services between E-UTRAN and GERAN is less than 300 msec
f) Interruption time during handover of non real-time services between E-UTRAN and GERAN should be less than 500 ms
g) Non-active terminals (such as one being in Rel-6 idle mode or CELL_PCH) which support UTRAN and/or GERAN in addition to E-UTRAN shall not need to monitor paging messages only from one of GERAN, UTRA or E-UTRA
h) Interruption time during handover between an E-UTRA broadcast stream and a UTRAN unicast stream providing the same service (e.g. same TV channel) is less than FFS. (Value to be agreed following SA guidance)
i) Interruption time during handover between an E-UTRA broadcast stream and a GERAN unicast stream providing the same service (e.g. same TV channel) is less than FFS. (Value to be agreed following SA guidance)
j) Interruption time during handover between an E-UTRA broadcast stream and a UTRAN broadcast stream providing the same service (e.g. same TV channel) is less than FFS. (Value to be agreed following SA guidance)

The above requirements apply where the GERAN and/or UTRAN networks provide support for E-UTRAN handover.

Reduction in network and terminal complexity and cost by not mandating support for the measurements and handovers to/from GERAN/UTRAN should be considered.

The interruption times above are to be considered as maximum values. These values may be revisited when the overall architecture and the E-UTRA physical layer has been defined in more detail.

This work adds functionality to the GERAN specifications to meet the above requirements. This includes changes to:

Petitioners' Exhibit 1003, p. 276
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- (P)BCCH System Information
- MS capabilities
- Packet Switched handover
- Session continuity
- InterRAT NACC
- MBMS

- Idle Mode measurements and cell (re)selection;
- Connected and GPRS mode MS measurements on LTE, and measurement reporting;
- MS timing aspects of interRAT change.

Based on experience in network deployment

- changes are performed for A/Gb mode only

17.1.1 Testing for GERAN support for GERAN - 3G Long Term Evolution interworking UID_54583

Resources: G3new

UID	Name	Resource	Hyperlink	Notes	TS_TR
54583	**Testing**	G3new	GP-061757	GP#52 completed	51.010

Petitioners' Exhibit 1003, p. 277
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

17.2 U-TDOA Enhancement (GUTEN) UID_50586

Resources: GP

References

Document	Title/Contents
WID(s)	
GP-070865	WID on U-TDOA Enhancement
Impacted Specifications	
TS 45.008	Radio subsystem link control
TS 43.059	Functional Stage 2 Description of Location Services in GERAN
TS 48.071	SMLC-BSS interface Layer 3 specification
New Dedicated Specifications/Reports	

Supporting Individual Members: TruePosition, T-Mobile USA, Cingular Wireless, SiRF Technology

For E9-1-1 calls, initial positioning is calculated at the beginning of a call. At that time, the MS is transmitting at the maximum power allowed by a BTS. When a mid-call request is received from a Public Safety Answering Point (PSAP) for a location update, the MS operates at a reduced power level in most cases. This results in a typical degradation of 20% for mid-call location accuracy when compared with initial call location accuracy. The goal is to provide the same level of location accuracy performance in mid-call scenarios as is currently provided in the initial call scenarios.

Upon receipt of an Uplink - Time Difference Of Arrival (U-TDOA) Request, the BSC orders the MS to increase power. The resulting interference from the additional power-up is minimal. In current network deployments, the MS typically transmits at the full power allowed by the BTS for approximately 3 seconds at the start of a call, prior to reducing the power level for the remainder of the call via the power control algorithms. This 3-second period accounts for approximately 25% of the total interference of the call, assuming an average call duration of two minutes. The proposed feature would cause the MS to be powered up to the maximum power level allowed by the BTS for about 3 seconds at some point mid-call when the updated location is required. Each location event for a given call would cause a 25% increase in the overall interference contributed by that particular call. E9-1-1 calls account for < 0.1% of all calls. Even in the case of a location update request for every E-9-1-1 call, the effect on the overall interference would be negligible (<0.025%). For services, a single power-up for a duration of 3 seconds for 1% of all calls would result in an interference increase of ~0.25%.

An alternative implementation would be to have the U-TDOA Response message indicate the timing of the power-up (i.e. frame number). This would reduce the needed power-up time to 1 second, further reducing interference concerns. The ability to eliminate this loss in call location accuracy through the use of temporary power-up for mid-call locations has been tested and proven effective in field trials.

This technique increases the probability of determining an MS location under circumstances which could cause degradation in location accuracy. An optional capability to increase MS transmit power was added to the U-TDOA location method.

Petitioners' Exhibit 1003, p. 278
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

17.3 GAN Enhancements (GANENH) UID_50587

Resources: GP

References

Document	Title/Contents
WID(s)	
GP-071484	WID on GAN Enhancements
GP-071560	WID on Update to GAN specifications, TS 43.318 and TS 44.318 for GAN Enhancements
Impacted Specifications	
TS 43.318	Generic Access Network (GAN); Stage 2
TS 44.318	Generic Access Network (GAN); Mobile GAN interface layer 3 specification
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: T-Mobile USA., 3, TeliaSonera, Nokia, Kineto, Alcatel-Lucent, LG Electronics.

Rel-7 GERAN TR 43.902 "Enhanced Generic Access Networks (EGAN) study" showed that all three technical proposals met the objectives of this GAN Enhancement WID, providing enhancement through different approaches.

GERAN found all options in TR 43.902 as feasible but decided to select the Iu-mode as it can be done completely within TSG GERAN and independently of the I-WLAN or SAE work items. The GAN Iu-mode:

- reduces the complexity for delivery of CS and PS services
- reduces the number of functions in the overhead and latency for PS services
- provides good optimization process for future integration

This work adds the GAN Iu-mode to the GAN specifications, TS 43.318 and TS 44.318.

17.3.1 Update TS 51.010 Mobile Station (MS) Conformance Specification for GAN Enhancements UID_53089

Resources: G3new

References

Document	Title/Contents
WID(s)	
GP-071563	WID on Update to TS 51.010 Mobile Station (MS) Conformance Specification for GAN Enhancements
Impacted Specifications	
TS 51.010	Mobile Station (MS) conformance specification
New Dedicated Specifications/Reports	
-	-

Petitioners' Exhibit 1003, p. 279
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

17.4 A-interface over IP (AoIP) UID_50591

Resources: GP,S4,C4,C1,C3

This Feature contains three building blocks as follows:

- GERAN UID_400041 GERAN aspects of AoIP (AoIP)
- SA4 UID_400042 Media Requirements for CS over IP based User Plane (AoIP-CSoIP)
- CTx UID_400y24 Core Network Impacts for A-Interface User Plane over IP (AoIP-CN)

GERAN aspects of AoIP UID_400041

Resources: GP

References

Document	Title/Contents
WID(s)	
GP-080901	WID on AoIP (A-interface over IP)
Impacted Specifications	
TS 48.001	Base Station System - Mobile-services Switching Centre (BSS - MSC) interface; General aspects
TS 48.002	Base Station System - Mobile-services Switching Centre (BSS - MSC) interface; Interface principles
TS 48.008	Mobile Switching Centre - Base Station system (MSC-BSS) interface; Layer 3 specification
TS 48.020	Rate Adaptation on the Base Station System - Mobile Service Switching Centre (BSS-MSC) Interface
TS 49.008	Application of the Base Station System Application Part (BSSAP) on the E-Interface
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: China Mobile, Vodafone, Ericsson, Huawei, ZTE, Alcatel-Lucent, Nokia Siemens Networks, Telecom Italia.

This work was triggered by GERAN Rel-8 TR 43.903 Study on A-interface over IP (AINTIP) UID_50589.

BSS (Base Station System) over IP is a technical trend in wireless network evolution, which can construct high bandwidth efficient networks. BSS over IP consists of Gb interface over IP and A interface over IP.
Gb interface over IP has been specified in Rel-4.
As for the A-interface, only the control plane signalling over IP (SIGTRAN) has been introduced in Rel-7.

TR 43.903 compared different AoIP solutions in terms of related criteria, Phase I (general requirements) and Phase II (technical solutions). This work covers the spin-off AoIP specification activity.

Based on the working assumptions agreed in TR 43.903, one technical option was standardized to meet all the migration deployment scenarios defined during feasibility study.

Media Requirements for CS over IP based User Plane (AoIP-CSoIP) UID_400042

Resources: S4

References

Document	Title/Contents
WID(s)	
SP-080444	WID on Media Requirements for CS over IP based User Plane (AoIP-CSoIP)
Impacted Specifications	
TS 26.102	Mandatory speech codec; Adaptive Multi-Rate (AMR) speech codec; Interface to Iu, Uu and Nb [specify the Nb framing for GSM_FR and GSM_HR and the RTP Parameters for all NB Codecs]
TS 26.103	Speech codec list for GSM and UMTS [specify the parameters for SDP signalling for 3GPP Codecs]
TS 26.202	Speech codec speech processing functions; Adaptive Multi-Rate - Wideband (AMR-WB) speech codec; Interface to Iu, Uu and Nb [specify the RTP Parameters for AMR-WB]
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Alcatel-Lucent, China Mobile, Ericsson, Huawei, Nokia, Nokia Siemens Networks, Vodafone, Motorola.

Petitioners' Exhibit 1003, p. 280
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

AoIP allows removing transcoders from BSS, improving Transcoding-Free Operation (TrFO), maximizing flexibility for MSC-in-Pool networks and optimizing transport efficiency on the User Plane.
This new feature requires changes to A-Interface Control Plane, A-Interface User Plane and MSC-MGW interface.
To support end-to-end TrFO, minor changes were also necessary on the Nc and Nb interfaces.
The Core Network shall support all 3GPP Codec Types (TS 26.103) including GSM_EFR, GSM_FR and GSM_HR.

This new paradigm for User Plane transport via IP and addition of GSM_FR and GSM_HR for transport via the A- and Nc-interfaces required evaluation and definition of RTP profiles, payload formats and RTP parameters.
SA4 ensured that existing RTP Profiles and payload formats are sufficient for the CS speech telephony in 3GPP.
It also prepared input to standardize all missing RTP payload formats in IETF.
SA4 ensured that the User Plane transports on the AoIP-interface and the SIP-I-based Nb-interface are harmonized.
It standardized all RTP parameters for applications on AoIP-interface and Nb-interface controlled by SIP-I-based Nc interface. SA4 standardized the SDP parameters for all 3GPP Codecs for the SIP-I-based Nc-Interface.
It gave guidance to GERAN for the AoIP Control Plane negotiation for RTP parameters.
It standardized the Nb framing for GSM_FR and GSM_HR for the Nb-interface controlled by BICC-based Nc interface.
SA4 investigated issues related to transport of GTT (Global Text Telephony) and the potential need to support the RTP payload format for Text Conversation (IETF RFC 4103).

Core Network Impacts for A-Interface User Plane over IP (AoIP-CN) UID_400024

Resources: C4,C1,C3

References

Document	Title/Contents
WID(s)	
CP-080278	WID on Core Network Impacts for A-Interface User Plane over IP
Impacted Specifications	
TS 23.205	Bearer-independent circuit-switched core network; Stage 2 - CT4
TS 23.153	Out of band transcoder control; Stage 2 - CT4
TS 23.231	SIP-I based circuit-switched core network; Stage 2 - CT4
TS 23.009	Handover procedures - CT1
TS 29.232	Media Gateway Controller (MGC) - Media Gateway (MGW) interface; Stage 3 - CT4
TS 29.002	Mobile Application Part (MAP) specification - CT4
TS 29.007	General requirements on interworking between the Public Land Mobile Network (PLMN) and the Integrated Services Digital Network (ISDN) or Public Switched Telephone Network (PSTN) - CT3
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Alcatel-Lucent, China Mobile, Ericsson, Huawei, Nokia Siemens Networks, Vodafone.

CT standardized all Core Network Messages and Procedures to support A-interface User Plane over IP and the extension of Transcoder-Free Operation (TrFO/OoBTC) for GSM_EFR, GSM_FR, and GSM_HR.
All telephony, fax and data (CSD, HSCSD) services shall be supported by the Core Network.

CT made standards for SIP-I based Core Network signalling.
The agreed User Plane transport for the SIP-I based Nb-interface is RTP/UDP/IP, like foreseen for AoIP.

Petitioners' Exhibit 1003, p. 281
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

17.5 New multicarrier BTS class (MCBTS) UID_51147

Resources: G1

References

Document	Title/Contents
WID(s)	
GP-071542	WID on New multicarrier BTS class
Impacted Specifications	
TS 45.005	Radio transmission and reception
TS 45.050	Background for RF Requirements
TS 51.021	Base Station System (BSS) equipment specification; Radio aspects

Supporting Individual Members: Alcatel-Lucent, China Mobile, Ericsson, Huawei, TeliaSonera, T-Mobile, Vodafone, ZTE.

Multicarrier transceiver architectures applied to GSM BTSs would allow several (possibly hopping) GSM carriers to be processed by a single transmitter and power amplifier in the downlink and by a single wideband receiver in the uplink. This sharing of hardware resources by several carriers leads to significant cost reductions for the BTS equipment.

Given the recent advances in components technology, these architectures seem more and more feasible, however feasibility is still conditioned by the relaxation of some of the most severe requirements in TS 45.005.
The relaxation of those requirements must be considered with great care, as it might have impacts on operational scenarios, mainly in the case of uncoordinated operation of networks between two (or more) operators.
There are ongoing discussion in TSG GERAN on pros and cons of this relaxation in TS 45.005 and TS 51.021.
The proposed way addressing the remaining concerns is to specify a new class of BTS with relaxed radio requirements.
Regulatory restrictions apply to the usage of BTSs of this class at the border of the frequencies allocated to an operator. These restrictions could be based on the geographical area where such BTSs are operating.

This work defines a new BTS class based on relaxed radio requirements to allow multicarrier operations while ensuring that such relaxations cannot impact the performance of existing neighbouring networks. It investigated applicability of multicarrier GERAN BTS and identified the extent of required BTS radio modifications for selected deployment scenarios. Furthermore radio performance requirements for such BTS had been investigated for optimizing system integrity in high capacity deployment scenarios including:

- Extent of and need for possible modifications for TX inter-modulation performance at the BTS;
- Extent of and need for possible modifications for RX blocking performance at the BTS;
- Required modifications related to spurious emissions and switching transients at the BTS;
- Treatment of impacts to neighbour GERAN-based networks with prime consideration of 900MHz, 1800MHz bands

Availability of new technology based Multi-Carrier Power Amplifiers (MCPA) and wideband receiver architectures was included in the investigation.

Petitioners' Exhibit 1003, p. 282
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

17.6 Support for Additional Navigation Satellite Systems (ANSS) for LCS UID_38001

Resources: S1,G2,R2

References

Document	Title/Contents
WID(s)	
GP-080776	WID on Support for Additional Navigation Satellite Systems (ANSS) for LCS
Impacted Specifications	
TS 22.071	Location Services (LCS); Service description; Stage 1 (SA1 CR0077)
TS 43.059	Functional stage 2 description of Location Services (LCS) in GERAN
TS 44.031	Location Services (LCS); Mobile Station (MS) - Serving Mobile Location Centre (SMLC) Radio Resource LCS Protocol (RRLP)
TS 44.071	Location Services (LCS); Mobile radio interface layer 3 LCS specification
TS 48.031	Location Services LCS: Serving Mobile Location Centre - Serving Mobile Location Centre (SMLC - SMLC); SMLCPP specification
TS 49.031	Location Services (LCS); Base Station System Application Part LCS Extension (BSSAP-LE)
TS 51.010	Mobile Station (MS) conformance specification
RAN2 TS	25.305, 25.306, 25.331, 25.413, 25.423, 25.433, 25.453 (RAN2 considers performance requirements for Rel-9)
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Qualcomm, AT&T, Ericsson, Spirent, TeleCommunications Systems.

Galileo and Additional Navigation Satellite Systems (GANSS) support was added by Rel-7 work item A-GNSS-GP. Rel-7 GANSS supports only the Galileo navigation satellite system, but allows adding new satellite systems by assigning new GANSS IDs, GANSS Signal IDs and GANSS Time IDs, together with a few ASN.1 extensions to existing assistance data elements. These ANSS multiply the number of satellites and signals available for free open service positioning, and therefore, will increase the service availability, user experience and accuracy of LCS.
In particular, accuracy, yield and time to first fix will be improved in indoor and dense urban areas, where navigation satellite signals normally exhibit blocking, attenuation and multipath effects.
Higher accuracy is achieved in rural and suburban areas, where high yield and good accuracy are normally possible.

Signal In Space Interface Control Documents (SIS ICD) of the these satellite navigation systems are all freely available:

- Modernized GPS: IS-GPS-200, IS-GPS-705, IS-GPS-800 http://www.losangeles.af.mil/library/factsheets/factsheet.asp?id=9364
- SBAS http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/library/documents/
- QZSS http://qzss.jaxa.jp/is-qzss/IS-QZSS_10_E.pdf
- GLONASS http://www.glonass-ianc.rsa.ru/i/glonass/ICD02_e.pdf

This work adds support for ANSS by defining new GANSS IDs for the following navigation satellite systems:

- Modernized GPS;
- SBAS (Satellite Based Augmentation Systems; limited to EGNOS, WAAS, GAGAN, MSAS);
- QZSS (Quasi Zenith Satellite System);
- GLONASS.

Extensions to existing GANSS assistance data elements, where required, shall allow to natively support these ANSS (and their hybrid use) using GERAN signalling.

Petitioners' Exhibit 1003, p. 283
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

17.7 Conformance testing for the Latency Reductions feature (CTLATRED) UID_51149

Resources: G1, G3new

References

Document	Title/Contents
WID(s)	
GP-080367	WID on Conformance testing for the Latency Reductions feature
GP-080368	WID on MS conformance testing for the Latency Reductions feature
GP-080369	WID on BTS conformance testing for the Latency Reductions feature
Impacted Specifications	
TS 51.010	Mobile Station (MS) conformance specification - G3new
TS 51.021	Base Station System (BSS) equipment specification; Radio aspects - G1
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Huawei, InterDigital Communications, LG Electronics, Nokia, Research in Motion, Rodhe & Schwarz, Ericsson, T-Mobile International, Vodafone.

This work adds test cases to TS 51.010 and TS 51.021 for GERAN Rel-7 Latency Reductions (LATRED) UID_50582.

17.8 MS conformance testing of changes introduced by WI "Support of Packet-switched Handover for GERAN A/Gb mode" (PSHCT-MStest) UID_53091

Resources: G3new

References

Document	Title/Contents
WID(s)	
GP-080411	WID on Mobile Station conformance testing of Packet-switched Handover
Impacted Specifications	
TS 51.010	Mobile Station (MS) conformance specification
New Dedicated Specifications/Reports	
-	-

Supporting Individual Members: Rohde & Schwarz, Qualcomm, Ericsson, Nokia, Motorola

This work provides MS testing for Rel-6 Support of PS Handover for GERAN A/Gb mode (SPSHAGB) UID_50559.

Petitioners' Exhibit 1003, p. 284
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

18 SA1 Studies

18.1 Study on Customised Alerting Tone (FS_CAT) Requirements UID_7026

Resources: S1

References

Document	Title/Contents
WID(s)	
SP-060474	SID on Study of Customised Alerting Tone (CAT) Requirements
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 22.982	Study of Customised Alerting Tone (CAT) requirements

Supporting Individual Members: China Mobile, Ericsson, Siemens, Huawei, NEC, Comverse, Lucent.

The Customized Alerting Tone (CAT) service is an operator-specific service by which an operator enables the subscriber to customize the alerting tone which is played to the calling party. CAT service should not negatively affect the conversation between calling and called parties. The caller can experience favourite songs, multi-media clips or other CAT instead of the traditional ringing tones.

As there are many methods to realize the basic functions of CAT, standardization was needed especially for roaming support. Obviously, CAT should be available in spite of the called party's roaming status. Interoperability between different vendors and interoperability between different Public Land Mobile Networks (PLMNs) are required. Furthermore, more and more additional features of CAT are expected by the subscribers, e.g. a user may be able to easily subscribe to the same alerting tone at the same time as he is hearing it by for instance pressing a key.

Currently, most of the CAT mechanisms cannot support roaming scenarios perfectly and some lack scalability.

This work studied the CAT requirements to be standardized e.g.:

- Users can access and choose the alerting tones with more facility, e.g. the caller can easily subscribe to a called party's alerting tone by pressing a key. Digital Rights Management (DRM) issues should be covered in order to make sure that copyrights are not infringed.
- When calling a user of another PLMN, the caller can still hear the alerting tone set by the called party.
- When roaming to another PLMN, the caller can still hear the alerting tone set by the called party.
- The caller can experience the alerting tone set by the called party who is roaming to another PLMN.
- Interactions with: PS services, Supplementary Services, IMS Multimedia Telephony Service, Charging Services and the Generic User Profile (GUP).

TR 22.982 conclusions

- studied requirements and potential new capabilities in 3GPP that need to be standardized for the CAT service, especially additional features for roaming and interoperability support;
- specified the requirements for CAT service in CS and PS domains;
- Voice services were the main focus, but CAT for IMS Multimedia Telephony Service and supplementary services was also considered;

Genealogy of this spec:

antecedent(s)	this spec	descendant(s)
(no antecedents)	22.982	22.182

Spin-off Rel-8 Feature Customized Alerting Tone (CAT) Service UID_340029.

Petitioners' Exhibit 1003, p. 285
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

18.2 Study on Facilitating Machine to Machine Communication in GSM and UMTS (FS_M2M) UID_7027

Resources: S1

References

Document	Title/Contents
WID(s)	
SP-050527	SID on Facilitating Machine to Machine Communication in GSM and UMTS (M2M)
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 22.868	Study on Facilitating Machine to Machine Communication in 3GPP Systems

Supporting Individual Members: Siemens, Vodafone, Orange, China Mobile, Rogers Wireless, T-Mobile

Machine to Machine (M2M) communication is seen as a form of data communication between entities that do not necessarily need human interaction. It is different to current communication models as it involves:

- new or different market scenarios;
- a potentially very large number of communicating entities (terminals);
- to a large extend little traffic per equipment;

An example for M2M communication is a service which permanently checks the integrity and safety of a vehicle and reports problems to the garage service.

The role of M2M in the GSM/UMTS business is still limited, but a big potential growth in the 3GPP system is foreseen. The two major limiting factors are the costs for the operator and handling of M2M by both, the end-user and operator. M2M communication may become more relevant in future as:

- M2M in GSM/UMTS is a future growth sector in particular in mature markets;
- The ubiquitous coverage of mobile networks is one main enabler;
- Enhancement of the 3GPP standard could be a stimulator, as business could be addressed more cost efficiently.

Regarding the handling of M2M for the user and the operator the underlying mechanisms for handling subscriptions, subscriber data, numbering issues, etc. were studied. Requirements for M2M communication have been collected.

Lean and simple design as well as efficient use of resources (e.g. air interface and signalling resources) were major objectives. Special consideration was put on the following areas for optimization:

- Charging mechanisms (e.g. simplify charging in relation to M2M purposes);
- Addressing: Already today some networks are running out of E.164 numbering space. This would be aggravated by widespread usage of M2M. IP address space limitation was also studied.
- Types of communication (e.g. one to many, many to many, relevance of mobile originated mobile terminated and always on type of connectivity); Enhancements for the identified communication model; Preferred communication models that could be implemented cost efficiently for M2M
- Handling of large numbers of subscriptions and subscriber data within the network;
- Handling issues of large number of M2M subscriptions for the user of M2M services;
- Impact of optimizations for security (Denial of Service attacks by M2M devices, Effects of theft of M2M that are quite likely unattended, Secure handling of credentials, Access control for M2M terminals).

TR 22.868 conclusions - Possible Requirements

- De-activation of mobility signalling for stationary terminals
- Optimised mobility signalling for low mobility and low activity terminals
- Possibility to instruct individual/group of terminal types e.g. static, low mobility, low activity terminals, not to perform any periodic location updates, and optionally location updates due to movement between Location Area (LA) / Routing Area (RA).
- Possibility to instruct individual/groups of terminal types to perform a location update at a specific date and time
- Purging of subscriber data from VLR/SGSN for low activity / Mobile Originated (MO) only terminals
- Tamper Save/Theft proof terminal including a UICC
- Possibility to change subscription out in the field e.g. after contract expiry without human intervention

Petitioners' Exhibit 1003, p. 286
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Possibility to allocate the terminals at initial power up to a network operator without human intervention
- Re-use of PNM mechanisms for M2M communication
- Possibility to define groups and to have group counters to count the traffic to and from the servers at the network boundary
- Per group counters to count location update traffic
- Add a terminal type identifier to the subscription information to facilitate mobility management and charging
- Overcoming the limitations of the IMSI range by alternative addressing solutions
- Simplify terminal and network and thus reduce cost. CS should not be impacted and preferably PS should be used.

Spin-off SA3, CT6 Rel-9 Study on Security Aspects of Remote Provisioning and Change of Subscription for M2M Equipment UID_370053.

Spin-off Rel-10 Feature UID_400033 NIMTC (Network Improvements for Machine-type Communications).

Petitioners' Exhibit 1003, p. 287
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

18.3 Study on Network Composition UID_31089

Resources: S1

References

Document	Title/Contents
WID(s)	
SP-060478	WID on Network Composition
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 22.980	Network composition feasibility study

Supporting Individual Members: Siemens, Ericsson, Nokia, Vodafone, NTT DoCoMo, NEC, KDDI, BenQ Mobile.

Over the past years, an increasing number of heterogeneous network types have come to the focus of attention, e.g. heterogeneous access systems (otherwise known as multi-access) Personal Area Networks (PANs), Personal Networks (PNs), Moving Networks etc. This trend is expected to continue. Different scenarios have been studied in TR 22.978 All-IP network (AIPN) feasibility study, which lists "network extensibility/composition" as a key aspect of AIPN.
The integration of PANs and PNs was completed earlier (see Personal Network Management (PNM) UID_31081). Related Stage 1 was produced in TS 22.278 Service requirements for the Evolved Packet System (EPS) and TS 22.259 Service requirements for Personal Network Management (PNM); Stage 1.
3GPP networks had to integrate many of these heterogeneous network types, or to interwork with them, in an efficient manner that for operators is easy to manage and control.

This study builds on the AIPN work and studied in more detail the concept of heterogeneous network/system integration and interworking. This "Network Composition" includes integration of networks with different administrative domains, and the dynamic and flexible integration of ad-hoc networks, PANs, sensor networks etc.
It studied a uniform composition procedure independent of what kind of network is "composed" with the 3GPP system. Complementing the AIPN work a concrete dynamic "plug&play" and flexible composition procedure was studied.

The composition concept was also studied in the 6th FP IST Project of the EU "Ambient Networks" which was introduced in the joint SA2/RAN2/RAN3 meeting in Athens, May 2005 (S2-051145).

This study explores the feasibility of a uniform procedure for the integration of, and the interworking with, a large variety of heterogeneous network types. It focuses on ad-hoc networks, PANs, moving networks etc., but also includes access systems. The intention was to avoid the need for defining a new procedure for integration / interworking with each newly emerging network type and to explore the feasibility of making the composition procedure dynamic and to minimize human intervention ("plug&play"). This uniform procedure is called Network Composition. It is conceivable that roaming within a pre-set commercial and technological environment could be established dynamically using the same procedure.

The study covered the following aspects:

- Purpose and benefits of composition;
- Composition use cases highlighting uniformity, dynamicity, security, manageability, scalability, flexibility, as well as business aspects;
- Potential composition requirements;
- Traits and/or implications of introducing this functionality into the 3GPP system, covering subjects such as management, multi-link radio access, mobility, context & policy awareness, security, and media transcoding & adaptation capabilities;
- Composition process;
- Relations to other functionalities of the evolving 3GPP architecture (e.g. AIPN, PNM).

Service aspects include:

- Uniform handling for network composition (Identical handling of e.g. PANs, Moving Networks, heterogeneous access systems, etc.);
- Flexible control delegation (i.e. flexibility regarding what functionality is assumed in the composing network, such that e.g. a particular control feature can be executed in the 3GPP system or in the other network;
- Support of "plug&play" composition, including aspects such as service continuity in the composed networks.

TR 22.980 conclusions

Petitioners' Exhibit 1003, p. 288
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Defines principles, characteristics and requirements of Network Composition. Key terms and concepts are introduced and used when formulating use cases and requirements, as well as the Composition Process which is the core functionality of the novel idea of enabling so called composition-capable networks to connect and e.g. establish roaming agreements dynamically.
- Network Composition provides new ways of networking and interworking, and opens up both for new business opportunities, as well as providing a baseline for solutions on problems that have been identified already today. The use cases aid in giving insights into areas of interest for Network Composition, and describes how values and benefits can be provided to users and network operators as well as service providers, which are coming at different levels of cost and deployment increments.
- Recommends 3GPP to include Network Composition in future work on evolved systems.

Petitioners' Exhibit 1003, p. 289
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

18.4 Study on Requirements of IMS Multimedia Conferencing UID_320024

Resources: S1

References

Document	Title/Contents
	WID(s)
SP-060479	SID on Study of Requirements of IP-Multimedia Subsystem (IMS) Convergent Multimedia Conferencing
	Impacted Specifications
-	-
	New Dedicated Specifications/Reports
TR 22.948	Study of requirements of IP-Multimedia Subsystem (IMS) convergent multimedia conferencing

Supporting Individual Members: China Mobile, Huawei, Comverse, ZTE, Radvision.

Convergent MultiMedia Conferencing (CMMC) is a service for two or more parties in different locations to communicate using a combination of audio, video, messaging and data. The data communication covers a variety of applications including whiteboard, document sharing, application sharing, desktop sharing, file delivery etc. CMMC is used more and more for on-line collaboration, meeting, training, distance learning, medical treatment etc.

CMMC covers a range of communication activities and technologies. Audio, video and data co-exist in a conversation of multiple parties, which is different from point-to-point multimedia conversation. CMMC provides a variety of data sharing not standardized yet within IMS. This work reviews requirements and studies how to develop CMMC over IMS.

TS 22.228 (Service requirements for IMS; Stage 1) identifies general requirements of IMS convergent conferencing whereas TS 24.147 (Conferencing using IMS; Stage 3) provides protocol details of conferencing within IMS. However, many aspects for the complete IMS conferencing service have not been specified, such as data sharing, media control, floor control, conference policy etc.

IETF SIPPING specifies high-level requirements for conferencing and a framework for conferencing with SIP. IETF XCON specifies a suite of protocols for conference, but the protocols are not intended for wireless mobile environments and are not specified with SIP.

OMA PoC supports video, message and other media in addition to voice, and defines the floor control mechanisms for different media; however applicability to conferencing needs to be checked.

In summary, to enable IMS CMMC and achieve interoperability, many aspects need to be standardized, especially data sharing in conferencing. Requirements for CMMC need to be reviewed, related IMS requirements to support CMMC need to be derived and possible routes for standardization need to be studied. The study

a) identifies IMS CMMC features and describes use cases illustrating the IMS CMMC service requirements;
b) derives the IMS requirements for CMMC services:
   1) Conference framework;
   2) Data sharing session establishment/termination/management in a conference;
   3) Media Resource Function (MRF) function for CMMC;
   4) Multicast capability for CMMC;
   5) Media control for audio, video and data;
   6) Floor control for audio, video and data;
   7) Conference policy;
c) identifies possible routes to standardization:
   1) Adopting existing and emerging standards e.g. OMA, IETF;
   2) Modifying and enhancing existing and emerging standards;
   3) Developing new standards.

TR 22.948 conclusion:

CMMC architecture and protocol should be consistent with IMS conferencing in TS 22.147 and TISPAN TS 183 005. Avoid duplicate work with OMA.

Spin-off Rel-9 Feature UID_370026 Value-Added Services for Short Message Service (VAS4SMS).

Petitioners' Exhibit 1003, p. 290
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

18.5 Study on support of a Public Warning System (FS_PWS) UID_320025

Resources: S1

References

Document	Title/Contents
WID(s)	
SP-080054	SID on Study on support of a Public Warning System (PWS)
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 22.968	Study for requirements for a Public Warning System (PWS) service

Supporting Individual Members: AT&T, Fujitsu, KPN, NEC, Nokia, Nokia Siemens Networks, Nortel, NTT DoCoMo, Panasonic, Samsung, T-Mobile, Softbank Mobile.

Natural disasters such as earthquake, tsunami, etc. result in considerable damage to the affected area and loss of life. It is essential that emergency information from local agencies (e.g. government/public service organizations) is provided to the population within the disaster area in order to take action to reduce damage and avoid loss of life.

For earthquake, some in the scientific community believe that early warning information based on detection of Primary waves can help avoiding fatalities as it allows people in the affected area to execute safety measures (e.g. extinguishing gas stoves, opening doors, hiding under the table, moving to a safer place) before the arrival of the destructive Secondary wave.

Feasibility of systems delivering earthquake early warning information to mobile phone users needs to be studied.

This study identifies requirements for a Public Warning System (PWS) with particular emphasis on:

- duration of delivery time;
- volume of information (e.g. to sufficiently describe the warning to the user);
- granularity of the distribution of the public warning (e.g. prefecture, county);
- prevention of spoofing of public warning messages;
- interaction of the public warning message with the services active in the handset;
- support of public warning messages in legacy handsets;
- support of public warnings for roaming subscribers;
- impact on battery life of the handset;
- impact on existing infrastructure and dimensioning;
- support of multiple languages (e.g. deliver alert in the preferred language of the subscriber);
- support of individuals with physical disabilities (e.g. visually impaired);
- type of information to be provided (e.g. what is the event, where is the event, where is the event heading (like a tornado), what actions should be taken by the user, etc.);

As each Region has different requirements based on many factors (e.g. type of disaster, regulatory mandate, scientific community recommendation, current legacy base capability, etc.) this study addresses regional requirements and mandates for this type of service. However the regulatory requirements and use cases for a PWS have not been finalized in all regions, therefore the results of this study are not applicable for those regions. As this service is applicable to emergency situations, every effort should be made to define a service that can be provided over existing mobile networks in the near-term. Support of this service is optional to operators and/or subscribers based on regional requirements and mandates. The study took into account related work in other bodies.

This service should be introduced with minimal impact on current specifications and existing networks.
It should be provided using low cost and simple mechanisms based on those available within existing mobile networks.

This study focussed on providing this service using the CS/PS domain over GERAN/UTRAN. It shows how a public warning message interacts with the services a user is enjoying when receiving the message (e.g. during a voice call).

TR 22.968 conclusions

Petitioners' Exhibit 1003, p. 291
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Requirements from Europe and Japan for Earthquake Early Warning (EEW) have been identified. Further requirements are expected from other Regions.

The requirements/working assumptions from the three Regions included in the study are significantly different. However it is desirable to specify a PWS fulfilling all Regions' requirements.

The current specifications are not sufficient to cover all scenarios identified in TR 22.968.
The support for most urgent warning notifications is a matter for each PLMN operator or each Region.

Genealogy of this spec:

antecedent(s)	this spec	descendant(s)
(no antecedents)	22.968	22.168

Spin-off Rel-9 Feature UID_380057 (PWS)

Petitioners' Exhibit 1003, p. 292
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

18.6 Study on Paging Permission with Access Control (FS_PPAC) UID_330016

Resources: S1

References

Document	Title/Contents
WID(s)	
SP-060785	SID on Paging Permission with Access Control (PPAC)
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 22.908	Study on Paging Permission with Access Control (PPAC)

Supporting Individual Members: Fujitsu, NEC, NTT DoCoMo, Toshiba.

The Study on Paging Permission with Access Control (PPAC) investigated three issues caused by the current access control mechanism, which does not allow to reach UEs for which access class restriction was applied:

- **Priority service**
  There is a priority communication service which is produced to an authorized user (e.g. government) by using priority mechanisms such as special access class (i.e. access classes 11 to 15) allocation and high priority level allocation of eMLPP (enhanced Multi-Level Precedence and Pre-emption).
  However, there is an issue in the congestion situation (e.g. caused by earthquake) that the authorized user cannot access to the corresponded user when access class barring is applied to the corresponded user.

- **Emergency service**
  User sets up an emergency call and it is unfortunately released. At the condition, emergency agencies (e.g. police) would like to call back the user. However in the current specification, it is impossible to call back if access control restriction has been applied to the user.

- **Communication between UEs in the same area where access control is performed**
  There is an area where access control is performed. In order to allow all the users in the area to setup calls, broadcasting access class numbers are changed at an interval of some seconds. For example, in an interval UEs with access class 0 can perform setup and UEs with access classes 1-9 cannot do setup, in another interval UEs with access class 1 can do setup and UEs with access classes 0, 2-9 cannot do setup. However there is an issue that communication between UE with an access class number and UE with another access class number cannot be established in the area. The communication helps users in emergency situation, e.g. a mother's call to her child to know where he/she is.

TR 22.908 conclusion

- Use-cases investigated, performed gap analysis and clarified issues;
- Requirements recommended for PPAC (paging permission of the UE applied access control);
- Only one new capability identified: allow UEs with indications from the network to perform location registration and respond to a paging request even though it is under access class barring conditions to complete certain classes of calls or messages (e.g. calls from emergency personnel, etc.).

Spin-off Rel-8 Feature UID_370084 (PPACR)

Petitioners' Exhibit 1003, p. 293
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

18.7 Study on Non-3GPP access Network Selection Principles (NSP) UID_340033

Resources: S1

References

Document	Title/Contents
WID(s)	
SP-080318	SID on Study on Non-3GPP access Network Selection Principles (NSP)
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 22.912	Study into network selection requirements for non-3GPP access

Supporting Individual Members: O2, RIM, Gemalto, BT, Softbank Mobile.

Network access via WLAN is becoming more widespread. UEs supporting both 3GPP and non-3GPP access technologies such as WLAN become available. Hence, it is important to have clear requirements describing how multiple access devices use and prioritize networks providing these access technologies.

Selection of networks available only through non-3GPP access technologies is not covered yet by 3GPP and therefore how mobile devices select these networks is undefined.

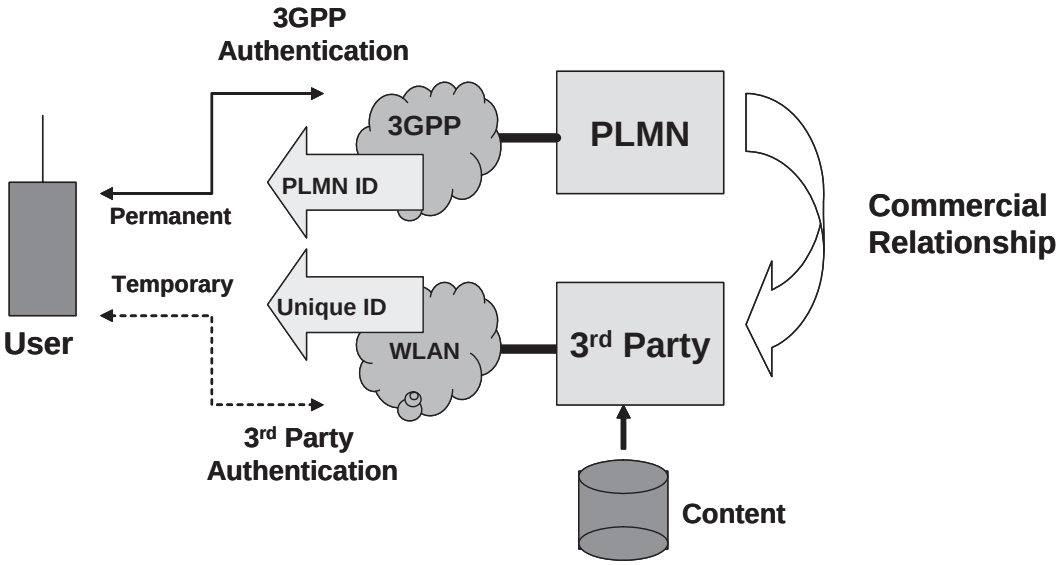
Non-3GPP access technologies were considered in Rel-7 TR 22.811 (Review of Network Selection Principles), which concluded that where multiple technologies are available in a given location, a single mechanism for identifying preferences should be provided.

This work studies how a UE supporting networks through both 3GPP and non-3GPP accesses performs the network selection procedures. It could lead updating TS 22.011 (Service accessibility) to include selection of networks offering these access types. The following aspects for networks offered through non-3GPP access types were considered:

- Automatic selection
- Manual selection
- Operator management of network preferences;
- Operator management of how the device accesses networks.

TR 22.912 provides five use cases; one being when a GSM/3G operator has a commercial relationship with a 3rd party content provider having its own WLAN giving access to a server containing specialized content and services (e.g. music download). The operator arranges with the 3rd party that its subscribers can access the 3rd party over its WLAN to complement its own products and services available over GSM/3G. Authentication and authorization in the WLAN is independent of authentication and authorization in the 3GPP network.

Petitioners' Exhibit 1003, p. 294
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121



Use Case for Non-3GPP access NSP

The connection to the 3rd Party is temporary while delivering content or other service. The UE remains registered on the PLMN while also being connected to the WLAN access.

The facility to set an operator- (and user-) defined preference for the selection of this WLAN network is required.

TR 22.912 conclusions

Currently, the network selection behaviour of the UE is defined only for 3GPP access types (i.e. GERAN, UTRAN, E-UTRAN, I-WLAN). With increasing availability of UEs supporting other types of access (currently mainly WLAN but could include other types) it is desirable to define how and when these new access types can be selected.

The reason for this is to ensure predictable behaviour and also allow the user or application to select the most appropriate type of access for the service required. The various considerations include ability to uniquely identify the access, security, the circumstances under which the non-3GPP access would be selected and the user experience.

Concerning the access identity, an agreement should be sought with the specification body (IEEE 802.11) on how to uniquely identify the access. Security requirements should be met and may need consultation with other groups.

A mechanism needs to be defined to control how the UE selects non-3GPP access types and this should complement the mechanisms already in place for the selection of 3GPP access types (GERAN, UTRAN, E-UTRAN, I-WLAN). This should include similar features to those for PLMN network selection mechanism including consideration of "Steering of Roaming".

NOTE: "Steering of Roaming" by the VPLMN is not envisaged for GSM or UMTS.

TR 22.912 identifies requirements for selection of non-3GPP access and lead to TS 22.011 / TS 22.234 CRs.

Spin-off New Feature UID_380062 (N3GTONSP)

Petitioners' Exhibit 1003, p. 295
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

18.8 Study on Value-Added Services for Short Message Service UID_340034

Resources: S1

References

Document	Title/Contents
WID(s)	
SP-060786	SID on Study on Value-Added Services for Short Message Service
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 22.942	Study on Value Added Services (VAS) for Short Message Service (SMS)

Supporting Individual Members: China Mobile, Huawei, Comverse, TeliaSonera, RIM.

This study assesses requirements for Value-Added Services (VAS) for the Short Message Service (SMS) and identifies which can be met by existing solutions or could be candidates for future standardization. The study covered:

- Service definition of different VAS for SMS;
- Service interaction between different VAS for SMS;
- Existing solutions from other standards bodies (OMA etc.);
- Identify provisioning aspects of VAS for SMS (e.g. registration, activation, deactivation and withdrawal).

It studied enhanced SMS features, which is of great importance for increasing mobile operators' revenues.
These enhanced capabilities for SMS are proposed as VAS for SMS and include:

- **SM forwarding**
  permits a called mobile subscriber to have the network send all incoming SMs, addressed to the called mobile subscriber's directory number to another directory number. SMs can be forwarded unconditionally, or based on different time period, etc.
- **SM filtering**
  permits the network to filter some SMs on behalf of a called party based on the called party's preferences (e.g. calling party's number, time to send message, etc).
- **SM receipt**
  permits the network to send a receipt (that the called party has customized) to the calling party.
- **SM network storage**
  permits the network helping the subscriber to store messages that the subscriber has sent or received.

Due to some limitations of the current architecture to deploy VAS, SA1 examined:

- The most efficient solution for the implementation of VASs for SMS;
- The most appropriate way to specify such functionality in 3GPP documentation;
- The architectural impact on the existing 3GPP defined architecture;
- If full backward compatibility with existing SMS architecture can be guaranteed.

TR 22.942 conclusions

- Studied requirements of VASs for SMS, which are enhancements (or supplements) of GSM SMS requirements;
- Recommends creating Stage 1 followed by Stage 2 specifications on VAS for SMS in 3GPP;
- Architecture and protocol of various VAS listed in TR 22.942 should be consistent with each other;

Genealogy of this spec:

this spec	descendant(s)
22.942	22.142

Spin-off Rel-9 Feature UID_370026 Value-Added Services for Short Message Service (VAS4SMS).

Petitioners' Exhibit 1003, p. 296
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

18.9 Study on Service continuity between mobile and WLAN networks UID_340035

Resources: S1

References

Document	Title/Contents
	WID(s)
SP-060936	SID on Requirements for seamless roaming and service continuity between mobile and WLAN networks
	Impacted Specifications
-	-
	New Dedicated Specifications/Reports
TR 22.937	Requirements for service continuity between mobile and Wireless Local Area Network (WLAN) networks

Supporting Individual Members: BT, AT&T, Huawei, Giesecke & Devrient, Gemalto.

For Fixed-Mobile Convergence (FMC), some scenarios require seamless roaming between GSM/GPRS/3G mobile and WLAN networks. Both networks may independently be authenticated. To maintain the quality of the customer experience, and due to the difference of networks, handovers to support service continuity may require that the handset is authenticated to both networks simultaneously, for relatively short periods of time.

One use case is where the user, on the way to office, is having a call on a 3GPP access network using the mobile phone. Roaming onto the office WLAN (and vice versa), while still being on the line and the call is transferred without the user noticing any interruption to the network served by the WLAN..

The study proposes requirements while roaming between a GSM/GPRS/3G mobile network and a WLAN network for:

- seamless roaming and service continuity;
- maintaining service quality and service continuity;
- charging;
- security, in particular when networks may be independently authenticated.

TR 22.937 develops use cases and requirements for service continuity between a 3GPP network and another network, which can be:

- a TISPAN NGN with an IMS, accessed by a WLAN;
- an ISP accessed via a WLAN.

Each access network has its own separate security system and the network operators have a commercial agreement for roaming and handover.

TR 22.937 Recommendations

General recommendations

- to reuse the mechanisms already defined in 3GPP specifications and the roaming mechanisms.
- to use the flexibility already defined in 3GPP specification, such as taking benefit from the possibility to establish multiple ISIM (IM Services Identity Module) on the UICC when multiple IMS subscriptions are needed.

Proposed requirements

Security aspects

- It shall be possible for the 3GPP Network Operator (NO) and the WLAN NO to operate their own completely separate security systems, including independent authentication centres in their respective CNs.
- UE shall be capable of connecting to the non-3GPP network via a WLAN in a secure way using the appropriate security and authentication mechanisms for that network.
- UICC shall be able to support separate NAAs for the 3GPP access and WLAN access, where the credentials in each NAA are different.
- Where the UICC supports separate NAAs (Network Access Applications on the UICC) for 3GPP access and WLAN access, the UICC shall permit simultaneous sessions with both NAAs on different logical channels.

Petitioners' Exhibit 1003, p. 297
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- In case the PNO (Primary Network Operator; a non-3GPP operator with WLAN coverage) has a commercial roaming agreement with the SNO (Secondary Network Operator; a 3GPP operator) that allows PNO users to roam into SNO mobile network, the already defined I-WLAN specification TS 22.234 allows to re-use USIM authentication and network selection mechanism.
- UE shall be capable of connecting to the 3GPP network via a WLAN in a secure way using I-WLAN security and authentication mechanisms for that network as defined in TS 22.234.
- UE shall support already defined security and authentication requirements to connect to the 3GPP network (e.g. USIM-AKA, SIM-AKA) or to the 3GPP IMS domain (e.g. IMS-AKA, HTTP digest).

AKA Authentication and Key Agreement

NOTE: The WLAN network could be considered an IP-CAN when used to access the IMS domain

Service aspects

- It shall be possible to support service continuity of the multimedia session, including the IMS session, if used, from the WLAN to the 3GPP network and vice-versa.
- The system shall be capable of assuring service continuity to the end user, when moving between WLAN access network and the 3GPP access network.
- In the case service continuity is required, there is a work in Rel-8 to define multimedia sessions continuity.
- UE shall be capable of providing information to the user regarding the current type of access used.
- The ability to maintain service continuity when changing networks shall be dependent on the QoS capabilities of the target network.
- It shall be possible for the PNO to reject the change of network if the target network does not provide adequate QoS to maintain service continuity.
- It shall be possible to release the session on change of network if the target network does not provide adequate QoS.
- The system may adapt the service (e.g. degrade or enhance the service) to the capability of the target access.

Charging aspects

- NO shall be aware of the status of the UE with respect to the network attachment and shall be capable of charging the subscriber according to the type of access used.
- NO shall be capable of collecting on-line and off-line charging information.

Petitioners' Exhibit 1003, p. 298
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

18.10 Study on Services Alignment and Migration UID_370086

Resources: S1

References

Document	Title/Contents
WID(s)	
SP-070126	SID on Services Alignment and Migration
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 22.983	Services alignment and migration

Supporting Individual Members: 3, China Mobile, Telefónica O2 Europe, Orange, RIM, Siemens, T-Mobile, Telecom Italia, Vodafone.

As IMS is introduced there is a need supporting new and existing services by either CS or IMS or in both CS and IMS. In the long term all services will be provided using IMS, however there will be a long transition period when some services will be offered to a user over both CS and IMS. It is important, therefore, that in this transition period, the user experience for each service should be consistent.

In order to ensure a consistent user experience, this study defines how services to the end-user should be delivered and managed regardless of how the user accesses the services (e.g. using CS or IMS).

The study defines how to support existing ("traditional") services as currently defined by 3GPP for CS while allowing new, innovative services to be provided to the end-user using the enhanced capabilities of the IMS.
The study also covers possible migration paths from existing to new service capabilities, and also the user experience of the services when accessing over CS and over IMS including terminal impacts. It considered roaming and call handling, supplementary services (administration, invocation, mid-call service handling), level of support of legacy terminals, and the consideration of UE state and location for services established on CS or IMS and for services transferred between them.

How a consistent user experience can be provided was investigated in the cases where users access services using CS or IMS and where service continuity between CS and IMS is required.

The following aspects were considered for each type of service for each type of access:

- What service features can be supported (e.g. ability for either user on a video call to switch off the video);
- How the service features should be controlled (e.g. by the supplementary services);
- How the service behaves when handing over between CS and IMS based systems.

TR **22.983** studies how services to the end user should be delivered and managed regardless of how the user accesses the services (e.g. using CS or IMS) and to ensure a consistent user experience. The services include but are not restricted to: conversational voice and video services; messaging services and supplementary services as applied to the above. For each of the above types, the service features that should be supported when accessing the service via CS or IMS using any appropriate access type are described. Also, how each service will behave when transferring between domains is described.

TR 22.983 conclusions

With the various types of access and core networks that can be used, it is important that a consistent and predictable service is offered to the end-user. This applies to Tele-Services and Bearer Services and their IMS equivalents as well as to the Supplementary Services.

For the various voice, video and data services, it is important that the user experience is as consistent as possible across the different domains and that as the user moves from one domain to another the service is maintained as far as possible within the capabilities of the domain. This also applies to the various Supplementary Services that are applicable.
It is important, therefore, that the new capabilities offered by enhanced networks are made available to the end-user while at the same time ensuring that the service offered is degraded gracefully if the user moves to a less capable domain.

This also means that it is highly desirable to have some consistency in how the different types of mobile device interact with the network. This is to ensure that services such as Call/Communication Waiting, Call Forwarding/Communication

Petitioners' Exhibit 1003, p. 299
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Diversion and Call/Communication Barring all work correctly. The cases that need to be considered are where the user moves from one domain (i.e. a particular access network and a particular core network) to another and where the operator enhances the network by changing out old technology for new.

Consideration needs to be given to the user experience when roaming also to ensure that it is possible to deliver the appropriate service level consistent with the capabilities of the serving and home networks.

Some identified requirements are met by ICS (IMS Centralized Services) and VCC (Voice Call Continuity).
Some requirements identified in TR 22.983 may need changes to the existing Stage 1.
The intention is to ensure consistency of data across the domains for Supplementary Services and that service control allows transfer of services across domains whilst maintaining the highest possible level of service consistent with the capabilities of the domain.

Spin-off Rel-9 Feature UID_330017 Services Alignment and Migration (ServAl).

Petitioners' Exhibit 1003, p. 300
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

19 SA2 Studies

19.1 Study on 3GPP System Architecture Evolution UID_32085

Resources: S2,S3

References

Document	Title/Contents
WID(s)	
SP-070163	SID on 3GPP System Architecture Evolution
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 23.882	3GPP system architecture evolution (SAE): Report on technical options and conclusions
TR 33.821	Rationale and track of security decisions in Long Term Evolution (LTE) RAN / 3GPP System Architecture Evolution (SAE)
TR 33.822	Security aspects for inter-access mobility between non 3GPP and 3GPP access network

Supporting Individual Members: Vodafone, Ericsson, Siemens, NTT DoCoMo, Nokia, LG Electronics, China Mobile, TeliaSonera, NEC, Huawei, Fujitsu, TIM, Samsung, T-Mobil, 3, ZTE.

In order to ensure competitiveness, a Long-Term Evolution (LTE) of the 3GPP access technology was considered.

The ability of the 3GPP system to cope with the rapid growth in IP data traffic, the Packet-Switched technology utilized within 3G mobile networks requires further enhancement. A continued evolution and optimization of the system concept is also necessary in order to maintain a competitive edge in terms of both performance and cost.
The LTE includes reduced latency, higher user data rates, improved system capacity and coverage, and reduced overall cost for the operator.

Additionally, IP based 3GPP services will be provided through various access technologies. Seamless mobility between heterogeneous access networks (e.g. I-WLAN and 3GPP access systems) is a useful feature for network evolution.

In order to achieve this, an evolution or migration of the network architecture, as well as an evolution of the radio interface were considered.

Architectural considerations covered end-to-end systems aspects, including core network and a variety of IP connectivity access networks (e.g. fixed broadband access).

TR 23.882 provides an evolution / migration framework of the 3GPP system towards higher-data-rate, lower-latency, packet-optimized, multi-RAT. The focus is on PS domain assuming that voice services are supported in this domain.

TR 23.882 addressed the following aspects:

- Architecture impacts stemming from requirements coming from 3GPP TSG RAN. The architectural developments take into account the targets for the evolution of the radio-interface:
    - whether there is a need for a modified network architecture and/or different functional split between network nodes (compared to the current 3GPP architecture);
    - how to provide a very low latency (including C-plane) for the overall network (including Core Network, Radio Access Network and Radio Access Technology);
    - how to provide efficient support of various types of services, especially from the PS domain (e.g. Voice over IP, Presence).

- Architecture impacts stemming from SA1 Rel-7 TR 22.978 "All-IP network (AIPN) feasibility study":
    - support of a variety of different access systems (existing and future) and access selection based on combinations of operator policies, user preferences and access network conditions;
    - how to realize improvements in basic system performance e.g. communication delay, communication quality, connection set-up time etc.;
    - how to maintain the negotiated QoS across the whole system; in particular to address include inter-domain and inter-network interworking.

Petitioners' Exhibit 1003, p. 301
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Architecture aspects of supporting mobility between heterogeneous access networks, including service continuity:
    - service continuity between I-WLAN and the 3GPP PS domain;
    - how to support multiple RATs and terminal mobility between different RATs;
    - how to maintain and support the same capabilities of access control (authentication, authorization), privacy and charging when moving between different RATs.

Migration aspects were taken into account for the above, i.e. how to migrate from the existing architecture.

In the course of conducting this study, implementation Work Items were created to address certain aspects.

SA3 studied security aspects in TR 33.821 and TR 33.822.

Spin-off Features:

UID_320005	(SAES)	3GPP System Architecture Evolution Specification-Evolved Packet System (see clause 4)
UID_20068	(LTE)	3G Long Term Evolution - Evolved Packet System RAN part (see clause 5)
UID_50583	(GELTE)	GERAN support for GERAN - 3G Long Term Evolution interworking (see clause 6)

Petitioners' Exhibit 1003, p. 302
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

19.2 Study on Stage 2 aspects of IMS Service Brokering UID_320028

Resources: S2

References

Document	Title/Contents
WID(s)	
SP-060443	SID on IMS Service Brokering enhancements
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 23.810	Study on architecture impacts of Service Brokering

Supporting Individual Members: Telcordia, Comverse, Huawei, BT, Orange, Telecom Italia, T-Mobile, GET (Groupe des Ecoles de Tel).

3GPP has adopted the approach of creating a number of IMS enablers that can be used by a number of services.
The success of this approach is proven by the adoption of IMS by other standardisation bodies (e.g. TISPAN, OMA).

Various IMS specifications provide the ability to sequence invocations of IP Multimedia Applications (or their servers) providing a static sequence handing off session control to individual applications (or their servers).
This IMS service control architecture was developed in Rel-5 and remained essentially unchanged since. It includes a Service Interaction Manager (SCIM) as part of the Application Server domain (see TS 23.002).
Additionally, as part of Rel-7 Open Service Access (OSA) Application Programming Interface (API); Service broker Service Capability Feature (SCF) has been developed (TS 29.198-16).

3GPP and OMA have provided specifications for IMS enablers and applications.

This study looks if the current service interaction management architecture (e.g. SCIM as part of AS and Service Broker as part of OSA SCS) properly supports these enablers and applications along with other non-standard applications.

It studied if enhancement to the current service interaction management architecture are needed in order to satisfy the requirements in TS 22.228.

The study considered the concern that if services are provided by different service providers, then the solutions must be able to prevent undesirable alterations of interaction characteristics.

TR 23.810 has proposed no spin-off activity.

NOTE: UID_31088 "IMS Service Brokering enhancements" was moved back from Rel-8 to Rel-7 in order to give a home to 22228CR0036_(Rel-7)_S1-051232.
Hence, Rel-7 ISB has Stage 1 only and is misaligned with Rel-7 Stages 2/3.

Petitioners' Exhibit 1003, p. 303
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

19.3 Study on IMS utilizing multicast bearer services UID_7049

Resources: S2

References

Document	Title/Contents
WID(s)	
SP-060148	SID on IMS utilizing multicast bearer services
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 23.847	Enhancements to IMS service functionalities facilitating multicast bearer services

Supporting Individual Members: Siemens, China Mobile, Panasonic, Alcatel.

This work is linked to SA1 Rel-7 MBMS Enhancements (MBMSE) UID_31084.

During the definition of MBMS enhancement requirements in Rel-7 TS 22.228, IMS support of media delivery over multicast bearers was identified as follows:

> "Multicast services allow IMS users and service providers to send multimedia to a group of IMS users simultaneously in an unidirectional way of communication. The underlying network may be able to support mechanisms that optimize the delivery of multimedia to the individual members of that group (e.g. MBMS)"

Initial understanding of architectural implications were based on regional services to grouped IMS users provided at hotspots such as a football stadium.

This work studied feasibility of using multicast bearers (e.g. MBMS) in the context of IMS-based applications. It captured the results of technical considerations and solutions into the facilitation of IMS services over multicast bearer services with a focus on the possible enhancements to IMS functionalities and relevant charging, security and service provision procedures. Considerations included:

- Signalling procedures of multicast enabled IMS services should be analyzed based on the grouped communication scenarios and possible optimizations to the delivery mechanisms should be investigated;
- Identify charging and policy control procedures according to the PCC architecture;
- Identify service provision procedures both in Network Elements and UEs;
- Investigate possible security requirements to multicast enabled IMS functionalities and bearer service entities;
- Real-time QoS requirements e.g. delay , interruption;
- UE capability requirements.

TR 23.847 conclusions

- Documented technical alternatives on the reference architecture with preferred developing principles, signalling flows, PCC impacts.
- Alternative signalling flows were documented for both IMS grouped applications, IPTV and more value-added service cases (provided examples of combined signalling flow of IMS and MBMS in the actual use cases).
- Stage 2 and modification to PCC should be created when needed.
- Concerns on security and media plane QoS were removed because of missing appropriate expertise.

Petitioners' Exhibit 1003, p. 304
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

19.4 Study on Multimedia Session Continuity UID_350051

Resources: S2

References

Document	Title/Contents
WID(s)	
SP-070818	SID on Multimedia Session Continuity
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 23.893	Feasibility Study on Multimedia Session Continuity; Stage 2

Supporting Individual Members: Orange, Telecom Italia, SK Telecom, China Mobile, Ericsson, Fujitsu Laboratories of Europe, Huawei, LG Electronics, Marvell, Motorola, NEC, Nokia, Nokia Siemens Networks, RIM, Samsung, Telcordia, Toshiba.

This study took into account ongoing activities in TISPAN and other bodies, and aligns with the following studies to result in a common framework for Service Continuity.

- System enhancements for fixed broadband access to IMS (FBI) (UID_32074)
- Voice Call Continuity between CS and IMS (incl. I-WLAN) (VCC) (UID_32091)
- Study on centralized IMS service control (FS_ICS) (UID_330012)
- 3GPP System Architecture Evolution (FS_SAE) (UID_32085)
- Study on Mobility between 3GPP-WLAN Interworking and 3GPP Systems (FS_SM3GWLAN) (UID_350017)
- Personal Network Management (PNM) (UID_31081)

Service Continuity Stage 1 was included in TS 22.278 "Service requirements for the Evolved Packet System (EPS)".

In the context of studying the general issue of IMS sessions continuity, it was also felt necessary to investigate the following enhancements to the Rel-7 specified continuity mechanisms:

- Support of network based control of domain transfer;
- Handling of the components of a session (PS-PS session continuity), including handling of non-voice components in conjunction with PS-CS continuity;
- Support of session-level continuity between CS and non-3GPP IP accesses for MMSC.

Continuity at the IMS session layer are applicable to both EPC and non-EPC networks, and thus cannot depend solely on the existence of transport layer mobility mechanisms in the EPS.

TR 23.893 studied IMS-level MMSC including potential enhancements to IMS specifications relevant to MMSC e.g.:

- Identification of Session Continuity scenarios;
- PS-PS session continuity;
- PS-PS session continuity in conjunction with PS-CS continuity;
- Session continuity between 3GPP and non-3GPP systems (e.g. TISPAN, WiMAX);
- Network-initiated Multimedia Session Transfer;
- Mobility of media components of a session between different terminals under the control of the same user;
- Coexistence and/or potential interactions with possible underlying mobility solutions defined by 3GPP. Solutions developed within TR 23.893 should not have any impacts to underlying mobility solutions.

Consistent user experience was investigated where Services Continuity between heterogeneous access systems (e.g. different radio accesses) is needed.

Charging impacts have been studied, especially the ability to generate appropriate accounting parameters as subscribers move between various access networks.

Security in each domain is covered by existing security specifications in that specific domain; i.e. CS security aspects are covered by existing CS security specifications, IP-CAN security aspects by existing IP-CAN security specifications, non-3GPP systems security aspects by existing non-3GPP systems specifications and IMS security aspects by existing IMS security specifications.
Voice Call Continuity across these domains should not compromise the security mechanisms of the individual domains.

Petitioners' Exhibit 1003, p. 305
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

TR 23.893 conclusions are given in clause 9 on:

- MMSC scenarios
- MMSC architecture and anchoring solution
- session transfer operator policy
- relationship between ICS and MMSC
- specification of session split/merger functionality
- T-ADS (Terminating - Access Domain Selection) and session split/merger functionality for MMSC and ICS (IMS Centralized Services)
- applicable scope of MMSC
- Single Radio MMSC
- Session Transfer Information
- UE Transfer information flows
- Keep and Release Control Mechanism in UE Transfer Mode

Petitioners' Exhibit 1003, p. 306
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

19.5 Study on centralized IMS services UID_380034

Resources: S2,S1

References

Document	Title/Contents
WID(s)	
SP-070494	SID on Centralised IMS Service Control
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 22.892	Study on IMS Centralized Services (ICS) requirements
TR 23.892	IP Multimedia Subsystem (IMS) centralized services

Supporting Individual Members: Alcatel-Lucent, Nortel, , Telcordia, Ericsson, AT&T, Nokia, , Cingular, Telecom Italia, Siemens, Motorola, Huawei, Samsung, NEC, Newstep, Marvell Semiconductor, Airbiquity, LG Electronics, Rogers Communications, T-Mobile, TeliaSonera.

Communication networks are evolving towards packet based infrastructures, and a need exists to specify service requirements and an architecture that support the provision of IMS based services across a variety of access networks (e.g. wireless and wireline, enterprise and consumer, etc.).

Development of the architecture for Voice Call Continuity (VCC) has identified that supporting domain transfer of active mid-call services by implementing these services in both the CS domain and IMS is not a viable solution in the Rel-7 timeframe. Therefore an architecture is necessary allowing implementation of such services in IMS while also allowing control when the serving access network is in the CS domain. In addition to the VCC scenario, the increased deployment of VoIP capable access technologies encourages further service development on IMS also increasing the importance of being able to access these services via CS domain access, independently of the support of VCC.

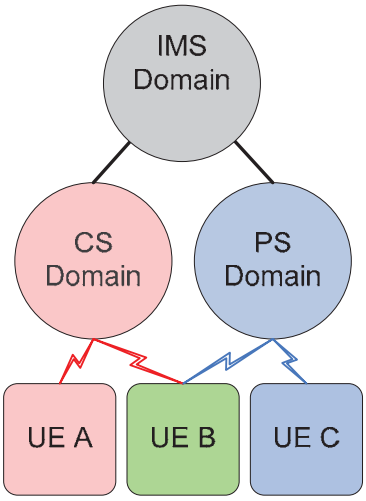
The first objective is the delivery of consistent services to the user mainly via IMS centralized services regardless of the attached access type (e.g. CS domain access or Internet Protocol - Connectivity Access Network (IP-CAN)).

SA1 TR 22.892 describes service experience and proposes service requirements.

SA2 TR 23.892 focuses on how to access IMS-based multimedia telephony services while still allowing innovative services. It includes investigation into call/session establishment via CS domain access and IP-CAN and for calls/sessions transferred across CS domain access and IP-CAN, including the interactions with domain selection. Furthermore it provides consideration for the handling of the multiple media that are enabled by the multimedia telephony communication service. The proposed solution applies to terminals with VCC capabilities and to non-VCC capable terminals. Impact on legacy terminals with the same subscription (e.g. SIM swapping) was studied.

The standardization of an IMS Centralized Services architecture is to be started later based on the results of this study. This can be achieved without completely resolving evolution considerations. A high-level conceptual overview of ICS is provided in the following figure, extracted from TR 22.892.

Petitioners' Exhibit 1003, p. 307
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121



IMS Centralized Services concept

TR 22.892 conclusions

- TR 22.892 clause 6 identifies requirements for the 3GPP system on IMS Centralized Services (ICS), which should be used as a basis for introducing ICS requirements into Rel-8.
- ICS related requirements should be captured in a single place (a new clause in TS 22.101 is one alternative).

TR 23.892 conclusions

- **ICS architecture solutions**
  Different approaches have been identified as possible solutions to enable ICS for ICS UE.
  The SIP Application Server approach with I1-cs and I1-ps is recommended as the working assumption for ICS UE.
  I1-cs IMS CS Control Channel implemented over the CS domain
  I1-ps IMS CS Control Channel implemented over the PS domain

The remaining conclusions cover:

- Use of ICCC (IMS CS Control Channel)
- Centralization of conditional call forwarding
- ICS UE receiving home IMS services via an IMSC (ICS Enhanced MSC Server)
- Handling of multiple media for ICS
- Use of ICCC for CS terminations
- Relation between ICS and Service Continuity
- Relation between ICS and MMSC (Multimedia Session Continuity)
- T-ADS (Terminating - Access Domain Selection)

Genealogy of this spec:

this spec	descendant(s)
23.892	23.292

Petitioners' Exhibit 1003, p. 308
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

19.6 Study on Architecture of IMS based Customized Alerting Tone (CAT) UID_380078

Resources: S2

References

Document	Title/Contents
WID(s)	
SP-070905	SID on the Architecture of IMS based Customized Alerting Tone
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 23.872	Study on architecture of IP Multimedia Subsystem (IMS) based Customized Alerting Tone (CAT)

Supporting Individual Members: China Mobile, SK Telecom , Comverse, LG Electronics, Huawei.

This study is linked to Rel-7 Study on Multimedia Telephony Capabilities for IMS (MITE) UID_31082, Rel-8 Support of Customised Alerting Tone Service (CAT) UID_340029 and Rel-8 Study on Customized Alerting Tone (CAT) solution for voice and video call in CS domain (FS_CAT_VVC_CS) UID_360031.

CAT is an alerting tone customized by the called subscriber or the calling subscriber which may e.g. be a piece of recorded or composed music, greeting words, voice, advertisement or video. With CAT, the caller can experience favourable songs, multimedia clips or other customized alerting or ringing instead of traditional ones.

Following the completion of TS 22.182 (CAT requirements), standardization of one solution among various alternatives for implementing the basic functions of IMS based CAT (including voice and video call) in IMS domain.

CAT in CS domain was studied by CT4 in TR 29.882 (Customized Alerting Tones in 3GPP CS domain).

Inter-working issues were taken into consideration especially in case when a CAT user is changing domains (between IMS and CS).

This work studied architectural impacts and potential enhancements to IMS specifications to meet the TS 22.182 requirements for CAT in IMS domain, including:

- Architecture and procedures to support basic call scenarios for CAT (including both voice and video call) in IMS domain;
- Interaction with other service, e.g. IMS Multimedia Telephony Supplementary Services;
- Abnormal case handling (e.g. when CAT server fails);
- Multiple domains (including IMS and CS) roaming/interworking.

TR 23.872 Conclusion

- Both, Forking and Early-Session models need to be specified in Rel-8.
- Gateway model (RFC 3960) supports CAT provided by terminating IMS network without additional stage 2.
- CAT inter-working between CS and IMS is included in Rel-8;
- Service Notification requires no additional stage 2 specification;
- Content indirection is not to be included.

Petitioners' Exhibit 1003, p. 309
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

20 SA3 Studies

20.1 Study on Home (e)NodeB Security UID_380085

Resources: S3

UID	Name	Hyperlink	Notes	TS_TR
380085	Study on Home (e)NodeB Security	SP-070783	SP#43 completed	33.820

Supporting Individual Members: Huawei, Vodafone, Nokia, Nokia Siemens Networks, T-Mobile, Samsung, Alcatel-Lucent, Nortel.

This study is linked to the RAN4 Study on 3G Home NodeB/eNodeB (UID_350039) and to the SA5 Study on Self-Organizing Networks (SON) related OAM interfaces for Home NodeB (UID_360007).

H(e)NB is able to provide new services with higher data rate in a low cost. Operators have already indicates their interest in this area. Study of H(e)NB has already started in 3GPP in order to investigate the feasibility of developing a standard solution for H(e)NB. Security is an critical aspect of H(e)NB, but it is not sufficiently covered by the existing work items.

This work studied special security threats of H(e)NB and countermeasures to these threats.

The study included threat analysis of H(e)NB, mutual authentication and security protection between H(e)NB and rest of network, maintenance of the security context between H(e)NB and rest of network, security requirements on the H(e)NB, provisioning of security credentials on the H(e)NB, security solution for verifying the location of the H(e)NB etc. With regard to security protection between the H(e)NB and the rest of the network, bandwidth efficiency had been taken into consideration.

Petitioners' Exhibit 1003, p. 310
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

21 SA5 Studies

21.1 Study of Element Operations Systems Function (EOSF) definition UID_390053

Resources: S5

References

Document	Title/Contents
	WID(s)
SP-070307	SID on Element Operations Systems Function (EOSF) definition
	Impacted Specifications
-	-
	New Dedicated Specifications/Reports
TR 32.819	Telecommunications management; Element management layer - Operation System Function (E-OSF) definition

Supporting Individual Members: China Mobile, CATT, Huawei, TeliaSonera, ZTE.

In the Logical Layered Architecture (LLA) of TMN, Network OSF concerns management at network level and Element OSFs concerns management at Network Element level. These two logical layers respectively play the role of network management function.

The Element Management System (EMS) developed by vendors mainly covers network management functions described in E-OSF and / or N-OSF.

TS 32.101 states that the Element Manager (EM) has two functions element management and sub-network management. However, 3GPP SA5 32.xxx-series do not provide a clear definition for E-OSF to help operators and vendors clarifying what is required when deploying a network.

An EM provided by a vendor implements E-OSF logical functions and may or may not implement N-OSF functions. Even more, the Network Management System (NMS) may or may not direct access NE and implement part of E-OSF. Whether NMS implement or not any E-OSF and whether EM implement or not any N-OSF is outside the 3GPP scope. Mapping rules between physical (EMS, NMS) and logical entities (E-OSF, N-OSF) is outside the scope of this study.

E-OSF definition is based on network operation and maintenance experience and considers the UMTS application environment.
Existing 3GPP documentation does not provide sufficient E-OSF guidelines to operators and vendors.

TR 32.819 defines what is needed in E-OSF. The intention was not to define new requirements for standardization of new Interface IRP and/or NRM IRP and/or System Context.

Petitioners' Exhibit 1003, p. 311
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

21.2 Study on SA5 MTOSI XML Harmonization UID_390037

Resources: S5

References

Document	Title/Contents
WID(s)	
SP-070305	SID on SA5 MTOSI - XML Harmonization
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 32.818	Telecommunication management; Study on 3GPP SA5 / MTOSI XML harmonization

Supporting Individual Members: Nortel, Huawei, Alcatel-Lucent, Ericsson, ZTE.

Industry-wide there is a need for harmonization of XML specification methodologies, best practices and guidelines.

SA5 has studied the TMF MTOSI solutions on XML specification methodologies, best practices and guidelines.

This study determined harmonization items with respect to the 3GPP and TMF 608 XML specifications. It identified possible updates to MTOSI XML framework as well as to 3GPP SA5 XML specifications based on dialogue between 3GPP SA5 and TM Forum MTOSI.

TR 32.818 conclusion:

This study assessed whether MTOSI XML recommendations could be considered for future SA5 XML-Based implementations.

On methodology, SA5 is willing to help MTOSI to align with SA5's specifications structure (Requirements, IS, SS).

Concerning IRP specifications, the following was agreed:

- Existing IRP specifications (and their future versions) such as SuM, Notification etc., that have already a SOAP implementation shall be kept untouched.
- Existing IRP specifications that do not have a defined SOAP SS could be considered for XML-Based implementation, considering MTOSI XML recommendations.
- For new IRP specifications requiring XML-based implementation, MTOSI XML recommendation should be considered.

Model harmonization was not needed.

TR 32.818 is a guideline for SA5 Rel-8 and beyond.

Petitioners' Exhibit 1003, p. 312
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

21.3 Study of Common Profile Storage Framework of User Data for network services and management UID_390038

Resources: S5

References

Document	Title/Contents
	WID(s)
SP-060263	SID on Common Profile Storage (CPS) Framework of User Data for network services and management
	Impacted Specifications
-	-
	New Dedicated Specifications/Reports
TR 32.808	Telecommunication management; Study of Common Profile Storage (CPS) Framework of User Data for network services and management

Supporting Individual Members: T-Mobile, Siemens, Nokia, Cingular, Vodafone, Huawei, Orange.

This study is linked to Rel-6 Subscription Management (SuM) and Rel-6 Generic User Profile (GUP).

Introducing a Common Profile Storage (CPS) Framework of User Data ("Common" meaning common to all applications) for network services and management applications could significantly enhance the ability of 3GPP networks to offer complex and combined services in the areas of:

- Multimedia;
- Data services;
- Value Added Services;
- End-to-end applications.

In light of developments both within 3GPP (e.g. IMS, MBMS, OCS, PCC) and outside 3GPP (e.g. NGN, OMA, etc.) with a growing number of physically disjoint but logically correlated user data stored in several data bases a consolidation and co-ordination of these is needed to prevent further redundancy and possible contradiction and to enable operators to administer and provision complex and combined services.

An initial study of user-related data - in and outside 3GPP - assessed the properties of such a CPS Framework based on:

- needs of Network Elements (NEs) like MMS-RS, HLR, HSS, BM-SC and
- features like Service Management, Subscription Management (SuM) and Charging Management.

Efforts within the mobile and Next Generation Network (NGN) communities to define advanced services within the network (e.g. 3GPP, TISPAN) provided valuable drive for developing the CPS Framework functionality for 3GPP.

This study:

- analysed the consequences of creating one common data model structure for an end-user
  - looked at the existing data specifications in 3GPP;
  - addressed issues like minimizing data redundancy, access control, providing views for applications;
  - analyzed the relationship between an end-user and a subscriber as defined by 3GPP;
- analysed and evaluated current initiatives inside and outside 3GPP;
- analysed the gap between 3GPP specifications (e.g. GUP, SuM, etc.) and existing/emerging solutions with centralized respectively distributed storage models.
- proposes a way forward for standardizing inside or outside 3GPP the "gap" (if existent).

Service Aspects

SA5 investigated features of user data storage arising from the fact that user data is handled within a CPS Framework (with centralized or distributed storage models) and accessed from a variety of NEs and enterprise applications.
SA5 studied the need to develop user data management capabilities arising from service requirements (defined by SA1).

MMI-Aspects

SA5 studied the interface aspects between subscriber/user and service provider.

Petitioners' Exhibit 1003, p. 313
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

TR 32.808 conclusions - proposed standardization actions based on the gaps with the current 3GPP concepts:

- Introduce the Concept of End-User (in SA1)
- Introduce the Concept of Contract (in SA1)
- Introduce the network function Common Profile Store (CPS)

Spin-off New Rel-9 SA1 Feature on User Data Convergence (UDC) UID_400034

21.4 Study of Management for LTE and SAE UID_340036

Resources: S5

References

Document	Title/Contents
WID(s)	
SP-060753	SID on Management for LTE and SAE
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 32.816	Telecommunication management; Study on management of E-UTRAN and Evolved Packet Core (EPC)

Supporting Individual Members: Ericsson, Nortel, Nokia, Vodafone, Huawei, Motorola, Siemens, China Mobile, ZTE.

The Evolved 3GPP System (SAE/LTE) needs to be managed. Being an evolution of UMTS, the management should also evolve from UMTS. Reuse of existing UMTS management standard solutions has the following benefits:

- It is proven in operation;
- Minimizes both the standardization and product development efforts (i.e. cost and time);
- Provides a base on which more functionality can be developed (compared with starting from scratch);
- Shortens the time to market for LTE and SAE systems;
- Facilitates a seamless coexistence with UMTS management systems.

Complexity of the LTE network places new demands on the Operations and Maintenance of the Network. Therefore in parallel with reuse/evolve existing Management solutions, new revolutionary elements are needed (e.g. Auto-Configuration, Auto-Optimization, Information Model Discovery and P2P Interfaces).

Functionality is supported by use cases or other documented justification.

SA5 assessed reusing the UMTS management for LTE and SAE in order to decide which existing parts can be reused without change, which need changes and which cannot be reused at all.

The study resulted in decisions on management principles for LTE and SAE, e.g. the management architecture, auto-configuration and KPIs, P2P Interface for exchange of Inter Cell Parameters and Information Model Discovery.

Before completing TR 32.816 several implementation WIs had been stared by SA5 e.g.:

- E-UTRAN Network Resource Model (NRM) Integration Reference Point (IRP) UID_380036
- Self-Organizing Networks (SON) UID_390004
- EPC Network Resource Model (NRM) Integration Reference Point (IRP) UID_380037

Petitioners' Exhibit 1003, p. 314
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

21.5 Study on Charging Aspects of 3GPP System Evolution UID_350004

Resources: S5

References

Document	Title/Contents
	WID(s)
SP-070174	SID on Charging Aspects of 3GPP System Evolution
	Impacted Specifications
-	-
	New Dedicated Specifications/Reports
TR 32.820	Telecommunication management; Study on charging management; 3GPP Evolved Packet Core (EPC): Charging aspects

Supporting Individual Members: Alcatel-Lucent, Ericsson, Huawei, Nortel, Nokia, Siemens Networks, T-Mobile.

The Evolved 3GPP System (SAE/LTE) needs reliable and efficient charging solutions. Being an evolution of UMTS, also the charging solutions need to evolve. Reuse of existing UMTS charging solutions has the following benefits:

- It is proven in operation;
- Minimizes both the standardization and product development efforts (i.e. cost and time);
- Provides a base on which more functionality can be developed (compared with starting from scratch);
- Shortens the time to market for LTE and SAE systems;
- Facilitates a seamless coexistence with UMTS management systems.

Functionality is supported by use cases or other documented justification.

SA5 assessed reusing the UMTS charging for the Evolved 3GPP System in order to decide which existing parts can be reused without change, which need changes and which cannot be reused at all.

TR 32.820 conclusions

Charging Requirements and Principles - no changes required.

Charging Architecture - modifications needed for the P-GW and thus the PCEF being in the visited network. Full PCEF with service-aware flow-based charging is located only in P-GW.

Charging Data and Protocols - changes required to the charging data to take into account the new information available due to the different mobility models. The scope of these changes is not large. Changes are also required to the Transferred Account Procedure (TAP) for subscriber charging in case of Local Breakout.

Implementation Work Item - under the Feature SAES UID_320005, a new Building Block UID_390010 (EPC Charging) covers the charging aspects of the Evolved Packet System (EPS).

Specification structure - existing charging TS 32.251 for PS-domain and TS 32.252 for WLAN should be extended for the EPS. Changes are needed to TS 32.240 charging architecture and TS 32.296 OCS architecture and corresponding enhancements of the charging protocols in TS 32.298 and TS 32.299.

Petitioners' Exhibit 1003, p. 315
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

22 CT Studies

22.1 Study on AS-MRFC media server control protocol UID_7048

Resources: C1

References

Document	Title/Contents
WID(s)	
CP-060180	SID on AS, MRFC media server control protocol definition
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 24.880	Media server control using the IP Multimedia (IM) Core Network (CN) subsystem; Stage 3

Supporting Individual Members: Hewlett-Packard, BT, Comverse, IAEI, Intel, Vodafone, Huawei.

SIP signalling over the S-CSCF – MRFC interface (Mr-interface) and the AS – S-CSCF interface (ISC) are specified but not the format of the media commands/instructions and results/events carried over this interface.

CT1 studied the definition of a media server control protocol in parallel with CT4's work on Mp interface definition (using H.248 protocol and packages are defined for the required media commands/instructions and results/events). CT1 considered supporting more advanced services (e.g. dialled in conferences, digit collection) and whether 3GPP should specify such a protocol.
The study has identified Stage 2/3 work on the media server control protocol to be used over the Mr/ISC interfaces.

TR 24.880 describes the implementation options and requirements for a media server control protocol to be used with the Mr and ISC interfaces giving several recommendations for media server control:

- both the delegation and protocol models described should be supported. This study recommend the creation of a Cr reference point that can be used for both models;
- RFC 4240 should be supported with the clarifications to VoiceXML invocation defined in the draft-ietf-mediactrl-vxml specification;
- VoiceXML should be used to specify all user dialogs;
- a dedicated control channel should be supported;
- mid-call media processing should be supported;
- the AS/MRFC functional split should be supported with a top-level focus, notification server and conference policy on the AS and with media conference policy handling and low-level conference focus on the MRFC;
- the media server control methods should support organization, registration and extension of capabilities;
- RTSP URLs should be used for services which require the sourcing of streamed media.

TR 24.880 defines requirements for a media server control protocol as follows:

- multimedia services' media control requirements;
- response time requirements;
- packaging, registration and extensibility requirements;
- charging requirements;
- resource Management requirements;
- High Availability requirements;
- QoS control requirements;
- security requirements;
- lawful intercept requirements;
- priority requirements.

Spin-off new implementation Feature UID_380035 (MRFC_TS)

Petitioners' Exhibit 1003, p. 316
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

22.2 Study on IMS Restoration Procedures UID_350018

Resources: C4

References

Document	Title/Contents
WID(s)	
CP-070031	SID on IMS Restoration Procedures
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 23.820	Study of IMS restoration procedures

Supporting Individual Members: Ericsson, Nortel Networks, Huawei, Vodafone, Orange.

Although network nodes in the IMS Core Network should have a very high availability, some maintenance stops and occasional failures are unavoidable. Communication links although designed with robust protocols between the Network Elements (NEs) are also subject to failures. There is currently no defined procedure in 3GPP specifications to restore a consistent state in the IMS Core Network after or during a planned or unplanned stop of a NE.
Protocol details and procedures to detect this kind of failures in NEs and communication links are also not specified. This leads to vendor-specific implementations that might not interoperate.
A set of standardized procedures for automatic restoration after loss or corruption of data could reduce the impact of these problems resulting in the improved service to the users. The intention is to have for the IMS domain similar Restoration procedures as for the CS and PS domains in TS 23.007.

CT4 studied behaviour of IMS Core Network upon restart of its NEs or failure of communication links between them, and analyzed alternatives ensuring minimum impact on service to the end-user (the availability of the UE to make and receive IMS sessions). The study also covers procedures triggered by external events indicating problems in IP-CAN.

The study proposes necessary operational protocol recovery mechanisms in the IMS Core Network in order to:

- Limit the time an end-user is affected by restart and downtime of the NEs in the IMS Core Network or the communication links between them.
- Improve the behaviour of the IMS Core Network with indications of network unavailability in the IP-CAN.
- Reduce the operating cost of the IMS Core Network by making as much as possible of the recovery procedures from a restart automatic.
- Ensure that critical services, such as security and charging are not affected in an unacceptable way.

The results of the study may also be used in other interfaces, not part of the IMS Core Network, but with similar protocol implementations, e.g.: I-WLAN, GAA. UE changes should be avoided if possible.

TR 23.820 identified changes required in 3GPP IMS specifications so that a consistent state is restored in the IMS Core Network, after or during a planned or unplanned stop of an NE. The study went through the following steps:

- Establish the requirements that should be covered with these procedures.
  I.e. after a network failure which impacts to the end-user service are acceptable and which not.
- List the service interruption scenarios that need to be studied.
- Provide solutions, so that in all the service interruption scenarios listed, the impacts to the end-user service comply with the requirements. These solutions provide procedures for the automatic restoration to a consistent state in the network and indicate how to trigger these procedures.
- Analyze the impacts of the solutions in the current specifications.
- Conclusion and recommended way forward.

These operational procedures for restoration must avoid overlap with OA&M procedures, which could cause clashes.

TR 23.820 made recommendations on:

- S-CSCF Re-Selection during Re-Registration
- S-CSCF, SIP-AS, HSS and P-CSCF service interruptions

Further improvements might be needed in future releases (see TR 23.820 clause 6.3) and are for further study.

Spin-off new implementation Feature UID_400012 (IMS_RP).

Petitioners' Exhibit 1003, p. 317
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

22.3 Study on IMS Application Server Service Data Descriptions for AS interoperability UID_360030

Resources: C4

References

Document	Title/Contents
WID(s)	
CP-070685	SID on IMS Application Server Service Data Descriptions for AS interoperability
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 29.864	Study on IMS Application Server Service Data Descriptions for AS interoperability

Supporting Individual Members: Alcatel-Lucent, Verizon Wireless, Motorola, Nortel, Nokia-Siemens Networks, ZTE.

This work is linked to the CT4 Study on Restoration Procedures (FS_IMS_RP) UID_320006.

Application data for IMS is defined as being "Transparent". Transparency means that HSS and Sh interface do not semantically understand the data but just syntactically how to deal with its entirety.
Application Servers (AS) are free to store data without an openly distributed definition of the stored content. However, because the data is transparent (the format is not standardized) it is potentially an issue for one AS to make use of data defined for another AS (e.g. ASs are supplied by different vendors).

Standardizing the data formats would facilitate interoperation among ASs supplied by the same or different vendors. These AS vendors may be primary and secondary suppliers of the same Service Provider (SP) within an SP's IMS network. This is especially true of mature services, such as the features provided in basic voice subscriptions, and is likely to be true of any future services that achieve a wide deployment.

There has already been work incorporated into 3GPP from TISPAN that point towards the need for definition of common data. The UE may update a service setting (e.g. a forward-to number) in an AS via Ut. The AS may store this information in transparent data in the HSS, but unless the data is defined it cannot be shared with other AS's.
TISPAN defined data structures associated with multimedia telephony services which have been copied into TS 24.173. For example, 24173-ETSI-TS-183-004 provides the XML schema for the call diversion service..

Benefits of standardizing the data formats for services:

- **Multi-vendor AS support.**
  Today's telecom SPs regularly use two or more vendors to provide identical capabilities.
  Standardization has facilitated this, as products must conform to the defined interfaces.
  SPs use this to build competition among vendors and to build business contingencies.
  The AS market, especially for high-penetration services, is expected to follow a similar path.
- **Data Synchronization**
  In defining IMS centralized services, interworking between the HLR/HSS and the Telephony AS may occur to exchange data that is administered in CS domain and IMS. Definition of IMS AS service data descriptions facilitate this exchange.
- **Feature Interaction**
  Advertising and defining data for each application is expected to increase communication regarding features within applications. This makes integration of complex features more likely to succeed, as the information is available to examine for interactions.
- **User re-homing and load balancing**
  To facilitate re-homing of users to ASs and load balancing, the definition of IMS AS service data descriptions increases the opportunity for hosting services on alternative ASs.

This work studied the necessary components of an AS subscriber data definition and the procedures necessary to follow in enabling other applications to define, extend and publish data definitions.

- Clarify the requirements for defining application specific data descriptions
- Study mechanisms for the transfer of service data descriptions to AS.
- Provide solutions to defining data for the Telephony Application Server (TAS).

Petitioners' Exhibit 1003, p. 318
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Provide recommendations for how the framework defined for the service data schema can be reused and extended for future service definitions.

TR 29.864 identifies an AS service data representation specific to an IMS Telephony Application Server.
It studies requirements for AS service data definition and transfer of defined service data between AS and HSS.
Further, it exposes a service data definition for a TAS for services defined in TS 22.173 (IMS Multimedia Telephony Service and supplementary services; Stage 1).
It provides recommendations for how the framework can be reused and extended for future IMS service definitions.

TR 29.864 Recommendations

- provide a definition of the IMS Telephony Supplementary service (MMTel) data understood by a variety of TASs;
- define a binary format for these service data in the context of Rel-8;
- define an XML format based on the one defined for Supplementary Services in TS 24.6xy in the context of Rel-8;
- for the binary format, include a service description specifying the services and impacts on the IMS Telephony Supplementary Services for which this approach enables interoperability.
  For the binary approach, describe how an optional extension mechanism works that supports more complex features for some of the services, or introduces new services;
- for the XML format, include a possibility for compression, based on either gzip or EXI;
- this be complemented by the necessary mechanism for transmission over the Sh interface;
- insert this data into the Sh User Data AVP in such a manner that additional transparent data can also be transmitted.

Genealogy of this spec:

this spec	descendant(s)
29.864	29.364

Spin-off Feature UID_410003 (IMS_ASIO) IMS Application Server Service Data Descriptions for AS interoperability.

Petitioners' Exhibit 1003, p. 319
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

23.4 Study on Customized Alerting Tone solution for voice and video call in CS domain UID_360031

Resources: C4

References

Document	Title/Contents
WID(s)	
CP-070518	SID on CAT solution for voice and video call in CS domain / Support CAT (Customized Alerting Tone) in 3G CS domain
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 29.882	Customized Alerting Tones (CAT) in the 3GPP CS domain

Supporting Individual Members: China Mobile, Alcatel-Lucent, SK Telecom, Huawei, ZTE.

This work is linked to the feature Customized Alerting Tone (CAT) UID_340029.

CAT has been deployed in many countries. The inherited CAT service (content being: music, voice, text, video clip, etc.) becomes a carrier's focus when deploying a 3G network.

There is a need to study how to implement in 3GPP CS domain the CAT requirements in TS 22.182 for both voice and video calls, since there are many alternatives to implement the basic CAT function.

TR 29.882 studied the implementation of CAT (for voice and video call) in 3G CS domain including:

- Basic call scenario for CAT (including both voice and video call);
- Interaction with call forwarding and other supplementary services;
- Interaction with fall back (e.g. CAMEL, etc.);
- Abnormal case; especially CAT server outage.

TR 29.882 Conclusions and Recommendations

Feasibility & Limits of CAT services in the CS domain

- It is possible to provide audio CAT-A and CAT-B services in the CS domain indicating that the called party is being alerted. Providing audio CAT has no requirement on the calling party UE.

- With UEs enhanced with CAT capabilities it is possible to provide multimedia CAT-A and CAT-B services in the CS domain indicating that the called party is being alerted. The calling party may not be able to experience the multimedia CAT when the call spans over ANSI and ITU networks or traverses non-standard transit nodes that do not both-way through connect the bearer during the alerting phase.

- Solutions to provide multimedia CAT in the CS domain towards a non-CAT capable UE may work but in some cases the call will fail (if the end to end bearer is not both-way through-connected during the alerting phase) due to H.245 signalling being unsuccessful.

- CAT copy and CAT stop commands can be supported through the use of DTMF within the same PLMN (as per stage 1 requirements). CAT can only be copied between calling and called subscribers of the same PLMN since no interface is standardized to copy CAT between CAT Servers.
  CAT copy and CAT stop requests for an audio CAT may not work between PLMNs when the call spans over ANSI and ITU networks or traverses non-standard transit nodes that do not both-way through connect the bearer during the alerting phase.

Further analysis would be required to consider whether the following CATs could be supported:

- the progress of communication request (Call Forward, Call Wait, etc.);
- any alerting event during a call session.

CAT is optional for an operator to deploy. CAT services should not impact a network not supporting them.

Preferred solution(s)

Petitioners' Exhibit 1003, p. 320
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

1. **Audio CAT**
   using the GMSC Server Switched Architecture
2. **Multimedia CAT**
   using the GMSC Server Switched Architecture with multimedia UEs enhanced with CAT capabilities.
   CAT is optional for an operator to deploy. If it is deployed, multimedia UEs should support CAT capabilities.

   If an operator's policy is to support CAT service towards the calling party multimedia UE which has not been enhanced with CAT capabilities, the CAT Server Switch Architecture may be used in this case, however due to the number of limitations there was no consensus to pursue this alternative as a standardised solution.
3. **Signalling of calling UE's CAT capability to the GMSC**
   The calling UE's CAT capability should be signalled to the GMSC. This may be done either via the signalling of a new specific CAT indicator through the call control signalling protocol (ISUP/BICC/SIP-I) or via the interrogation of the originating MSC through the MAP Anytime Interrogation / Provide Subscriber Info messages.
   There was no objection to investigate either approach during the normative work.
   The method taking use of UEs session reset capability and transporting this information from the CAT-server to the GMSC Server requires a complex CAMEL 4-architecture and should therefore not be pursued.

Changes required by the GMSC Server switch architecture should be specified in existing specifications.

Spin-off UID_340029 Feature CAT

Petitioners' Exhibit 1003, p. 321
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

23.5 Study on InterWorking Function between MAP based and Diameter based interfaces UID_380023

Resources: C4

References

Document	Title/Contents
WID(s)	
CP-070760	SID on InterWorking Function (IWF) between MAP based and Diameter based interfaces
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 29.805	InterWorking Function (IWF) between MAP based and Diameter based interfaces

Supporting Individual Members: Huawei, Vodafone, Orange, T-Mobile, Ericsson, RITT, TeliaSonera, Motorola, Alcatel-Lucent, China Mobile.

This work is linked to the SAES Feature UID_320005.

With network evolution to an all-IP-network, IP based signalling protocols are getting widely used in 3GPP systems. The number 3GPP defined Diameter-based interfaces increased for e.g. PCC, I-WLAN, MBMS, GBA architecture. Due to coexistence in the same system of new and legacy protocols (based on different transport layers e.g. IP and SS7), interworking between these protocols is required by operators.

This study evaluated complexity, performance and duality of an IWF based on concrete use cases. It recommended how to map procedures and parameters, and where to locate the IWF within the network in order to ensure less IWF complexity and best performance.

TR 29.805 evaluates the introduction of an IWF between MAP-based and Diameter-based interfaces. For each interworking deployment scenario, it analyzed how the IWF fulfils specific interworking requirements, and performs mapping of procedures and corresponding parameter handling.

Uses cases involving inter-operator interfaces got higher priority than intra-operator interfaces.

TR 29.805 conclusions:

- IWF scenario 1 to 4 should be specified in Rel-8;
- IWF scenario 5 is not supported in Rel-8.

Spin-off implementation Building Block UID_410007 (MAP2Diam) under the SAES Feature UID_320005.

Petitioners' Exhibit 1003, p. 322
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

24 RAN Studies

24.1 Study on Scope of future HSPA Evolution for 1.28Mcps TDD UID_370041

Resources: R1

References

Document	Title/Contents
WID(s)	
RP-070748	SID on Scope of future HSPA Evolution for 1.28 Mcps TDD
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 25.824	Scope of High Speed Packet Access (HSPA) Evolution for 1.2 Mcps TDD

Supporting Individual Members: TD Tech, ZTE, CATT, Spreadtrum.

The importance of enhancing capabilities and performance of HSPA-based radio networks is widely recognized. For protecting operators' investments and offering a smooth migration path towards LTE, the following principles for HSPA evolution were considered:

- HSPA spectrum efficiency, peak data rate, state transition efficiency and latency of both user plane and control plane should continue to evolve;
- Evolved HSPA should be able to operate as a packet-only network based on utilization of Shared Channels only;
- HSPA evolution should be backward compatible in the sense that legacy terminals (R99-DCH and HSPA mobiles) should be able to share the same carrier with terminals implementing the latest features of the HSPA evolution track without any performance degradation;
- Evolved HSPA should be able to offer more efficient QoS support.

The study focussed on improving system performance for services delivered through PS-domain including voice and multimedia conversational services. Critical elements of such an evolution were included e.g. reduced latency, higher user data rates, improved system capacity and coverage, reduced operator cost while maintaining the highest possible level of backward compatibility. The study concentrated on the following items:

- Define a set of requirements for HSPA evolution which covers the following aspects:
  a) Targets for improvements in latency, throughput and spectrum efficiency utilizing the existing 1.28MHz bandwidth
  b) Define constraints in terms of acceptable hardware/software changes to current elements (UE, Node, RNC, SGSN, GGSN)
  c) Define constraints in terms of acceptable network architecture changes
- Determine performance benefits achievable by HSPA and in which scenario HSPA evolution applies most;
- Identify potential solutions to improve HSPA performance towards agreed targets within the defined constraints;
- Make recommendations for subsequent HSPA Evolution implementation work items.

Last Status Report in RP-080290.

NOTE: TR 25.824 and Status Report provide neither Conclusions and Recommendations nor a Work Plan.

Petitioners' Exhibit 1003, p. 323
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

24.2 Study on Synchronized E-DCH for UTRA FDD UID_370042

Resources: R1

References

Document	Title/Contents
WID(s)	
RP-070678	SID on Synchronized E-DCH for UTRA FDD
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 25.823	Feasibility study on synchronized E-DCH for UTRA FDD

Supporting Individual Members: Nokia, Nokia Siemens Networks, Qualcomm, T-Mobile International, Ericsson.

The goal of RAN1 Rel-5 study TR 25.854 Uplink Synchronous Transmission Scheme (USTS) was to improve orthogonality of the uplink signals by sharing a common scrambling code and assigning different channelization codes to UEs similarly to downlink. In order to achieve the improved orthogonality at the receiving side (Node B), the transmission time on the UE side needs to be adjusted so that the arrival times in Node B are sufficiently synchronized.

This study did not lead to an implementation work item due to lack of orthogonal codes space (as too many users with DTX would require multiple parallel codes) and at that time all resource allocation resided in RNC.

Since then 3GPP has introduced MAC layer functionality in the BTS to control radio resources with HSDPA and HSUPA, and thus the limitation of RNC-only control of resource allocation was removed. Also the use of 16QAM in the uplink offers potential for putting more data on an individual code channel.

As a consequence, the potential of synchronized uplink transmission should be studied to see what additional benefits could be obtained combining synchronized uplink transmission and BTS based uplink resource allocation. The original focus was on the resulting low data rate capacity (such as speech).

This work studies whether HSUPA-like uplink resource allocation allows more potential of synchronized uplink transmission to be achieved for uplink packet data transmission compared to Rel-5 TR 25.854, with the focus on:

- Resulting performance from BTS based dynamic uplink code allocation;
- Resulting L1/MAC signalling needs to enable BTS based code allocation and uplink synchronization on top of the Rel-7 specification;
- This study did not repeat the basic USTS analysis already existing in TR 25.854 on e.g. synchronization sensitivity.

TR 25.823 conclusion

Synchronised E-DCH study has investigated methods for increasing the capacity of WCDMA uplink, including CDM based Synchronized E-DCH, TDM based Synchronized E-DCH and interference cancellation.

Performance evaluation has been carried out at link and system level, comparing Synchronised E-DCH against Rel-7 HSUPA. At 80-90% HARQ throughput, the CDM based Synchronised E-DCH showed link level gains of 0.75-1dB in a multipath rich channel and 1-2dB in low dispersion channel, while 3 stage parallel IC on HSUPA showed link level gains of 2dB in both kinds of channel. Parallel IC on CDM based Synchronised E-DCH showed additional gains of 1.8dB in TU6 and <0.1dB in PedA (the OVSF already removed most of the interference in the latter case). At low HARQ throughput levels (25%), Synchronised E-DCH and IC showed link level gains of <0.5dB.

System level full buffer simulations were also performed in order to assess the capacity gains available with each of the techniques. Comparing the simulations at 6dB RoT, CDM based Synchronised E-DCH showed capacity gains of 50% in Pedestrian A and 10-15% in TU6. TDM based Synchronised E-DCH showed gains of 50% in Pedestrian A and 30-40% in TU6. Interference cancellation on Rel-7 HSUPA based on a realistic group serial/parallel algorithm showed gains of 50-60% in cell throughput and 40-75% in cell edge user throughput in both dispersive TU6 and non dispersive Pedestrian A channels.

The CDM and TDM approaches effectively share the time/OVSF code resources between users, whereas conventional HSUPA allows each user access to a full OVSF tree. At cell throughput levels of ≥2Mbps, higher coding rates or higher order modulation compared to asynchronous HSUPA would be needed if pure CDM or TDM operation is to be maintained.

Petitioners' Exhibit 1003, p. 324
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Interference cancellation may be applied to CDM based or TDM based Synchronised E-DCH or to HSUPA. Simulations indicated that application of IC to CDM based Synchronised E-DCH could reduce the number of interference cancellation stages required in a parallel interference canceller by 1 compared with an application to HSUPA. TDM based Synchronised E-DCH could benefit from the fact that the inter-cell interference is dominated by a low number of users in order to further boost capacity, e.g. by being able to operate at a higher RoT level by cancelling or suppressing these dominant interferers.

In terms of complexity, CDM based Synchronised E-DCH increases CM and PAPR at the UE transmitter and requires code scheduling and synchronisation at NodeB. TDM synchronisation requirements are looser, and scheduling may be more straightforward. Interference cancellation implies additional NodeB baseband processing complexity.

Impact on specifications is greatest for CDM based Synchronised E-DCH, significantly lower for TDM and zero for interference cancellation on Rel-7 HSUPA.

Last Status Report in RP-080068

NOTE: TR 25.823 and Status Report provide no Work Plan.

24.3 Study on Improved network controlled mobility between LTE and 3GPP2/mobile WiMAX radio technologies UID_360016

Resources: R2

References

Document	Title/Contents
	WID(s)
RP-070511	SID on Improved network controlled mobility between LTE and 3GPP2/mobile WiMAX radio technologies
	Impacted Specifications
-	-
	New Dedicated Specifications/Reports
TR 36.938	Improved Network Controlled Mobility between E-UTRAN and 3GPP2/Mobile WiMAX Radio Technologies

Supporting Individual Members: Motorola, Intel, Telecom Italia, Sprint, Samsung, NEC, Alcatel-Lucent, Vodafone, Nokia, Nokia Siemens Networks, Ericsson, Nortel, Qualcomm, KDDI, RIM

3GPP is going through Long Term Evolution and System Architecture Evolution implementation work and study items. Important LTE tasks include reduced latency, improved system capability, reduced cost per bit, higher user data rates. It is expected that IP based 3GPP services will be provided through various access technologies, including existing broadband radio access standards like IEEE 802.16e/ETSI BRAN, 3GPP2 including EVDO and 1xRTT.

This work:

- studies mobility between LTE and 3GPP2/mobile WiMAX systems in accordance with SA1 requirements;
- studies validity of existing 3GPP inter-RAT mobility mechanisms and their extendibility to non-3GPP RATs;
- identifies the versions of 3GPP2 and mobile WiMAX technologies (including technology variants) where mobility with LTE is needed;
- identifies frequency bands for which LTE and the studied non-3GPP systems should provide mobility support, including identification of duplex modes and channel bandwidths;
- characterizes impact on 3GPP UE supporting different solutions for handover between LTE and the studied non-3GPP technologies
- identifies requirements for availability of 3GPP2 and mobile WiMAX network configurations (including neighbour lists, raster index, cell identifiers) to 3GPP devices to enable mobility measurement of non-3GPP networks;
- identifies requirements for, and means of, reporting active mode measurements;
- identifies any additions to current mobility procedures.

TR 36.938 is a stage 2-level concept solution for each of the studied mobility scenarios which can be used as a basis for initiating Stage 3 work when moving to the implementation work item.

Even though a common solution is preferable, it is not required for the different mobility scenarios.

Petitioners' Exhibit 1003, p. 325
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The solution developed for LTE – mobile WiMAX mobility should be reusable for UTRA – WiMAX mobility.

TR 36.938 Conclusions and Recommendations

Conclusions

Minimize impacts on legacy cdma2000 and reduce dependencies between E-UTRA and legacy cdma2000 systems. It was decided to:

- re-use cdma2000 interwork between HRPD and 1XRTT, e.g. supporting S101 interface similar to A21 to exchange messages between E-UTRAN and cdma2000;
- use RRC and S1AP tunnelling to transport cdma2000 messages over E-UTRAN;
- use RRC command to trigger UE to initiate handover preparation at target network via tunnelling;
- support network control of mobility;
- support single- and dual-radio UEs, including single-transmitter dual-receiver configuration.

The cdma2000 inter-working solution is based on multiple E-UTRA mechanisms, e.g. broadcast, measurement control, cell reselection and UE capability handling. Where these are not decided yet, the study proposes to keep alignment with the final E-UTRA decisions.

The eight work objectives and the General Requirement on E-UTRAN in TR 36.938 clause 5 are fulfilled for cdma2000 interworking with E-UTRA.

For mobility between E-UTRAN and WiMAX, studies were made on network architecture and interfaces, WiMAX system information in E-UTRAN, measurement control for RRC_IDLE and RRC_Connected UEs, cell reselection, and handover. Key solutions agreed and captured comprise:

- TWG release 1 and NWG release 1.0.0 as a target WiMAX release
- Architecture and interfaces with FAF, X200, S301, and X101
- Definition of WiMAX system information
- CINR and RSSI as WiMAX measurement quantities
- Threshold based on LTE_IDLE mode measurement control
- Network controlled measurement gap creation for LTE_ACTIVE UEs
- Use of periodic measurement reports and events-triggered measurement reports to report preamble index, measured result on preamble index and BS id
- Priority based cell reselection to WiMAX
- Handover procedure with pre-registration and handover preparation by UE tunnelling of corresponding WiMAX messages to the WiMAX while the UE is in E-UTRAN

Many solutions are derived from existing intra-3GPP inter-RAT mobility mechanisms and they will be aligned to the outcome of the intra-3GPP Stage 3 as much as possible. Transport mechanism and termination/origination points between E-UTRAN and WiMAX outside the scope of TSG RAN and for SA2's decision.

Progress was made meeting mobility requirements between E-UTRAN and mobile WiMAX radio technologies.

Recommendations

It is feasible (Stage 2 solution has been described) to support interworking between:

- cdma2000 and E-UTRAN
- WiMAX and E-UTRAN

Status Report in RP-070827

Petitioners' Exhibit 1003, p. 326
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

24.4 Study on 3G Home NodeB/eNodeB UID_350039

Resources: R4

UID	Name	Hyperlink	Status_Report	Notes	TS_TR
350039	Study on 3G Home NodeB/eNodeB	RP-070257	RP-080289	RP#40 completed	25.820

Supporting Individual Members: Nokia, Siemens Networks, Ericsson, Motorola, Alcatel-Lucent, Samsung, Huawei. NEC.

With increased UMTS terminal penetration and Fixed-Mobile Convergence, a strong demand is observed for 3G HNB providing attractive services and data rates in home environments.
New services with higher data rate at lower cost, require the study of 3G HNB environments.
Many operators indicated interest, that could lead to fragmented markets with non-standardized solutions.

UTRAN is not optimal for this application as it was developed under the assumption of coordinated network deployment whereas HNB is typically associated with uncoordinated and large scale deployment.

This study investigates amendments to UTRAN (FDD) to fully support HNB application.
This work studies aspects of 3G HNB solution and develops a standardized scenario and solution assuring a multi-vendor environment. It includes architecture, HO scenario, interference consideration, OAM interface aspect, etc.

To minimize impact on existing network, the HNB concept for WCDMA shall operate with legacy terminal (R99 onwards) and core network, and minimize impact on UTRAN interfaces. No UE specifications impact is foreseen.
A feasible solution providing 3G HNB environment should be available.

Work on LTE HeNB (as part of the LTE work item) benefits from scenarios defined as part of this study.
Interference analysis is based on the same scenario for both UTRAN and E-UTRAN as deployment scenarios are the same.

This work develops a framework for 3G HNB. It focuses on building the 3G Femto/Pico environment capable of providing users with high bit rate and low-cost services.

TR 25.820 Summary

It analyzed impact of HNB on macro layer with downlink emphasis and prioritized the interference scenarios below.

Table: Interference Scenario analysis

Number	Aggressor	Victim
1	UE attached to HNB	MNB Uplink
2	HNB	MNB Downlink
3	UE attached to MNB	HNB Uplink
4	MNB	HNB Downlink
5	UE attached to HNB	HNB Uplink
6	HNB	HNB Downlink

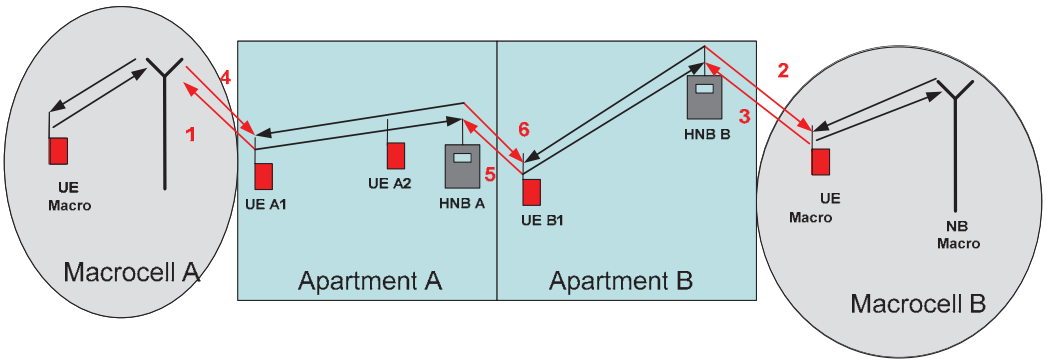


Figure: Interference scenarios

Petitioners' Exhibit 1003, p. 327
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

A wide range of possible HNB deployment configurations are envisaged. TR 25.820 uses interference scenarios to investigate impact of HNB deployment on existing BS requirements. However, the interference scenarios are dependent on the deployment configurations.

Successful HNB (dedicated or co-channel) deployment needs minimum performance requirements for all scenarios.

TR 25.820 Conclusions

RAN4 Conclusions

RAN4 identified new requirements affecting RF aspects. Their feasibility is addressed by:

- H(e)NB should not degrade significantly the performance of networks deployed in other channels. Feasible. Dedicated carrier deployment of HNB is feasible for both Open and Closed Subscriber Group systems in a wide range of deployment configurations. Co-existence between HNB and UTRAN networks in adjacent channels is comparable with co-existence for local area Bases Stations.
- H(e)NB configurations intended for deployment in the same channel as an existing E-UTRAN network should ensure their combined performance is not significantly worse than that of the original network. Feasible, however especially in the case of CSG there will be an increased level of interference relative to dedicated deployment; interference mitigation techniques have been studied to reduce this.
- H(e)NB should provide reasonable performance whether deployed in isolation or whether multiple H(e)NB are deployed in the same area. Feasible, however in high-density deployments, techniques may be needed to mitigate inter-HNB interference.
- As a H(e)NB may be privately owned and portable, it shall only radiate while it is confirmed that such an emission complies with regulatory requirements in force where that HNB is operating. Feasible
- The HNB must support UE speeds up to 30 km/h. Feasible
- HNB must support existing UTRAN UEs. Feasible

RAN2 Conclusions

RAN2 studied intra- and inter-frequency mobility solutions and access control for UMTS HNBs. Different solutions based on current Rel-7 have been studied. No quantitative results have been presented.

RAN2 concluded there are a few solutions but having drawbacks/limitations (restrictions on deployment) an operator needing to decide upon.

For Rel-8 UE some mechanisms that optimize mobility and access control have been presented already.

Recommendation for Rel-8 UMTS HNB:

1) Solutions to optimize the mobility and access control should be specified;
2) Solution for UMTS Home-NodeB aligned with the ones decided for E-UTRAN Home-eNBs ("CSG cells") should be analyzed first;
3) Removal of constraints in procedures for (macro) cell reselection to efficiently support HNB cells should be investigated (e.g. removal of cell barring for 300 s for reselection if highest ranked cell is a CSG cell).

RAN3 Conclusions

Deploying 3G HNB with legacy UEs and legacy CN nodes is feasible. Further proposed enhancements are FFS.

Petitioners' Exhibit 1003, p. 328
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

25 GERAN Studies

25.1 Study on A-interface over IP (AINTIP) UID_50589

Resources: GP

References

Document	Title/Contents
WID(s)	
GP-071562	SID on A-interface over IP
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 43.903	A-interface over IP Study (AINTIP)

Supporting Individual Members: China Mobile, Vodafone, Telecom Italia, Ericsson, Huawei, ZTE, Alcatel-Lucent, Nokia Siemens Networks, Motorola, Nortel Networks.

BSS (Base Station System) over IP is a trend in wireless network evolution, which can construct high bandwidth, high efficiency and low cost basic networks. BSS over IP involves Gb interface and A interface over IP (AINTIP).
Gb interface over IP was standardized in Rel-4. For AINTIP, control plane signalling over IP (SIGTRAN) has been introduced in Rel-7 while certain features (e.g. MSC in Pool and Layered Architecture) require an intermediate signalling network for best performance.

During the specification in Rel-7 of A interface control plane signalling over IP, some operators expressed the concern that in order to take full advantage of IP based technologies the protocols of A interface user plane should be adapted for IP based transport. The IP based transport protocols provide a low cost intermediate network which is very attractive to the operators because CAPEX and OPEX can be significantly reduced.

AINTIP can also simplify the implementation of MSCs in a pool. Furthermore, UTRAN and more advanced RAN can use a common IP backhaul with GERAN.

This study shows it is feasible to introduce in 3GPP specifications the User Plane transport over IP for the A-interface (BSS – MGW interface). In particular it is possible to define a solution that, at the same time:

- benefits from the flexibility of the IP transport on the A-interface,
- improves bandwidth efficiency through the use of 3GPP Codecs on the A-interface,
- allows to reuse installed Transcoder equipment,
- allows to remove Transcoders from the BSS,
- enables Transcoder Free Operation (TrFO) in the BSS,
- maximizes the likelihood for end-to-end TrFO and therefore improves service quality vs. existing TDM-based BSS.

TR 43.903 made a detailed analysis of all requirements, except:

a) All teleservices, bearer services, VGCS and supplementary services defined for GSM shall be supported on the BSC-MGW interface (Comment: Not studied in full detail, but no issues are expected.)
b) GSM/AMR Codec adaptation shall be possible, e.g. due to overloading of the BSC or radio conditions. The GSM/AMR Codec adaptation delay shall be in the same order as in the current A-interface solution. (Comment: This requirement could be understood as "Codec Type" adaptation or as "AMR Codec Mode" adaptation. AMR Codec Mode adaptation is addressed under Requirement 18, see below. Codec Type adaptation has been studied in clause 7. Several feasible solutions have been identified.)
c) End-to-end speech delay shall not be increased. Congestion in the IP transport may introduce additional delay; however the end-to-end delay shall not exceed the ITU G.114. (Comment: Not studied. This will be investigated further. It is, however, expected that the selected solution complies with this requirement.)
d) It shall be possible to secure the BSC-MGW interface (see item e) below). (Comment: Not studied in full detail, but the same method as for SIGTRAN should be applicable.)
e) Speech interruption times during handovers shall be in the same order as in the current TDM implementations (Comment: Not studied. This will be investigated further. It is, however, expected that the selected solution complies with this requirement.)

Petitioners' Exhibit 1003, p. 329
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

f) The interaction of dynamic AMR Codec change and TrFO shall not degrade the overall quality of the speech in the case of MS to MS calls. (Comment: Not studied in full detail. No issues are expected because AMR Codec Mode adaptation for MS-to-MS calls in TrFO is already specified in TS 45.009.)

From the items under "further investigation" two items have not been addressed in detail:

- Since IP transport is vulnerable to unauthorized intrusions, security aspects shall be investigated. (Comment: Not studied in full detail, but the same method as for SIGTRAN should be applicable.)
- Support for GAN (Comment: Not studied in detail, no issues expected.)

The investigated solution allows smooth migration from legacy, TDM-based A-interface to new, IP-based A-interface.

Working Assumptions were formulated to guide the specification phase.

The investigated solution assumes support on the MSC-MGW- (Mc) and the MGW-MGW- (Nb) interfaces and therefore cooperation with TSGs CT and SA is required.

Spin-off UID_50591 Rel-8 Feature AoIP (A-interface over IP).

Petitioners' Exhibit 1003, p. 330
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

25.2 Study on Multi-User Reusing-One-Slot (MUROS) UID_50590

Resources: GP

References

Document	Title/Contents
WID(s)	
GP-072033	WID on Study on Multi-User Reusing-One-Slot
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 45.914	Circuit switched voice capacity evolution for GSM/EDGE Radio Access Network (GERAN)

Supporting Individual Members: China Mobile, Ericsson, Nokia Siemens Networks, Nokia, Nortel Networks, NXP, Qualcomm, Telecom Italia, Vodafone.

This feature increases voice capacity of GERAN by a factor of two per BTS transceiver. The increase in user amount and voice traffic puts a huge pressure on operators especially within populous countries. Furthermore, as voice service price gets cheaper, most operators face the challenge to obtain efficient utilization of hardware and spectrum resource.

One approach of increasing voice capacity is to multiplex more than one user on a single time slot and ARFCN, thus the capacity can be significantly improved for a certain TRX hardware and possibly spectrum resource. Furthermore, such a feature is expected to provide voice capacity improvement both for full rate and half rate channels.
This work further enhances the voice capacity of GERAN by means of multiplexing at least two users simultaneously on the same radio resource both in downlink and in uplink. Channels under interest for doubled voice capacity are TCH/FS, TCH/HS, TCH/EFS, TCH/AFS, TCH/AHS and TCH/WFS with related associated signalling channels.

Implementation impact of Multi-User Reusing-One-Slot (MUROS) to the MS was investigated by analyzing different receiver types, e.g. legacy GMSK terminals supporting or not DARP phase 1 (Downlink Advanced Receiver Performance). For this the design of a new set of training sequences with improved cross correlation properties to the existing set of training sequences is foreseen and expected to be evaluated. Furthermore, the introduction of MUROS should change hardware as little as possible and should not decrease voice quality. The impact on network planning and frequency reuse was investigated.

The study included investigation of different optimised pulse shapes for MUROS for both the uplink and the downlink. For this purpose, link-level and system-level performance evaluation was used; including investigation into usage at the band edge, at the edge of an operator's band allocation and in country border regions with no frequency coordination. Impacts to the Abis interface was investigated.

Any TRX hardware capable of multiplexing more than one user on a single ARFCN time slot shall support legacy GMSK mobiles, this includes non-SAIC mobiles and SAIC mobiles.

GP#48 completed as Rel-8. Spin-off implementation WI UID_420002 VAMOS (Voice services over Adaptive Multi-user channels on One Slot)

Petitioners' Exhibit 1003, p. 331
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

25.3 Study on Optimized Transmit Pulse Shape for Downlink EGPRS2-B (WIDER) UID_51148

Resources: G1

References

Document	Title/Contents
WID(s)	
GP-072026	WID on Optimized Transmit Pulse Shape for Downlink EGPRS2-B
Impacted Specifications	
-	-
New Dedicated Specifications/Reports	
TR 45.913	Optimized transmit pulse shape for downlink Enhanced General Packet Radio Service (EGPRS2-B)

Supporting Individual Members: Ericsson, Nokia, Nokia Siemens Networks, Research In Motion, TeliaSonera, Vodafone.

This work is linked to GERAN Rel-7 REduced symbol Duration, Higher Order modulation and Turbo coding for downlink (REDHOT) UID_50121.

EGPRS2-B feature has been included into GERAN Rel-7 with the legacy GMSK pulse shape. This pulse shape yields good performance and can be used without any requirements on the operator network scenario.

Initial analysis showed that in certain network scenarios, a spectrally wider pulse shape can further improve data throughput performance. To obtain superior data throughput performance, investigation of a wider pulse shape is needed, including the network scenarios that will benefit from a wider pulse shape. Selection of either the legacy pulse shape or the new pulse shape will be under operator control.

It is not clear to what degree the current spectral mask can be widened without causing a detrimental impact on legacy MSs in these networks. It is also not clear if a spectral mask relaxation is dependent on the modulation transmitted or whether it can be assumed to be applicable for all modulations. It is important to continue to improve the GERAN system performance with new features, and as such it is relevant that this topic is carefully and independently studied. Spectral mask changes were also studied and implemented when 8-PSK modulation and the linearized GMSK pulse shape were introduced in 1998/1999.

This work investigated the impact of downlink spectral mask changes for EGPRS2-B on GSM system performance and identified an optimized transmit pulse shape This work involved investigations at the link level and at the system level. When ACP is referenced, this may be evaluated at several offsets from the carrier, to be determined by GERAN WG1.

When applying a new transmit pulse shape, implementation margin must be taken into account when ensuring that the pulse shape conforms to the new spectral mask when transmitter impairments and issues such as spectral regrowth are taken into account. Design impacts of the optimized pulse shape with regard to the usage at band edge, at edge of an operator's band allocation, and in country border regions where no frequency coordination is in place, were also described.

Selection of an optimized pulse shape is performed based on optimization criteria to be agreed by GERAN WG1.

Evaluation of an optimized pulse shape uses a similar approach as in the GERAN Rel-6 TR 45.903 (Feasibility study on Single Antenna Interference Cancellation (SAIC) for GSM networks) UID_51101.

Network Level Analysis

Network level analysis was performed for network configurations agreed by GERAN WG1 for different penetrations of legacy GMSK pulse shape and optimised pulse shape, respectively, being operated in downlink. The purpose of this analysis is to define different interferer profiles for a given penetration of the wider TX pulse shape and a given network configuration.

Link Level Studies

Link level studies were performed using the set of interferer profiles agreed by GERAN WG1 that were determined in the network level analysis. The purpose of the link level studies is to determine the relevant inputs to feed into system level evaluation, analyzing both the impact to legacy users and data service throughput. The link level study:

Petitioners' Exhibit 1003, p. 332
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

1. Investigated the impact of the variation in legacy mobile implementations to the impact on legacy users and the system data throughput using the interferer profiles:
    a. One or more "reference MS receiver" designs may be defined to test the link level performance against. The resulting performance and impact for each tested transmit pulse shape will be assessed using these models;
    b. In addition to defining sample reference mobile implementations, mobile manufacturers will be encouraged to provide link level simulation results to determine the resulting performance and impact when different transmit pulse shapes are evaluated. This information shall then be used as an input to system level simulations (along with results from any "reference MS receiver(s)" agreed by GERAN WG1).
2. Investigated the impact of different channel profiles to the impact on legacy users and the system data throughput using the generated interferer profiles:
    a. Using vendor provided results plus reference MS receiver models (if any), determine how much the resulting performance and impact varies as the channel profile is changed. Profiles with high and low velocities as well as with and without frequency hopping shall be analyzed.

System Level Studies

Using the information determined from the link level studies described above, system simulations to determine overall impact and data throughput gains were performed for any studied transmit pulse shape. Representative network scenarios to be examined will be determined by GERAN WG1. The following system level impacts were studied:

1. The performance of legacy speech services is evaluated by examining the change in dropped calls of legacy mobile stations when:
    a. the transmitter output conforms to the spectral mask being studied with implementation margin taken into consideration;
    b. The legacy mobile is examined using the interferer profiles from the network level analysis.
2. The performance of legacy data services is evaluated by examining the change in mean throughput. Investigate the change in data performance of legacy mobile stations when:
    a. the transmitter output conforms to the spectral mask being studied with implementation margin taken into consideration;
    b. The legacy mobile is examined using the interferer profiles from the network level analysis.
3. The improvement in data throughput will be examined when:
    a. the transmitter output conforms to the spectral mask being studied with implementation margin taken into consideration;
    b. the interferer profiles from the network level analysis are used and different penetration levels of reference MS receivers (as previously defined) and MS receivers that are compatible with EGPRS2-A and EGPRS2-B are considered.

Petitioners' Exhibit 1003, p. 333
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

26 Rel-8 Completed Items

UID	Name	Acronym	Resource
0	Release 8 SA/CT Features	-	-
320005	3GPP System Architecture Evolution Specification - Evolved Packet System (non RAN aspects)	SAES	S1,S2,S3,S5,C1,C3,C4,C6,IETF
450022	Conformance Test Aspects – Mobility management based on DSMIPv6 (Dual-Stack Mobile IPv6)	DSMIPv6_UEConTest	R5
370025	IMS Centralized Service Control (ICSRA)	ICSRA	S1,S2,C1,C3,C4,IETF
370059	IMS Multimedia Telephony and Supplementary Services	IMSTSS	S1,S5,C1,C3,C4,IETF
390035	3GPP2 Input to Common IMS	CIMS_3GPP2	S1,S2,S3,C1,C3,C4
350005	IMS Enhancements for support of Packet Cable access	PktCbl	S2,S3,C1,C3,C4
360012	IMS System enhancements for corporate network access	IMS_Corp	S2,S1,C1,C4,IETF
380069	Maintenance of TISPAN documentation	MAINTISP	S2,C1,C3,C4,IETF
390056	IMS Service Continuity	IMS-Cont	S2,S1,C1
370078	Security Enhancements for IMS	IMS-Sec	S3,C1,C4
34046	IMS initiated and controlled PSS and MBMS User Service	IMS_PSS_MBMS_US	S4,S3,IETF
713024	Multimedia interworking between IMS and CS networks	MIW-IMS	C3,C4
360029	IMS Stage 3 IETF Protocol Alignment - phase 2	IMSProtoc2	C1,IETF
380014	Interworking between User-to-User Signalling (UUS) and SIP	UUSIW	C1,C3,IETF
380018	Support of Overlap signalling	Overlap	C3,C1,C4
380035	AS/MRFC Stage 2 and 3	MRFC_TS	C1,IETF
400012	IMS Restoration Procedures	IMS_RP	C4,C1
410003	IMS Application Server Service Data Descriptions for AS interoperability	IMS_ASIO	C4
340030	I-WLAN Network Selection Principle (NSP)	IWLANNSP	S1,C1,C6
370049	Mobility between 3GPP-WLAN Interworking and 3GPP Systems	IWLAN_Mob	S2,C1
460006	Conformance Test Aspects – Mobility between 3GPP WLAN Interworking and 3GPP Systems	IWLAN_Mob_UEConTest	R5
7042	Enhancements for Voice Group Call Service (VGCS) Applications (EVA)	EVA	S1,C1,C4,G2
31081	Personal Network Management	PNM	S1,C1,S3
330005	eCall Data Transfer	EData	S1,C1
34042	eCall data transfer Phase 2: Comparison of alternative in-band modem solutions and standardization of one in-band modem solution	eCall_Phase2	S4
450001	eCall Conformance Testing	eCall_MSTest	G3new
450023	Conformance Test Aspects – non-modem procedures of eCall sessions in UTRA	UMTS_eCall_UEConTest	R5
380060	IP Interconnection of Services	IPinterc	S1,S2,S5,C3
360025	Support of (G)MSC-S – (G)MSC-S Nc Interface based on the SIP-I protocol	SIP_Nc	C4,C3
370051	Earthquake and Tsunami Warning System	ETWS	S1,S2,C1,C4,G2
440011	Conformance Test Aspects – UMTS Earthquake and Tsunami Warning System (ETWS) FDD	ETWS_UMTS_UEConTestFDD	R5
380059	In Case of Emergency numbers storage and easy access on UICC	ICE	S1,C6
330006	Local Charging Zone Requirements	LCZR	S1
340029	Customized Alerting Tone (CAT) service	CAT	S1,C1,C3,C4
340031	Service-Level Interworking for Messaging Services	MESSIW	S1,S2,C3,C1
340044	Multimedia Priority Service	PRIOR	S1,C1,C3,C4
360010	Open Service Access (OSA) Rel-8	OSA8	S1,C5
360032	Paging Permission with Access Control (PPACR)	PPACR	S1,C1
490017	Conformance Test Aspects – Paging Permission with Access Control (PPAC)	PPAC_UEConTest	R5
380063	Charging for multi-phases services	CHRGMPH	S1
380065	Home NodeB / eNodeB	HomeNB	S1,C1,C4
390033	UTRA HNB	HNB	RP,S5
430022	UTRA HNB – UE Conformance Testing	HNB-UEConTest	R5
350015	Lawful Interception in the 3GPP Rel-8	LI8	S3

Petitioners' Exhibit 1003, p. 334
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

390046	**Generic Bootstrapping Architecture Push Function**	GBAPush	S3,C1,C4
34045	**Requirements and Test methods for Wideband Terminals**	RETEM_WB_T	S4
34043	**Extending PSS and MBMS User Services for optimized Mobile TV**	PSS_MBMS_OMTV	S4
400028	**Encoding formats, transport formats and media description signalling for interworking, QoE, and other enhancements to MTSI-MHI**	MTSI_eMHI	S4,C3,C4
340063	**Rel-8 Operations, Administration, Maintenance and Provisioning (OAM&P)**	OAM8	S5,C1,C4,IETF
350016	**Rel-8 Charging Management small Enhancements**	CH8	S5
380024	**Conferencing enhancements for Mp interface**	eMp	C4
320014	**Contact Manager for 3GPP UICC applications**	eUPHBOOK	C6
320001	**(Small) Technical Enhancements and Improvements for Rel-8**	TEI8	All

Petitioners' Exhibit 1003, p. 335
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

UID	Name	Acronym	Resource
0	Release 8 RAN/GERAN Features	-	-
20068	Rel-8 LTE – 3G Long Term Evolution - Evolved Packet System RAN part	LTE	RP,S5
25029	Rel-8 LTE – Terminal Conformance Test Specification	LTE-UEConTest	R5
350040	Rel-8 Improvements of the Radio Interface	RInImp8	RP
25125	Rel-8 Improvements of the Radio Interface - UE Conformance Testing	RInImp-UEConTest	R5
370035	Rel-8 RAN improvements	RANimp	RP
25126	Rel-8 RAN improvements - UE Conformance Testing	RANimp-UEConTest	R5
360008	3.84 Mcps TDD MBSFN Integrated Mobile Broadcast	MBSFN-DOB	R1
440008	Conformance Test Aspects – 3.84 Mcps TDD MBSFN Integrated Mobile Broadcast	MBSFN_IMB_UEConTest	R5
50583	GERAN support for GERAN - 3G Long Term Evolution interworking	GELTE	GP,G1,C1,G3new
55586	U-TDOA Enhancement	GUTEN	GP
50587	GAN Enhancements	GANENH	GP
50591	AoIP (A-interface over IP)	AoIP	GP,S4,C4,C1,C3
51147	New multicarrier BTS class	MCBTS	G1
38001	Support for Additional Navigation Satellite Systems (ANSS) for LCS	ANSS	S1,G2,R2
51149	Conformance testing for the Latency Reductions feature	CTLATRED	G1, G3new
53091	MS conformance testing of changes introduced by WI "Support of Packet-switched Handover for GERAN A/Gb mode"	PSHCT-MStest	G3new
400025	Test - (Small) Technical Enhancements and Improvements for Rel-8	TEI8_Test	R5,G3new

Petitioners' Exhibit 1003, p. 336
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

ID	Name	Acronym	Resource	TR
0	Release 8 SA/CT Studies	-	-	-
7026	Study on Customised Alerting Tone (CAT) Requirements	FS_CAT	S1	22.982
7027	Study on Facilitating Machine to Machine Communication in GSM and UMTS (M2M)	FS_M2M	S1	22.868
31089	Study on Network Composition	FS_NetComp	S1	22.980
320024	Study on Requirements of IMS Multimedia Conferencing	FS_IMSconf	S1	22.948
320025	Study on support of a Public Warning System	FS_PWS	S1	22.968
330016	Study on Paging Permission with Access Control	FS_PPAC	S1	22.908
340033	Study on Non-3GPP access Network Selection Principles (NSP)	FS_N3GtoNSP	S1	22.912
340034	Study on Value Added Services for Short Message Service	FS_VAS4SMS	S1	22.942
340035	Study on Service continuity between mobile and WLAN networks	FS_SMLSWLAN	S1	22.937
370086	Study on Services Alignment and Migration	FS_ServAl	S1	22.983
32085	Study on 3GPP System Architecture Evolution	FS_SAE	S2,S3	-
32086	Stage 2 Interim conclusion for RAN Work to start	FS_SAE	S2	23.882
32087	Stage 2 study on 3GPP architectural development	FS_SAE	S2	23.882
7024	Security study for Inter-access mobility between non-3GPP and 3GPP system	FS_SAE	S3	33.821, 33.822
320028	Study on Stage 2 aspects of IMS Service Brokering	FS_ISB_ST2	S2	23.810
7049	Study on IMS utilizing multicast bearer services	FS_MLTICAST-IMS	S2	23.847
350051	Study on Multimedia Session Continuity	FS_MMSC	S2	23.893
380034	Study on centralized IMS service control	FS_ICS	S2,S1	-
370087	Study on centralized IMS services requirements	FS_ICS-S1	S1	22.892
330012	Study on centralized IMS services control	FS_IMS_CSC	S2	23.892
380078	Study on Architecture of IMS based Customized Alerting Tone (CAT)	FS_CAT-St2	S2	23.872
380085	Study on Home (e)NodeB Security	FS_HNB_Sec	S3	33.820
360015	Study on Transferring of emergency call data – in-band modem solution	eCALLIBMS	S4	26.967
35065	Study on Element Operations Systems Function (EOSF) definition	OAM7-NIM- EOSF	S5	32.819
35074	Study on SA5 MTOSI XML Harmonization	OAM8-NIM-XML	S5	32.818
320006	Study on Common Profile Storage (CPS) Framework of User Data for network services and management	OAM7-CPS	S5	32.808
340036	Study on Management for LTE and SAE	FS_OAM_LTE_SAE	S5	32.816
350004	Study on Charging Aspects of 3GPP System Evolution	FS_SAEcharg	S5	32.820
7048	Study on AS-MRFC media server control protocol	MRFC	C1	24.880
350018	Study on IMS Restoration Procedures	FS_IMS_RP	C4	23.820
360030	Study on IMS Application Server Service Data Descriptions for AS interoperability	FS_IMS_ASIO	C4	29.864
360031	Study on Customized Alerting Tone (CAT) solution for voice and video call in CS domain	FS_CAT_VVC_CS	C4	29.882
380023	Study on InterWorking Function between MAP based and Diameter based interfaces	FS_MAP2Diam	C4	29.805

ID	Name	Acronym	Resource	TR
0	Release 8 RAN/GERAN Studies	-	-	-
370041	Study on Scope of future HSPA Evolution for 1.28 Mcps TDD		R1	25.824
370042	Study on Synchronized E-DCH for UTRA FDD		R1	25.823
360016	Study on Improved network controlled mobility between LTE and 3GPP2/mobile WiMAX radio technologies		R4	36.938
350039	Study on 3G Home NodeB/eNodeB		R4	25.820
50589	Study on A-interface over IP	AINTIP	GP	43.903
50590	Study on Multi-User Reusing-One-Slot	MUROS	GP	45.914
51148	Study on Optimized Transmit Pulse Shape for Downlink EGPRS2-B	WIDER	G1	45.913

Petitioners' Exhibit 1003, p. 337
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

27 Rel-8 Stopped Items

UID	Name	Acronym	Resource	Hyperlink	Notes
0	Release 8 Features	-		-	-
390020	**Deleted - Issues for CT4 TR 29.803**	SAES	C4	CP-080068	CP#41 Work stopped and continued in Normative specifications
350029	**Deleted (covered by 380068): Functions and procedures for SAE to support LCS**	SAES-SA-FP_LCS	S2	-	SP#37 stopped
350032	**Deleted (covered by 380064): SAE aspects of Emergency Calls**	SAES-SA-EmCall	S2	-	SP#37 stopped
340019	**Deleted - CT1 aspects of SAES**	SAES-St3	CP,C1	CP-060674	SP#37 stopped
350019	**Deleted - CT1 aspects of SAES**	SAES-St3	C1	CP-060674	SP#37 stopped
340052	**Deleted - Interoperability**	SAES-St3-interop	C1	CP-060674	SP#37 stopped
350020	**Deleted - CT3 aspects of SAES**	SAES-St3	C3	CP-060675	SP#37 stopped
350021	**Deleted - CT4 aspects of SAES**	SAES-St3	C4	CP-060676	SP#37 stopped
340021	**Deleted - UE to EPC NAS signalling (incl. MBMS and QoS aspects)**	SAES-St3-sig	C1	CP-060674	SP#37 stopped
340027	**Deleted - User and Control plane protocols**	SAES-St3-prot	C4	CP-060676	SP#37 stopped
340037	**Deleted - Architecture enhancements for non-3GPP accesses**	SAES-non_3GPP	S2	SP-060926	SP#34 stopped. Replaced by UID_350027 and its children
320030	**Deleted - Stage 2 of architecture for the 3GPP System Architecture Evolution**	SAES-St2	S2	SP-060926	SP#34 stopped. Replaced by UIDs 340018 and 340037. (SP#34 report discussion of SP-060917.)
350023	**Deleted - SA aspects of System Architecture Evolution**	SAES-SA	S2	-	SP#34 stopped
380046	**Deleted - WLAN Offline Charging**	CH8	S5	SP-070750	SP#42 stopped
350036	**Deleted - UMTS 2300 MHz FDD/TDD**	RInImp8-UMTS2300	R4	RP-070128	RP#41 stopped
31067	Deleted - All-IP Network	AIPN	S1	SP-050181	SP#38 stopped. 25/07/08 Moved UID_31059 Study on All-IP Network (FS_AIPN/was AIPFS) to Rel-7 out of the stopped Rel-8 Feature UID_31067 Deleted - All-IP Network (AIPN)
340032	Deleted - was Rel7 - LCS for 3GPP Interworking WLAN	LCS4_IWLAN	S2	SP-060818	SP-35 stopped
330010	Deleted - never approved- FBI Phase 2	FBI2	S2	-	SP#38 stopped
330007	Deleted -Enhancements to BS30 Bearer service for Videotelephony	BS30	S1	SP-060484	SP#38 stopped (no support)
370055	Deleted - IMS Enhancements Rel-8	IMS8	S1	-	SP#38 stopped
400023	Deleted - Contact Manager Conformance Test specifications	eUPHBOOK-Test	C6	CP-080430	CP#47 work stopped/abandoned
53092	Deleted - MS conformance testing of Support of Conversational Services in A/Gb mode via the PS domain	SCSAGBCT-MStest	G3new	GP-080330	GP#43 work stopped/abandoned (completion 0%)

Petitioners' Exhibit 1003, p. 338
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

UID	Name	Resource	Hyperlink	Notes	TS_TR
0	**Release 8 Studies**				
350017	**Deleted - Study on Mobility between 3GPP-WLAN Interworking and 3GPP Systems**	S2	SP-070106	SP#41 stopped. Draft TR 23.827 content implemented in TS 23.327.	withdrawn 23.827
370044	**Deleted - equals 340035 -FS on Service continuity between mobile and WLAN networks**	S1	SP-070557	SP#39 stopped	22.937
380068	**Deleted - Study on Evaluation of LCS Control Plane Solution for EPS**	S2	SP-070819	SP#40 spin-off Feature UID_400038 (LCS_CPS_EPS). SP#40 FS stopped	23.891
380080	**Deleted - Study on HS-PDSCH serving cell change enhancements**	R4	RP-071044	RP#39 stopped (no TR produced). Spin-off HS-DSCH Serving Cell Change Enhancements (UID_39003)	none
390032	**Deleted - Study on Dual-Cell HSDPA operation**	R1	RP-080228	RP#43 stopped (draft TR 25.825 v100 withdrawn). Conclusions in RP-090318 (RAN1 findings of the UTRA Multi-Carrier Evolution study). RP#42 New WI approved on Dual-Cell HSDPA operation on adjacent carriers (UID_400052)	withdrawn 25.825 v100

Petitioners' Exhibit 1003, p. 339
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

TSG#65 completed IETF dependency

UID	Name	Acronym	Rapporteur	Notes	TS_TR
531002	(IETF) CT1 aspects of IMS_Corp (RFC 7316)	IMS_Corp	Keith Drage	CP#65 completed	RFC 7316 (was draft-vanelburg-dispatch-private-network-ind)

Ongoing Rel-8 IETF dependency

UID	Name	Acronym	Resource	Rapporteur	Notes	TS_TR
521014	(IETF) CT1 aspects - Stage 3 for ICSRA (draft-ietf-salud-alert-info-urns)	ICSRA	C1-IETF	Roland Jesske	Submitted to IESG for publication	draft-ietf-salud-alert-info-urns
521020	(IETF) Stage 3 CW-IMS (salud-alert-info-urns)	CW_IMS	C1-IETF	Roland Jesske	Submitted to IESG for publication	draft-ietf-salud-alert-info-urns
521025	(IETF) IMS Stage 3 IETF Protocol Alignment (draft-ietf-salud-alert-info-urns)	IMSProtoc2	C1-IETF	Roland Jesske	Submitted to IESG for publication	draft-ietf-salud-alert-info-urns
521026	(IETF) Stage 3 MGCF UUSIW (cuss-sip-uui)	UUSIW	C1-IETF,C3-IETF	Roland Jesske	Submitted to IESG for publication	draft-ietf-cuss-sip-uui
551001	(IETF) Stage 3 MGCF UUSIW (cuss-sip-uui-isdn)	UUSIW	C1-IETF,C3-IETF	Keith Drage	Submitted to IESG for publication	draft-ietf-cuss-sip-uui-isdn

Petitioners' Exhibit 1003, p. 340
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Annex A:
Change history

Change history		
Date	**Subject/Comment**	**Ver.**
2007-12	Stage 1 frozen Dec 2007 (SA1 exceptions concluded Jun 2008)	
2008-06	Stage 2 frozen Jun 2008 (SA2 exceptions concluded Sep 2008, SA3 LI8 exception concluded Mar 2009)	0.0.1
2008-09	1st draft despatched to TSG#41 for comment	0.0.1
2008-11	Post-TSG#41 updates	0.0.2
2008-12	Stage 3 frozen Dec 2008 (SA4 eCall_Phase2 exception concluded Sep 2009)	0.0.3
2009-01	Post-TSG#42 updates. Draft despatched to TSG#43 for comment	0.0.4
2009-04	Post-TSG#43 updates	0.0.5
2009-04	Post-TSG#43 updates	0.0.6
2009-06	Post-TSG#44 updates	0.0.7
2009-09	Post-TSG#45 updates Completed: UID_320019 CT1 aspects of EVA UID_34042 eCall data transfer Phase 2: Comparison of alternative in-band modem solutions and standardization of one in-band modem solution (SA4) UID_390071 CAT solution for voice and video call in CS domain (CT3) UID_340012 Stage 3 for PRIOR (CT1) UID_400056 Conformance Test Aspects – Improved L2 for uplink (R5) UID_53089 Update TS 51.010 Mobile Station (MS) Conformance Specification for GAN Enhancements (G3new) Stopped/Abandoned/Deleted: UID_53092 MS conformance testing of Support of Conversational Services in A/Gb mode via the PS domain (SCSAGBCT-MStest) G3new Added New WIDs: UID_450052 Create missing specifications for IRP XML definitions (OAM8) S5 UID_450001 eCall Conformance Testing (eCall_MSTest) G3new UID_450023 Conformance Test Aspects - non-modem procedures of eCall sessions in UTRA (R5) UID_450024 Conformance Test Aspects – Continuous Connectivity for packet data users for 1.28 Mcps TDD (R5) UID_450025 Conformance Test Aspects – MIMO for 1.28 Mcps TDD (R5) UID_450022 Conformance Test Aspects – Mobility management based on DSMIPv6 (Dual-Stack Mobile IPv6) R5 UID_450026 Conformance Test Aspects – HS-DSCH Serving Cell Change Enhancements (R5)	0.0.8
2009-12	Post-TSG#46 updates Completed: UID_25029 LTE – Terminal Conformance Test Specifications (LTE-UEConTest) UID_410020 Conformance Test Aspects – Combination of 64QAM and MIMO for HSDPA (FDD) UID_430028 Conformance Test Aspects – Receiver Type3i UID_450052 Create missing specifications for IRP XML definitions (OAM8)	0.0.9
2010-04	Post-TSG#47 updates Completed: UID_360012 IMS System enhancements for corporate network access (IMS_Corp) UID_440011 Conformance Test Aspects – UMTS Earthquake and Tsunami Warning System (ETWS) FDD UID_450026 Conformance Test Aspects – HS-DSCH Serving Cell Change Enhancements UID_440008 Conformance Test Aspects – 3.84 Mcps TDD MBSFN Integrated Mobile Broadcast UID_51149 Conformance testing for the Latency Reductions feature (CTLATRED) Stopped/Abandoned/Deleted: UID_400023 Contact Manager Conformance Test specifications (eUPHBOOK-Test)	0.1.0
2010-06	Post-TSG#48 updates (added attachment Rel-8_Work_Plan_20100621) Completed: UID_51148 Study on Optimized Transmit Pulse Shape for Downlink EGPRS2-B (WIDER) UID_450023 Conformance Test Aspects – non-modem procedures of eCall sessions in UTRA UID_430023 Conformance Test Aspects – UTRA HNB (FDD) UID_420015 Conformance Test Aspects – Dual-Cell HSDPA operation on adjacent carriers UID_430024 Conformance Test Aspects – Enhanced Uplink for CELL_FACH State in FDD UID_450025 Conformance Test Aspects – MIMO for 1.28 Mcps TDD	0.1.1

Petitioners' Exhibit 1003, p. 341
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

2010-09	Post-TSG#49 updates Completed: UID_450022 Conformance Test Aspects – Mobility management based on DSMIPv6 (Dual-Stack Mobile IPv6) UID_460006 Conformance Test Aspects – Mobility between 3GPP WLAN Interworking and 3GPP Systems UID_440010 Conformance Test Aspects – 1.28 Mcps TDD Improved L2 support for high data rates UID_440009 Conformance Test Aspects – Enhanced CELL_FACH State in LCR TDD UID_450024 Conformance Test Aspects – Continuous Connectivity for packet data users for 1.28 Mcps TDD UID_450001 eCall Conformance Testing (by GERAN3new) Added New WIDs: UID_490015 Test interworking of IP Multimedia Services Identity Module (ISIM) terminals with IMS UID_490017 Conformance Test Aspects – Paging Permission with Access Control (PPAC)	0.2.0
2011-01	Post-TSG#50 updates. Completed: UID_50590 Study on Multi-User Reusing-One-Slot (MUROS) UID_420018 Test interworking of LTE Terminals with the USIM UID_490017 Conformance Test Aspects – Paging Permission with Access Control (PPAC) UID_25042 LTE – Terminal Radio Transmission and Reception Conformance Test Specifications	0.2.1
2011-04	Post-TSG#51 updates	0.2.2
2011-06	Post-TSG#52 updates Completed CT6 Testing: UID_490015 Test interworking of IP Multimedia Services Identity Module (ISIM) terminals with MS Added IETF dependencies: UID_521011 (IETF) Stage 3 for Mobility management based on DSMIPv6 SAES UID_521012 (IETF) Stage 3 for Mobility management based on DSMIPv6 SAES UID_521013 (IETF) Stage 3 for Interfaces EPC - non-3GPP IP access SAES UID_521014 (IETF) CT1 aspects - Stage 3 for ICSRA ICSRA UID_521015 (IETF) CT1 aspects - Stage 3 for ICSRA ICSRA UID_521016 (IETF) CT1 aspects - Stage 3 for ICSRA ICSRA UID_521017 (IETF) CT1 aspects - Stage 3 for ICSRA ICSRA UID_521018 (IETF) CT4 aspects - Stage 3 for ICSRA ICSRA UID_521019 (IETF) Stage 3 CCBS_CCNR CCBS_CCNR UID_521020 (IETF) Stage 3 CW-IMS CW_IMS UID_521021 (IETF) Maintenance of TISPAN R2 MAINT_R2 UID_521022 (IETF) IMS initiated and controlled PSS and MBMS User Service IMS_PSS_MBMS_US UID_521023 (IETF) IMS Stage 3 IETF Protocol Alignment IMSProtoc2 UID_521024 (IETF) IMS Stage 3 IETF Protocol Alignment IMSProtoc2 UID_521025 (IETF) IMS Stage 3 IETF Protocol Alignment IMSProtoc2 UID_521026 (IETF) Stage 3 MGCF UUSIW UUSIW UID_521027 (IETF) AS/MRFC Stage 2 and 3 MRFC_TS UID_521028 (IETF) Service Level Tracing in IMS OAM8-Trace UID_521029 (IETF) (Small) Technical Enhancements and Improvements for Rel-8 TEI8	0.2.3
2011-09	Post-TSG#53 updates. Completed IETF dependencies: UID_521012 (IETF) Stage 3 for Mobility management based on DSMIPv6 SAES UID_521022 (IETF) IMS initiated and controlled PSS and MBMS User Service IMS_PSS_MBMS_US	0.2.4
2012-01	Post-TSG#54 Dec 2011 updates. Completed: UID_531003 (IETF) Service Level Tracing in IMS (CT1 dependency) OAM8-Trace_IETF UID_54583 Testing for GERAN support for GERAN - 3G Long Term Evolution interworking GELTE	0.2.5
2012-03	Post-TSG#55 updates	0.2.6
2012-06	Post-TSG#56 updates	0.2.7
2012-09	Post-TSG#57 updates	0.2.8
2013-01	Post-TSG#58 Dec 2012 updates	0.2.9
2013-03	Post-TSG#59 updates	0.2.10
2013-06	Post-TSG#60 updates Completed IETF dependencies: Call Completion on Busy Subscriber (CCBS)/Call Completion on Non-Reachable (CCNR) on IMS UID_521019 (IETF) Stage 3 CCBS_CCNR C1-IETF,C3-IETF RFC 6910 (was draft-ietf-bliss-call-completion)	0.2.11
2013-09	Post-TSG#61 updated IETF dependencies	0.2.12
2013-12	Post-TSG#62 updated IETF dependencies. Completed: UID_521017 (IETF) CT1 aspects - Stage 3 for ICSRA (RFC 7006 was draft-ietf-mmusic-sdp-miscellaneous-caps)	0.3.0
2014-03	Post-TSG#63 updated IETF dependencies	0.3.1
2014-06	Post-TSG#64 updated IETF dependencies. Completed: UID_521016 (IETF) CT1 aspects - Stage 3 for ICSRA (RFC 7195) UID_521018 (IETF) CT4 aspects - Stage 3 for ICSRA (RFC 7254) Stopped: UID_521021 (IETF) Maintenance of TISPAN R2 (avasarala-dispatch-comm-div-notification)	0.3.2
2014-09	Post-TSG#65 updated IETF dependencies. Completed: UID_531002 (IETF) CT1 aspects of IMS_Corp (RFC 7316)	0.3.3

Petitioners' Exhibit 1003, p. 342
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

APPENDIX 2

4G

LTE / LTE-Advanced for Mobile Broadband

Erik Dahlman
Stefan Parkvall
Johan Sköld





Petitioners' Exhibit 1003, p. 3441
AT&T et al v. Asustek Technology & Celerity
IPR2024-01124

4G LTE/LTE-Advanced for Mobile Broadband

Petitioners' Exhibit 1003, p. 345
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

http://avaxho.me/blogs/ChrisRedfield

4G LTE/LTE-Advanced for Mobile Broadband

Erik Dahlman, Stefan Parkvall, and Johan Sköld



AMSTERDAM • BOSTON • HEIDELBERG • LONDON • NEW YORK • OXFORD
PARIS • SAN DIEGO • SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO
Academic Press is an imprint of Elsevier



Petitioners' Exhibit 1003, p. 346
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Academic Press is an imprint of Elsevier
The Boulevard, Langford Lane, Kidlington, Oxford, OX5 1GB, UK
30 Corporate Drive, Suite 400, Burlington, MA 01803, USA

First published 2011

Copyright © 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved

The rights of Erik Dahlman, Stefan Parkvall & Johan Sköld to be identified as the authors of this work has been asserted in accordance with the Copyright, Designs and Patents Act 1988.

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher. Details on how to seek permission, further information about the Publisher's permissions policies and our arrangement with organizations such as the Copyright Clearance Center and the Copyright Licensing Agency, can be found at our website: www.elsevier.com/permissions

This book and the individual contributions contained in it are protected under copyright by the Publisher (other than as may be noted herein).

Notices
Knowledge and best practice in this field are constantly changing. As new research and experience broaden our understanding, changes in research methods, professional practices, or medical treatment may become necessary.

Practitioners and researchers must always rely on their own experience and knowledge in evaluating and using any information, methods, compounds, or experiments described herein. In using such information or methods they should be mindful of their own safety and the safety of others, including parties for whom they have a professional responsibility.

To the fullest extent of the law, neither the Publisher nor the authors, contributors, or editors, assume any liability for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions, or ideas contained in the material herein.

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Control Number: 2011921244

ISBN: 978-0-12-385489-6

For information on all Academic Press publications visit our website at www.elsevierdirect.com

Typeset by MPS Limited, a Macmillan Company, Chennai, India
www.macmillansolutions.com

Printed and bound in the UK

11 12 13 14 10 9 8 7 6 5 4 3 2 1

Working together to grow libraries in developing countries
www.elsevier.com | www.bookaid.org | www.sabre.org
ELSEVIER BOOK AID International Sabre Foundation

Petitioners' Exhibit 1003, p. 348
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Preface

During the past years, there has been a quickly rising interest in radio access technologies for providing mobile as well as nomadic and fixed services for voice, video, and data. The difference in design, implementation, and use between telecom and datacom technologies is also becoming more blurred. One example is cellular technologies from the telecom world being used for broadband data and wireless LAN from the datacom world being used for voice-over IP.

Today, the most widespread radio access technology for mobile communication is digital cellular, with the number of users passing 5 billion by 2010, which is more than half of the world's population. It has emerged from early deployments of an expensive voice service for a few car-borne users, to today's widespread use of mobile-communication devices that provide a range of mobile services and often include camera, MP3 player, and PDA functions. With this widespread use and increasing interest in mobile communication, a continuing evolution ahead is foreseen.

This book describes LTE, developed in 3GPP (*Third Generation Partnership Project*) and providing true 4G broadband mobile access, starting from the first version in release 8 and through the continuing evolution to release 10, the latest version of LTE. Release 10, also known as LTE-Advanced, is of particular interest as it is the major technology approved by the ITU as fulfilling the IMT-Advanced requirements. The description in this book is based on LTE release 10 and thus provides a complete description of the LTE-Advanced radio access from the bottom up.

Chapter 1 gives the background to LTE and its evolution, looking also at the different standards bodies and organizations involved in the process of defining 4G. It also gives a discussion of the reasons and driving forces behind the evolution.

Chapters 2–6 provide a deeper insight into some of the technologies that are part of LTE and its evolution. Because of its generic nature, these chapters can be used as a background not only for LTE as described in this book, but also for readers who want to understand the technology behind other systems, such as WCDMA/HSPA, WiMAX, and CDMA2000.

Chapters 7–17 constitute the main part of the book. As a start, an introductory technical overview of LTE is given, where the most important technology components are introduced based on the generic technologies described in previous chapters. The following chapters provide a detailed description of the protocol structure, the downlink and uplink transmission schemes, and the associated mechanisms for scheduling, retransmission and interference handling. Broadcast operation and relaying are also described. This is followed by a discussion of the spectrum flexibility and the associated requirements from an RF perspective.

Finally, in Chapters 18–20, an assessment is made on LTE. Through an overview of similar technologies developed in other standards bodies, it will be clear that the technologies adopted for the evolution in 3GPP are implemented in many other systems as well. Finally, looking into the future, it will be seen that the evolution does not stop with LTE-Advanced but that new features are continuously added to LTE in order to meet future requirements.

Petitioners' Exhibit 1003, p. 349
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Acknowledgements

We thank all our colleagues at Ericsson for assisting in this project by helping with contributions to the book, giving suggestions and comments on the contents, and taking part in the huge team effort of developing LTE.

The standardization process involves people from all parts of the world, and we acknowledge the efforts of our colleagues in the wireless industry in general and in 3GPP RAN in particular. Without their work and contributions to the standardization, this book would not have been possible.

Finally, we are immensely grateful to our families for bearing with us and supporting us during the long process of writing this book.

Petitioners' Exhibit 1003, p. 350
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Abbreviations and Acronyms

3GPP	Third Generation Partnership Project
3GPP2	Third Generation Partnership Project 2
ACIR	Adjacent Channel Interference Ratio
ACK	Acknowledgement (in ARQ protocols)
ACLR	Adjacent Channel Leakage Ratio
ACS	Adjacent Channel Selectivity
AM	Acknowledged Mode (RLC configuration)
AMC	Adaptive Modulation and Coding
A-MPR	Additional Maximum Power Reduction
AMPS	Advanced Mobile Phone System
AQPSK	Adaptive QPSK
ARI	Acknowledgement Resource Indicator
ARIB	Association of Radio Industries and Businesses
ARQ	Automatic Repeat-reQuest
AS	Access Stratum
ATIS	Alliance for Telecommunications Industry Solutions
AWGN	Additive White Gaussian Noise
BC	Band Category
BCCH	Broadcast Control Channel
BCH	Broadcast Channel
BER	Bit-Error Rate
BLER	Block-Error Rate
BM-SC	Broadcast Multicast Service Center
BPSK	Binary Phase-Shift Keying
BS	Base Station
BSC	Base Station Controller
BTS	Base Transceiver Station
CA	Carrier Aggregation
CC	Convolutional Code (in the context of coding), or Component Carrier (in the context of carrier aggregation)
CCCH	Common Control Channel
CCE	Control Channel Element
CCSA	China Communications Standards Association
CDD	Cyclic-Delay Diversity
CDF	Cumulative Density Function
CDM	Code-Division Multiplexing
CDMA	Code-Division Multiple Access

Petitioners' Exhibit 1003, p. 352
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CEPT	European Conference of Postal and Telecommunications Administrations
CN	Core Network
CoMP	Coordinated Multi-Point transmission/reception
CP	Cyclic Prefix
CPC	Continuous Packet Connectivity
CQI	Channel-Quality Indicator
C-RAN	Centralized RAN
CRC	Cyclic Redundancy Check
C-RNTI	Cell Radio-Network Temporary Identifier
CRS	Cell-specific Reference Signal
CS	Circuit Switched (or Cyclic Shift)
CS	Capability Set (for MSR base stations)
CSA	Common Subframe Allocation
CSG	Closed Subscriber Group
CSI	Channel-State Information
CSI-RS	CSI reference signals
CW	Continuous Wave
DAI	Downlink Assignment Index
DCCH	Dedicated Control Channel
DCH	Dedicated Channel
DCI	Downlink Control Information
DFE	Decision-Feedback Equalization
DFT	Discrete Fourier Transform
DFTS-OFDM	DFT-Spread OFDM (DFT-precoded OFDM, see also SC-FDMA)
DL	Downlink
DL-SCH	Downlink Shared Channel
DM-RS	Demodulation Reference Signal
DRX	Discontinuous Reception
DTCH	Dedicated Traffic Channel
DTX	Discontinuous Transmission
DwPTS	The downlink part of the special subframe (for TDD operation).
EDGE	Enhanced Data rates for GSM Evolution, Enhanced Data rates for Global Evolution
EGPRS	Enhanced GPRS
eNB	eNodeB
eNodeB	E-UTRAN NodeB
EPC	Evolved Packet Core
EPS	Evolved Packet System
ETSI	European Telecommunications Standards Institute
E-UTRA	Evolved UTRA
E-UTRAN	Evolved UTRAN
EV-DO	Evolution-Data Only (of CDMA2000 1x)
EV-DV	Evolution-Data and Voice (of CDMA2000 1x)
EVM	Error Vector Magnitude

Petitioners' Exhibit 1003, p. 353
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

FACH	Forward Access Channel
FCC	Federal Communications Commission
FDD	Frequency Division Duplex
FDM	Frequency-Division Multiplex
FDMA	Frequency-Division Multiple Access
FEC	Forward Error Correction
FFT	Fast Fourier Transform
FIR	Finite Impulse Response
FPLMTS	Future Public Land Mobile Telecommunications Systems
FRAMES	Future Radio Wideband Multiple Access Systems
FSTD	Frequency Switched Transmit Diversity
GERAN	GSM/EDGE Radio Access Network
GGSN	Gateway GPRS Support Node
GP	Guard Period (for TDD operation)
GPRS	General Packet Radio Services
GPS	Global Positioning System
GSM	Global System for Mobile communications
HARQ	Hybrid ARQ
HII	High-Interference Indicator
HLR	Home Location Register
HRPD	High Rate Packet Data
HSDPA	High-Speed Downlink Packet Access
HSPA	High-Speed Packet Access
HSS	Home Subscriber Server
HS-SCCH	High-Speed Shared Control Channel
ICIC	Inter-Cell Interference Coordination
ICS	In-Channel Selectivity
ICT	Information and Communication Technologies
IDFT	Inverse DFT
IEEE	Institute of Electrical and Electronics Engineers
IFDMA	Interleaved FDMA
IFFT	Inverse Fast Fourier Transform
IMT-2000	International Mobile Telecommunications 2000 (ITU's name for the family of 3G standards)
IMT-Advanced	International Mobile Telecommunications Advanced (ITU's name for the family of 4G standards)
IP	Internet Protocol
IR	Incremental Redundancy
IRC	Interference Rejection Combining
ITU	International Telecommunications Union
ITU-R	International Telecommunications Union-Radiocommunications Sector

Petitioners' Exhibit 1003, p. 354
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

J-TACS	Japanese Total Access Communication System
LAN	Local Area Network
LCID	Logical Channel Index
LDPC	Low-Density Parity Check Code
LTE	Long-Term Evolution
MAC	Medium Access Control
MAN	Metropolitan Area Network
MBMS	Multimedia Broadcast/Multicast Service
MBMS-GW	MBMS gateway
MBS	Multicast and Broadcast Service
MBSFN	Multicast-Broadcast Single Frequency Network
MC	Multi-Carrier
MCCH	MBMS Control Channel
MCE	MBMS Coordination Entity
MCH	Multicast Channel
MCS	Modulation and Coding Scheme
MDHO	Macro-Diversity Handover
MIB	Master Information Block
MIMO	Multiple-Input Multiple-Output
ML	Maximum Likelihood
MLSE	Maximum-Likelihood Sequence Estimation
MME	Mobility Management Entity
MMS	Multimedia Messaging Service
MMSE	Minimum Mean Square Error
MPR	Maximum Power Reduction
MRC	Maximum Ratio Combining
MSA	MCH Subframe Allocation
MSC	Mobile Switching Center
MSI	MCH Scheduling Information
MSP	MCH Scheduling Period
MSR	Multi-Standard Radio
MSS	Mobile Satellite Service
MTCH	MBMS Traffic Channel
MU-MIMO	Multi-User MIMO
MUX	Multiplexer or Multiplexing
NAK, NACK	Negative Acknowledgement (in ARQ protocols)
NAS	Non-Access Stratum (a functional layer between the core network and the terminal that supports signaling and user data transfer)
NDI	New-data indicator
NSPS	National Security and Public Safety
NMT	Nordisk MobilTelefon (Nordic Mobile Telephony)

Petitioners' Exhibit 1003, p. 355
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

NodeB	NodeB, a logical node handling transmission/reception in multiple cells. Commonly, but not necessarily, corresponding to a base station.
NS	Network Signaling
OCC	Orthogonal Cover Code
OFDM	Orthogonal Frequency-Division Multiplexing
OFDMA	Orthogonal Frequency-Division Multiple Access
OI	Overload Indicator
OOB	Out-Of-Band (emissions)
PAPR	Peak-to-Average Power Ratio
PAR	Peak-to-Average Ratio (same as PAPR)
PARC	Per-Antenna Rate Control
PBCH	Physical Broadcast Channel
PCCH	Paging Control Channel
PCFICH	Physical Control Format Indicator Channel
PCG	Project Coordination Group (in 3GPP)
PCH	Paging Channel
PCRF	Policy and Charging Rules Function
PCS	Personal Communications Systems
PDA	Personal Digital Assistant
PDC	Personal Digital Cellular
PDCCH	Physical Downlink Control Channel
PDCP	Packet Data Convergence Protocol
PDSCH	Physical Downlink Shared Channel
PDN	Packet Data Network
PDU	Protocol Data Unit
PF	Proportional Fair (a type of scheduler)
P-GW	Packet-Data Network Gateway (also PDN-GW)
PHICH	Physical Hybrid-ARQ Indicator Channel
PHS	Personal Handy-phone System
PHY	Physical layer
PMCH	Physical Multicast Channel
PMI	Precoding-Matrix Indicator
POTS	Plain Old Telephony Services
PRACH	Physical Random Access Channel
PRB	Physical Resource Block
P-RNTI	Paging RNTI
PS	Packet Switched
PSK	Phase Shift Keying
PSS	Primary Synchronization Signal
PSTN	Public Switched Telephone Networks
PUCCH	Physical Uplink Control Channel

Petitioners' Exhibit 1003, p. 356
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

PUSC	Partially Used Subcarriers (for WiMAX)
PUSCH	Physical Uplink Shared Channel
QAM	Quadrature Amplitude Modulation
QoS	Quality-of-Service
QPP	Quadrature Permutation Polynomial
QPSK	Quadrature Phase-Shift Keying
RAB	Radio Access Bearer
RACH	Random Access Channel
RAN	Radio Access Network
RA-RNTI	Random Access RNTI
RAT	Radio Access Technology
RB	Resource Block
RE	Reseource Element
RF	Radio Frequency
RI	Rank Indicator
RIT	Radio Interface Technology
RLC	Radio Link Control
RNC	Radio Network Controller
RNTI	Radio-Network Temporary Identifier
RNTP	Relative Narrowband Transmit Power
ROHC	Robust Header Compression
R-PDCCH	Relay Physical Downlink Control Channel
RR	Round-Robin (a type of scheduler)
RRC	Radio Resource Control
RRM	Radio Resource Management
RS	Reference Symbol
RSPC	IMT-2000 radio interface specifications
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
RTP	Real Time Protocol
RTT	Round-Trip Time
RV	Redundancy Version
RX	Receiver
S1	The interface between eNodeB and the Evolved Packet Core.
S1-c	The control-plane part of S1
S1-u	The user-plane part of S1
SAE	System Architecture Evolution
SCM	Spatial Channel Model
SDMA	Spatial Division Multiple Access
SDO	Standards Developing Organization
SDU	Service Data Unit
SEM	Spectrum Emissions Mask

Petitioners' Exhibit 1003, p. 357
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

SF	Spreading Factor
SFBC	Space-Frequency Block Coding
SFN	Single-Frequency Network (in general, see also MBSFN) or System Frame Number (in 3GPP)
SFTD	Space–Frequency Time Diversity
SGSN	Serving GPRS Support Node
S-GW	Serving Gateway
SI	System Information message
SIB	System Information Block
SIC	Successive Interference Combining
SIM	Subscriber Identity Module
SINR	Signal-to-Interference-and-Noise Ratio
SIR	Signal-to-Interference Ratio
SI-RNTI	System Information RNTI
SMS	Short Message Service
SNR	Signal-to-Noise Ratio
SOHO	Soft Handover
SORTD	Spatial Orthogonal-Resource Transmit Diversity
SR	Scheduling Request
SRS	Sounding Reference Signal
SSS	Secondary Synchronization Signal
STBC	Space–Time Block Coding
STC	Space–Time Coding
STTD	Space-Time Transmit Diversity
SU-MIMO	Single-User MIMO
TACS	Total Access Communication System
TCP	Transmission Control Protocol
TC-RNTI	Temporary C-RNTI
TD-CDMA	Time-Division Code-Division Multiple Access
TDD	Time-Division Duplex
TDM	Time-Division Multiplexing
TDMA	Time-Division Multiple Access
TD-SCDMA	Time-Division-Synchronous Code-Division Multiple Access
TF	Transport Format
TIA	Telecommunications Industry Association
TM	Transparent Mode (RLC configuration)
TR	Technical Report
TS	Technical Specification
TSG	Technical Specification Group
TTA	Telecommunications Technology Association
TTC	Telecommunications Technology Committee
TTI	Transmission Time Interval
TX	Transmitter

Petitioners' Exhibit 1003, p. 358
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

UCI	Uplink Control Information
UE	User Equipment, the 3GPP name for the mobile terminal
UL	Uplink
UL-SCH	Uplink Shared Channel
UM	Unacknowledged Mode (RLC configuration)
UMB	Ultra Mobile Broadband
UMTS	Universal Mobile Telecommunications System
UpPTS	The uplink part of the special subframe (for TDD operation).
US-TDMA	US Time-Division Multiple Access standard
UTRA	Universal Terrestrial Radio Access
UTRAN	Universal Terrestrial Radio Access Network
VAMOS	Voice services over Adaptive Multi-user channels
VoIP	Voice-over-IP
VRB	Virtual Resource Block
WAN	Wide Area Network
WARC	World Administrative Radio Congress
WCDMA	Wideband Code-Division Multiple Access
WG	Working Group
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WMAN	Wireless Metropolitan Area Network
WP5D	Working Party 5D
WRC	World Radiocommunication Conference
X2	The interface between eNodeBs.
ZC	Zadoff-Chu
ZF	Zero Forcing

Petitioners' Exhibit 1003, p. 359
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CHAPTER

Background of LTE

1

1.1 INTRODUCTION

Mobile communications has become an everyday commodity. In the last decades, it has evolved from being an expensive technology for a few selected individuals to today's ubiquitous systems used by a majority of the world's population. From the first experiments with radio communication by Guglielmo Marconi in the 1890s, the road to truly mobile radio communication has been quite long. To understand the complex mobile-communication systems of today, it is important to understand where they came from and how cellular systems have evolved. The task of developing mobile technologies has also changed, from being a national or regional concern, to becoming an increasingly complex task undertaken by global standards-developing organizations such as the *Third Generation Partnership Project* (3GPP) and involving thousands of people.

Mobile communication technologies are often divided into generations, with 1G being the analog mobile radio systems of the 1980s, 2G the first digital mobile systems, and 3G the first mobile systems handling broadband data. The *Long-Term Evolution* (LTE) is often called "4G", but many also claim that LTE release 10, also referred to as *LTE-Advanced*, is the true 4G evolution step, with the first release of LTE (release 8) then being labeled as "3.9G". This continuing race of increasing sequence numbers of mobile system generations is in fact just a matter of labels. What is important is the actual system capabilities and how they have evolved, which is the topic of this chapter.

In this context, it must first be pointed out that LTE and LTE-Advanced is the same technology, with the "Advanced" label primarily being added to highlight the relation between LTE release 10 (LTE-Advanced) and ITU/IMT-Advanced, as discussed later. This does not make LTE-Advanced a different system than LTE and it is not in any way the final evolution step to be taken for LTE. Another important aspect is that the work on developing LTE and LTE-Advanced is performed as a continuing task within 3GPP, the same forum that developed the first 3G system (WCDMA/HSPA).

This chapter describes the background for the development of the LTE system, in terms of events, activities, organizations and other factors that have played an important role. First, the technologies and mobile systems leading up to the starting point for 3G mobile systems will be discussed. Next, international activities in the ITU that were part of shaping 3G and the 3G evolution and the market and technology drivers behind LTE will be discussed. The final part of the chapter describes the standardization process that provided the detailed specification work leading to the LTE systems deployed and in operation today.

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 360
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

1.2 EVOLUTION OF MOBILE SYSTEMS BEFORE LTE

The US *Federal Communications Commission* (FCC) approved the first commercial car-borne telephony service in 1946, operated by AT&T. In 1947 AT&T also introduced the cellular concept of reusing radio frequencies, which became fundamental to all subsequent mobile-communication systems. Similar systems were operated by several monopoly telephone administrations and wire-line operators during the 1950s and 1960s, using bulky and power-hungry equipment and providing car-borne services for a very limited number of users.

The big uptake of subscribers and usage came when mobile communication became an international concern involving several interested parties, in the beginning mainly the operators. The first international mobile communication systems were started in the early 1980s; the best-known ones are NMT that was started up in the Nordic countries, AMPS in the USA, TACS in Europe, and J-TACS in Japan. Equipment was still bulky, mainly car-borne, and voice quality was often inconsistent, with "cross-talk" between users being a common problem. With NMT came the concept of "roaming", giving a service also for users traveling outside the area of their "home" operator. This also gave a larger market for mobile phones, attracting more companies into the mobile-communication business.

The analog first-generation cellular systems supported "plain old telephony services" (POTS) – that is, voice with some related supplementary services. With the advent of digital communication during the 1980s, the opportunity to develop a second generation of mobile-communication standards and systems, based on digital technology, surfaced. With digital technology came an opportunity to increase the capacity of the systems, to give a more consistent quality of the service, and to develop much more attractive and truly mobile devices.

In Europe, the GSM (originally *Groupe Spécial Mobile*, later *Global System for Mobile communications*) project to develop a pan-European mobile-telephony system was initiated in the mid 1980s by the telecommunication administrations in CEPT[1] and later continued within the new *European Telecommunication Standards Institute* (ETSI). The GSM standard was based on *Time-Division Multiple Access* (TDMA), as were the US-TDMA standard and the Japanese PDC standard that were introduced in the same time frame. A somewhat later development of a *Code-Division Multiple Access* (CDMA) standard called IS-95 was completed in the USA in 1993.

All these standards were "narrowband" in the sense that they targeted "low-bandwidth" services such as voice. With the second-generation digital mobile communications came also the opportunity to provide data services over the mobile-communication networks. The primary data services introduced in 2G were text messaging (*Short Message Services*, SMS) and circuit-switched data services enabling e-mail and other data applications, initially at a modest peak data rate of 9.6 kbit/s. Higher data rates were introduced later in evolved 2G systems by assigning multiple time slots to a user and through modified coding schemes.

Packet data over cellular systems became a reality during the second half of the 1990s, with *General Packet Radio Services* (GPRS) introduced in GSM and packet data also added to other cellular technologies such as the Japanese PDC standard. These technologies are often referred to as 2.5G. The success of the wireless data service iMode in Japan, which included a complete "ecosystem"

[1] The European Conference of Postal and Telecommunications Administrations (CEPT) consists of the telecom administrations from 48 countries.

Petitioners' Exhibit 1003, p. 361
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

for service delivery, charging etc., gave a very clear indication of the potential for applications over packet data in mobile systems, in spite of the fairly low data rates supported at the time.

With the advent of 3G and the higher-bandwidth radio interface of UTRA (*Universal Terrestrial Radio Access*) came possibilities for a range of new services that were only hinted at with 2G and 2.5G. The 3G radio access development is today handled in 3GPP. However, the initial steps for 3G were taken in the early 1990s, long before 3GPP was formed.

What also set the stage for 3G was the internationalization of cellular standards. GSM was a pan-European project, but it quickly attracted worldwide interest when the GSM standard was deployed in a number of countries outside Europe. A global standard gains in economy of scale, since the market for products becomes larger. This has driven a much tighter international cooperation around 3G cellular technologies than for the earlier generations.

1.2.1 The First 3G Standardization

Work on a third-generation mobile communication started in ITU (*International Telecommunication Union*) in the 1980s, first under the label *Future Public Land Mobile Telecommunications Systems* (FPLMTS), later changed to IMT-2000 [1]. The World Administrative Radio Congress WARC-92 identified 230 MHz of spectrum for IMT-2000 on a worldwide basis. Of these 230 MHz, 2×60 MHz was identified as paired spectrum for FDD (*Frequency-Division Duplex*) and 35 MHz as unpaired spectrum for TDD (*Time-Division Duplex*), both for terrestrial use. Some spectrum was also set aside for satellite services. With that, the stage was set to specify IMT-2000.

In parallel with the widespread deployment and evolution of 2G mobile-communication systems during the 1990s, substantial efforts were put into 3G research activities worldwide. In Europe, a number of partially EU-funded projects resulted in a multiple access concept that included a Wideband CDMA component that was input to ETSI in 1996. In Japan, the *Association of Radio Industries and Businesses* (ARIB) was at the same time defining a 3G wireless communication technology based on Wideband CDMA and also in the USA a Wideband CDMA concept called WIMS was developed within the T1.P1[2] committee. South Korea also started work on Wideband CDMA at this time.

When the standardization activities for 3G started in ETSI in 1996, there were WCDMA concepts proposed both from a European research project (FRAMES) and from the ARIB standardization in Japan. The Wideband CDMA proposals from Europe and Japan were merged and came out as part of the winning concept in early 1998 in the European work on Universal Mobile Telecommunication Services (UMTS), which was the European name for 3G. Standardization of WCDMA continued in parallel in several standards groups until the end of 1998, when the *Third Generation Partnership Project* (3GPP) was formed by standards-developing organizations from all regions of the world. This solved the problem of trying to maintain parallel development of aligned specifications in multiple regions. The present organizational partners of 3GPP are ARIB (Japan), CCSA (China), ETSI (Europe), ATIS (USA), TTA (South Korea), and TTC (Japan).

At this time, when the standardization bodies were ready to put the details into the 3GPP specifications, work on 3G mobile systems had already been ongoing for some time in the international arena within the ITU-R. That work was influenced by and also provided a broader international framework for the standardization work in 3GPP.

[2]The T1.P1 committee was part of T1, which presently has joined the ATIS standardization organization.

Petitioners' Exhibit 1003, p. 362
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

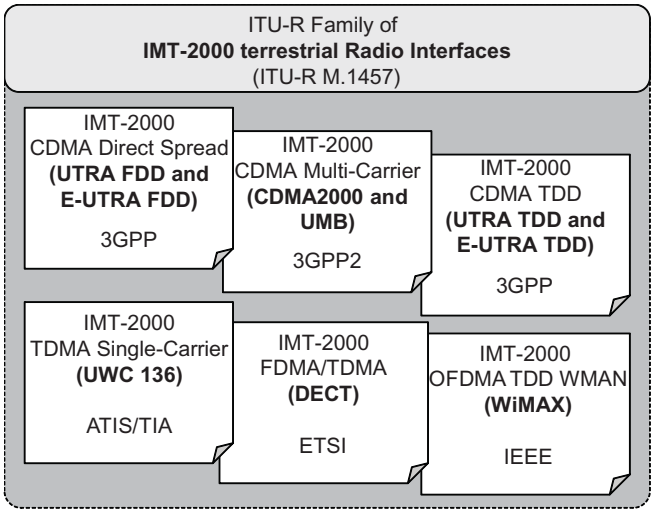


FIGURE 1.1

The definition of IMT-2000 in ITU-R.

1.3 ITU ACTIVITIES

1.3.1 IMT-2000 and IMT-Advanced

ITU-R *Working Party 5D* (WP5D) has the responsibility for IMT systems, which is the umbrella name for 3G (IMT-2000) and 4G (IMT-Advanced). WP5D does not write technical specifications for IMT, but has kept the role of defining IMT in cooperation with the regional standardization bodies and to maintain a set of recommendations for IMT-2000 and IMT-Advanced.

The main IMT-2000 recommendation is ITU-R M.1457 [2], which identifies the IMT-2000 *radio interface specifications* (RSPC). The recommendation contains a "family" of radio interfaces, all included on an equal basis. The family of six terrestrial radio interfaces is illustrated in Figure 1.1, which also shows the *Standards Developing Organizations* (SDO) or Partnership Projects that produce the specifications. In addition, there are several IMT-2000 satellite radio interfaces defined, not illustrated in Figure 1.1.

For each radio interface, M.1457 contains an overview of the radio interface, followed by a list of references to the detailed specifications. The actual specifications are maintained by the individual SDOs and M.1457 provides references to the specifications maintained by each SDO.

With the continuing development of the IMT-2000 radio interfaces, including the evolution of UTRA to Evolved UTRA, the ITU recommendations also need to be updated. ITU-R WP5D continuously revises recommendation M.1457 and at the time of writing it is in its ninth version. Input to the updates is provided by the SDOs and Partnership Projects writing the standards. In the latest revision of ITU-R M.1457, LTE (or E-UTRA) is included in the family through the 3GPP family members for UTRA FDD and TDD, as shown in the figure.

Petitioners' Exhibit 1003, p. 363
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

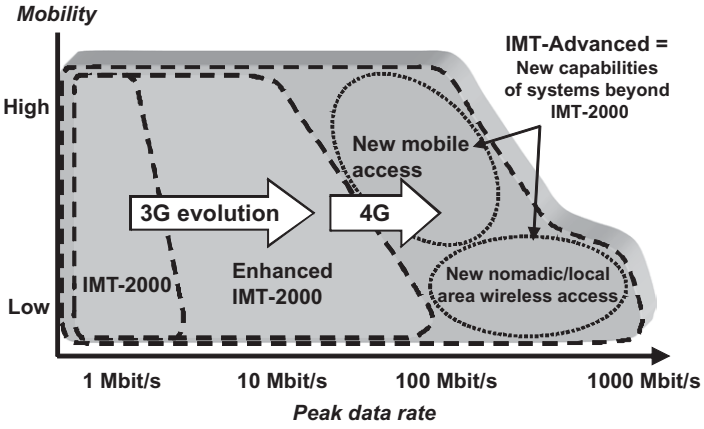


FIGURE 1.2

Illustration of capabilities of IMT-2000 and IMT-Advanced, based on the framework described in ITU -R Recommendation M.1645 [4].

In addition to maintaining the IMT-2000 specifications, a main activity in ITU-R WP5D is the work on systems beyond IMT-2000, now called IMT-Advanced. The term IMT-Advanced is used for systems that include new radio interfaces supporting the new capabilities of systems beyond IMT-2000, as demonstrated with the "van diagram" in Figure 1.2. The step into IMT-Advanced capabilities is seen by ITU-R as the step into 4G, the next generation of mobile technologies after 3G.

The process for defining IMT-Advanced was set by ITU-R WP5D [3] and was quite similar to the process used in developing the IMT-2000 recommendations. ITU-R first concluded studies for IMT-Advanced of services and technologies, market forecasts, principles for standardization, estimation of spectrum needs, and identification of candidate frequency bands [4]. Evaluation criteria were agreed, where proposed technologies were to be evaluated according to a set of minimum technical requirements. All ITU members and other organizations were then invited to the process through a circular letter [5] in March 2008. After submission of six candidate technologies in 2009, an evaluation was performed in cooperation with external bodies such as standards-developing organizations, industry forums, and national groups.

An evolution of LTE as developed by 3GPP was submitted as one candidate to the ITU-R evaluation. While actually being a new release (release 10) of the LTE system and thus an integral part of the continuing LTE development, the candidate was named LTE-Advanced for the purpose of ITU submission. 3GPP also set up its own set of technical requirements for LTE-Advanced, with the ITU-R requirements as a basis. The specifics of LTE-Advanced will be described in more detail as part of the description of LTE later in this book. The performance evaluation of LTE-Advanced for the ITU-R submission is described further in Chapter 18.

The target of the process was always harmonization of the candidates through consensus building. ITU-R determined in October 2010 that two technologies will be included in the first release of IMT-Advanced, those two being LTE release 10 ("LTE-Advanced") and WirelessMAN-Advanced [6] based on the IEEE 802.16m specification. The two can be viewed as the "family" of IMT-Advanced

Petitioners' Exhibit 1003, p. 364
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

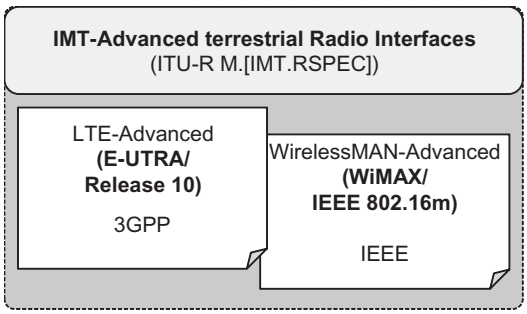


FIGURE 1.3

Radio interface technologies for IMT-Advanced.

technologies as shown in Figure 1.3. The main IMT-Advanced recommendation, identifying the IMT-Advanced radio interface specifications, is presently named ITU-R.[IMT.RSPEC] [7] and will be completed during 2011. As for the corresponding IMT-2000 specification, it will contain an overview of each radio interface, followed by a list of references to the detailed specifications.

1.3.2 Spectrum for IMT Systems

Another major activity within ITU-R concerning IMT-Advanced has been to identify globally available spectrum, suitable for IMT systems. The spectrum work has involved sharing studies between IMT and other technologies in those bands. Adequate spectrum availability and globally harmonized spectrum are identified as essential for IMT-Advanced.

Spectrum for 3G was first identified at the *World Administrative Radio Congress* WARC-92, where 230 MHz was identified as intended for use by national administrations that want to implement IMT-2000. The so-called IMT-2000 "core band" at 2 GHz is in this frequency range and was the first band where 3G systems were deployed.

Additional spectrum was identified for IMT-2000 at later World Radio communication conferences. WRC-2000 identified the existing 2G bands at 800/900 MHz and 1800/1900 MHz plus an additional 190 MHz of spectrum at 2.6 GHz, all for IMT-2000. As additional spectrum for IMT-2000, WRC'07 identified a band at 450 MHz, the so-called "digital dividend" at 698–806 MHz, plus an additional 300 MHz of spectrum at higher frequencies. The applicability of these new bands varies on a regional and national basis.

The worldwide frequency arrangements for IMT-2000 are outlined in ITU-R recommendation M.1036 [8], which is presently being updated with the arrangements for the most recent frequency bands added at WRC'07. The recommendation outlines the regional variations in how the bands are implemented and also identifies which parts of the spectrum are paired and which are unpaired. For the paired spectrum, the bands for uplink (mobile transmit) and downlink (base-station transmit) are identified for *Frequency-Division Duplex* (FDD) operation. The unpaired bands can, for example, be used for *Time-Division Duplex* (TDD) operation. Note that the band that is most globally deployed for 3G is still 2 GHz.

Petitioners' Exhibit 1003, p. 365
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

1.4 DRIVERS FOR LTE

The evolution of 3G systems into 4G is driven by the creation and development of new services for mobile devices, and is enabled by advancement of the technology available for mobile systems. There has also been an evolution of the environment in which mobile systems are deployed and operated, in terms of competition between mobile operators, challenges from other mobile technologies, and new regulation of spectrum use and market aspects of mobile systems.

The rapid evolution of the technology used in telecommunication systems, consumer electronics, and specifically mobile devices has been remarkable in the last 20 years. Moore's law illustrates this and indicates a continuing evolution of processor performance and increased memory size, often combined with reduced size, power consumption, and cost for devices. High-resolution color displays and megapixel camera sensors are also coming into all types of mobile devices. Combined with a high-speed internet backbone often based on optical fiber networks, we see that a range of technology enablers are in place to go hand-in-hand with advancement in mobile communications technology such as LTE.

The rapid increase in use of the internet to provide all kinds of services since the 1990s started at the same time as 2G and 3G mobile systems came into widespread use. The natural next step was that those internet-based services also moved to the mobile devices, creating what is today know as *mobile broadband*. Being able to support the same *Internet Protocol* (IP)-based services in a mobile device that people use at home with a fixed broadband connection is a major challenge and a prime driver for the evolution of LTE. A few services were already supported by the evolved 2.5G systems, but it is not until the systems are designed primarily for IP-based services that the real mobile IP revolution can take off. An interesting aspect of the migration of broadband services to mobile devices is that a mobile "flavor" is also added. The mobile position and the mobility and roaming capabilities do in fact create a whole new range of services tailored to the mobile environment.

Fixed telephony (POTS) and earlier generations of mobile technology were built for circuit switched services, primarily voice. The first data services over GSM were circuit switched, with packet-based GPRS coming in as a later addition. This also influenced the first development of 3G, which was based on circuit switched data, with packet-switched services as an add-on. It was not until the 3G evolution into HSPA and later LTE/LTE-Advanced that packet-switched services and IP were made the primary design target. The old circuit-switched services remain, but will on LTE be provided over IP, with Voice-over IP (VoIP) as an example.

IP is in itself service agnostic and thereby enables a range of services with different requirements. The main service-related design parameters for a radio interface supporting a variety of services are:

- **Data rate.** Many services with lower data rates such as voice services are important and still occupy a large part of a mobile network's overall capacity, but it is the higher data rate services that drive the design of the radio interface. The ever increasing demand for higher data rates for web browsing, streaming and file transfer pushes the peak data rates for mobile systems from kbit/s for 2G, to Mbit/s for 3G and getting close to Gbit/s for 4G.
- **Delay.** Interactive services such as real-time gaming, but also web browsing and interactive file transfer, have requirements for very low delay, making it a primary design target. There are, however, many applications such as e-mail and television where the delay requirements are not as strict. The delay for a packet sent from a server to a client and back is called *latency*.

Petitioners' Exhibit 1003, p. 366
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- **Capacity.** From the mobile system operator's point of view, it is not only the peak data rates provided to the end-user that are of importance, but also the total data rate that can be provided on average from each deployed base station site and per hertz of licensed spectrum. This measure of capacity is called *spectral efficiency*. In the case of capacity shortage in a mobile system, the Quality-of-Service (QoS) for the individual end-users may be degraded.

How these three main design parameters influenced the development of LTE is described in more detail in Chapter 7 and an evaluation of what performance is achieved for the design parameters above is presented in Chapter 18.

The demand for new services and for higher peak bit rates and system capacity is not only met by evolution of the technology to 4G. There is also a demand for more spectrum resources to expand systems and the demand also leads to more competition between an increasing number of mobile operators and between alternative technologies to provide mobile broadband services. An overview of some technologies other than LTE is given in Chapter 19.

With more spectrum coming into use for mobile broadband, there is a need to operate mobile systems in a number of different frequency bands, in spectrum allocations of different sizes and sometimes also in fragmented spectrum. This calls for high spectrum flexibility with the possibility for a varying channel bandwidth, which was also a driver and an essential design parameter for LTE.

The demand for new mobile services and the evolution of the radio interface to LTE have served as drivers to evolve the core network. The core network developed for GSM in the 1980s was extended to support GPRS, EDGE, and WCDMA in the 1990s, but was still very much built around the circuit-switched domain. A *System Architecture Evolution* (SAE) was initiated at the same time as LTE development started and has resulted in an *Evolved Packet Core* (EPC), developed to support HSPA and LTE/LTE-Advanced, focusing on the packet-switched domain. For more details on SAE/EPC, please refer to [9].

1.5 STANDARDIZATION OF LTE

With a framework for IMT systems set up by the ITU-R, with spectrum made available by the WRC and with an ever increasing demand for better performance, the task of specifying the LTE system that meets the design targets falls on 3GPP. 3GPP writes specifications for 2G, 3G, and 4G mobile systems, and 3GPP technologies are the most widely deployed in the world, with more than 4.5 billion connections in 2010. In order to understand how 3GPP works, it is important to understand the process of writing standards.

1.5.1 The Standardization Process

Setting a standard for mobile communication is not a one-time job, it is an ongoing process. The standardization forums are constantly evolving their standards trying to meet new demands for services and features. The standardization process is different in the different forums, but typically includes the four phases illustrated in Figure 1.4:

1. *Requirements*, where it is decided what is to be achieved by the standard.
2. *Architecture*, where the main building blocks and interfaces are decided.

Petitioners' Exhibit 1003, p. 367
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

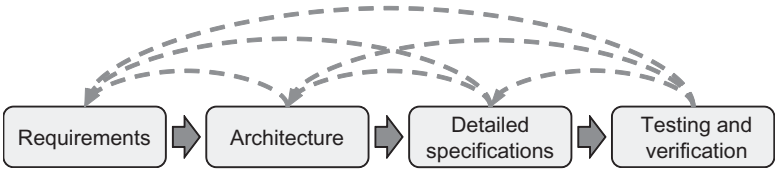


FIGURE 1.4

The standardization phases and iterative process.

3. *Detailed specifications*, where every interface is specified in detail.
4. *Testing and verification*, where the interface specifications are proven to work with real-life equipment.

These phases are overlapping and iterative. As an example, requirements can be added, changed, or dropped during the later phases if the technical solutions call for it. Likewise, the technical solution in the detailed specifications can change due to problems found in the testing and verification phase.

Standardization starts with the *requirements* phase, where the standards body decides what should be achieved with the standard. This phase is usually relatively short.

In the *architecture* phase, the standards body decides about the architecture – that is, the principles of how to meet the requirements. The architecture phase includes decisions about reference points and interfaces to be standardized. This phase is usually quite long and may change the requirements.

After the architecture phase, the *detailed specification* phase starts. It is in this phase the details for each of the identified interfaces are specified. During the detailed specification of the interfaces, the standards body may find that previous decisions in the architecture or even in the requirements phases need to be revisited.

Finally, the *testing and verification* phase starts. It is usually not a part of the actual standardization in the standards bodies, but takes place in parallel through testing by vendors and interoperability testing between vendors. This phase is the final proof of the standard. During the testing and verification phase, errors in the standard may still be found and those errors may change decisions in the detailed standard. Albeit not common, changes may also need to be made to the architecture or the requirements. To verify the standard, products are needed. Hence, the implementation of the products starts after (or during) the detailed specification phase. The testing and verification phase ends when there are stable test specifications that can be used to verify that the equipment is fulfilling the standard.

Normally, it takes one to two years from the time when the standard is completed until commercial products are out on the market. However, if the standard is built from scratch, it may take longer since there are no stable components to build from.

1.5.2 The 3GPP Process

The *Third-Generation Partnership Project* (3GPP) is the standards-developing body that specifies the LTE/LTE-Advanced, as well as 3G UTRA and 2G GSM systems. 3GPP is a partnership project formed by the standards bodies ETSI, ARIB, TTC, TTA, CCSA, and ATIS. 3GPP consists of four *Technical Specifications Groups* (TSGs) – see Figure 1.5.

Petitioners' Exhibit 1003, p. 368
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

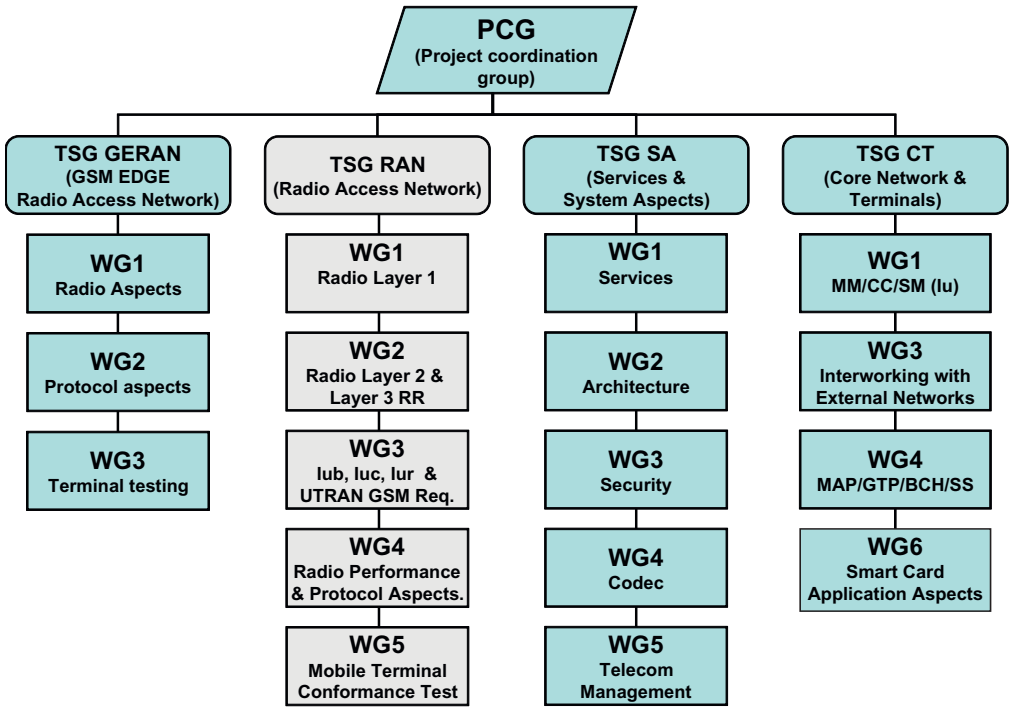


FIGURE 1.5

3GPP organization.

A parallel partnership project called 3GPP2 was formed in 1999. It also develops 3G specifications, but for CDMA2000, which is the 3G technology developed from the 2G CDMA-based standard IS-95. It is also a global project, and the organizational partners are ARIB, CCSA, TIA, TTA, and TTC.

3GPP TSG RAN (*Radio Access Network*) is the technical specification group that has developed WCDMA, its evolution HSPA, as well as LTE/LTE-Advanced, and is in the forefront of the technology. TSG RAN consists of five working groups (WGs):

1. RAN WG1, dealing with the physical layer specifications.
2. RAN WG2, dealing with the layer 2 and layer 3 radio interface specifications.
3. RAN WG3, dealing with the fixed RAN interfaces – for example, interfaces between nodes in the RAN – but also the interface between the RAN and the core network.
4. RAN WG4, dealing with the *radio frequency* (RF) and *radio resource management* (RRM) performance requirements.
5. RAN WG 5, dealing with the terminal conformance testing.

The scope of 3GPP when it was formed in 1998 was to produce global specifications for a 3G mobile system based on an evolved GSM core network, including the WCDMA-based radio access of

Petitioners' Exhibit 1003, p. 369
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

the UTRA FDD and the TD-CDMA-based radio access of the UTRA TDD mode. The task to maintain and develop the GSM/EDGE specifications was added to 3GPP at a later stage and the work now also includes LTE (E-UTRA). The UTRA, E-UTRA and GSM/EDGE specifications are developed, maintained, and approved in 3GPP. After approval, the organizational partners transpose them into appropriate deliverables as standards in each region.

In parallel with the initial 3GPP work, a 3G system based on TD-SCDMA was developed in China. TD-SCDMA was eventually merged into release 4 of the 3GPP specifications as an additional TDD mode.

The work in 3GPP is carried out with relevant ITU recommendations in mind and the result of the work is also submitted to ITU. The organizational partners are obliged to identify regional requirements that may lead to options in the standard. Examples are regional frequency bands and special protection requirements local to a region. The specifications are developed with global roaming and circulation of terminals in mind. This implies that many regional requirements in essence will be global requirements for all terminals, since a roaming terminal has to meet the strictest of all regional requirements. Regional options in the specifications are thus more common for base stations than for terminals.

The specifications of all releases can be updated after each set of TSG meetings, which occur four times a year. The 3GPP documents are divided into releases, where each release has a set of features added compared to the previous release. The features are defined in Work Items agreed and undertaken by the TSGs. The releases from release 8 and onwards, with some main features listed for LTE, are shown in Figure 1.6. The date shown for each release is the day the content of the release was frozen. Release 10 of LTE is the version approved by ITU-R as an IMT-Advanced technology and is therefore also named *LTE-Advanced*.

1.5.3 The 3G Evolution to 4G

The first release of WCDMA Radio Access developed in TSG RAN was called release 99[3] and contained all features needed to meet the IMT-2000 requirements as defined by the ITU. This included circuit-switched voice and video services, and data services over both packet-switched and circuit-switched bearers. The first major addition of radio access features to WCDMA was HSPA, which was added in release 5 with *High Speed Downlink Packet Access* (HSDPA) and release 6 with *Enhanced Uplink*. These two are together referred to as HSPA and an overview of HSPA is given in Chapter 19 of this book. With HSPA, UTRA goes beyond the definition of a 3G mobile system and also encompasses broadband mobile data.

The 3G evolution continued in 2004, when a workshop was organized to initiate work on the 3GPP *Long-Term Evolution* (LTE) radio interface. The result of the LTE workshop was that a study item in 3GPP TSG RAN was created in December 2004. The first 6 months were spent on defining the requirements, or design targets, for LTE. These were documented in a 3GPP technical report [10] and approved in June 2005. Most notable are the requirements on high data rate at the cell edge and the importance of low delay, in addition to the normal capacity and peak data rate requirements. Furthermore, spectrum flexibility and maximum commonality between FDD and TDD solutions are pronounced.

[3]For historical reasons, the first 3GPP release is named after the year it was frozen (1999), while the following releases are numbered 4, 5, 6, etc.

Petitioners' Exhibit 1003, p. 370
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

During the fall of 2005, 3GPP TSG RAN WG1 made extensive studies of different basic physical layer technologies and in December 2005 the TSG RAN plenary decided that the LTE radio access should be based on OFDM in the downlink and DFT-precoded OFDM in the uplink. TSG RAN and its working groups then worked on the LTE specifications and the specifications were approved in December 2007. Work has since then continued on LTE, with new features added in each release, as shown in Figure 1.6. Chapters 7–17 will go through the details of the LTE radio interface in more detail.

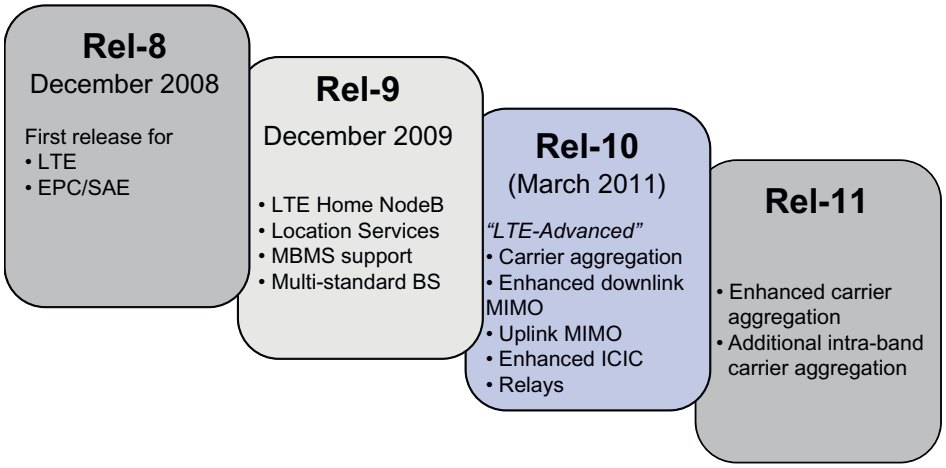


FIGURE 1.6

Releases of 3GPP specifications for LTE.

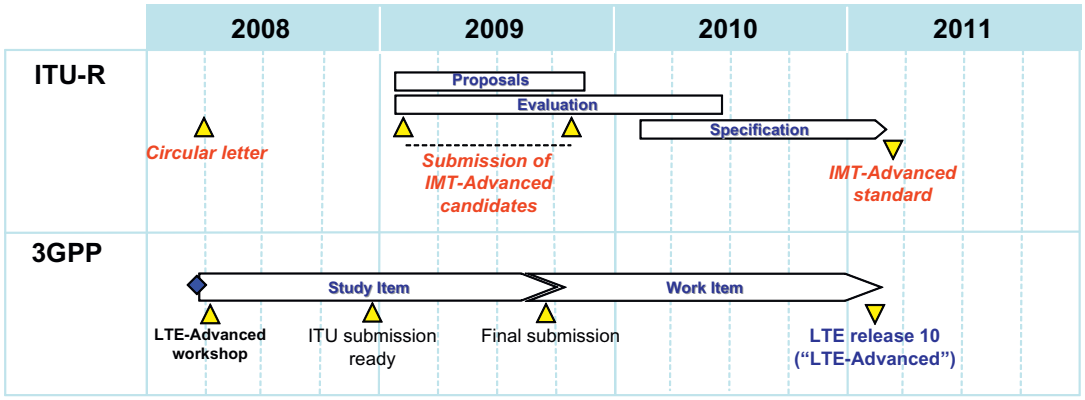


FIGURE 1.7

3GPP time schedule for LTE-Advanced in relation to ITU time-schedule on IMT-Advanced.

Petitioners' Exhibit 1003, p. 371
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The work on IMT-Advanced within ITU-R WP5D came in 2008 into a phase where the detailed requirements and process were announced through a circular letter [5]. Among other things, this triggered activities in 3GPP, where a study item on *LTE-Advanced* was started. The task was to define requirements and investigate and propose technology components to be part of LTE-Advanced. The work was turned into a Work Item in 2009 in order to develop the detailed specifications.

Within 3GPP, LTE-Advanced is seen as the next major step in the evolution of LTE. LTE-Advanced is therefore not a new technology; it is an evolutionary step in the continuing development of LTE. As shown in Figure 1.6, the features that form LTE-Advanced are part of release 10 of 3GPP LTE specifications. Wider bandwidth through aggregation of multiple carriers and evolved use of advanced antenna techniques in both uplink and downlink are the major components added in LTE release 10 to reach the IMT-Advanced targets.

The work on LTE-Advanced within 3GPP is planned with the ITU-R time frame in mind, as shown in Figure 1.7. LTE-Advanced was submitted as a candidate to the ITU-R in 2009 and is now included in the set of radio interface technologies announced by ITU-R [6] in October 2010 to be included as a part of the IMT-Advanced radio interface specifications. This is very much aligned with what was from the start stated as a goal for LTE, namely that *LTE should provide the starting point for a smooth transition to 4G (= IMT-Advanced) radio access*.

Since LTE-Advanced is an integral part of 3GPP LTE release 10, it is described in detail together with the corresponding components of LTE in Chapters 7–17 of this book.

Petitioners' Exhibit 1003, p. 372
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CHAPTER

2 High Data Rates in Mobile Communication

As discussed in Chapter 1, one main target for the evolution of mobile communication is to provide the possibility for significantly higher end-user data rates compared to what is achievable with, for example, the first releases of the 3G standards. This includes the possibility for higher peak data rates but, as pointed out in the previous chapter, even more so the possibility for significantly higher data rates over the entire cell area, also including, for example, users at the cell edge. The initial part of this chapter will briefly discuss some of the more fundamental constraints that exist in terms of what data rates can actually be achieved in different scenarios. This will provide a background to subsequent discussions in the later part of the chapter, as well as in the subsequent chapters, concerning different means to increase the achievable data rates in different mobile-communication scenarios.

2.1 HIGH DATA RATES: FUNDAMENTAL CONSTRAINTS

In Ref. [11], Shannon provided the basic theoretical tools needed to determine the maximum rate, also known as the *channel capacity*, by which information can be transferred over a given communication channel. Although relatively complicated in the general case, for the special case of communication over a channel, for example a radio link, only impaired by additive white Gaussian noise, the channel capacity C is given by the relatively simple expression [12]:

$$C = BW \cdot \log_2\left(1 + \frac{S}{N}\right), \tag{2.1}$$

where BW is the bandwidth available for the communication, S denotes the received signal power, and N denotes the power of the white noise impairing the received signal.

Already from Eqn (2.1) it should be clear that the two fundamental factors limiting the achievable data rate are the available received signal power, or more generally the available signal-power-to-noise-power ratio S/N, and the available bandwidth. To further clarify how and when these factors limit the achievable data rate, assume communication with a certain information rate R. The received signal power can then be expressed as $S = E_b \cdot R$, where E_b is the received energy per information bit. Furthermore, the noise power can be expressed as $N = N_0 \cdot BW$, where N_0 is the constant noise power spectral density measured in W/Hz.

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 374
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Clearly, the information rate can never exceed the channel capacity. Together with the above expressions for the received signal power and noise power, this leads to the inequality:

$$R \le C = BW \cdot \log_2\left(1 + \frac{S}{N}\right) = BW \cdot \log_2\left(1 + \frac{E_b \cdot R}{N_0 \cdot BW}\right) \tag{2.2}$$

or, by defining the radio-link *bandwidth utilization* $\gamma = R/BW$,

$$\gamma \le \log_2\left(1 + \gamma \cdot \frac{E_b}{N_0}\right). \tag{2.3}$$

This inequality can be reformulated to provide a lower bound on the required received energy per information bit, normalized to the noise power density, for a given bandwidth utilization γ:

$$\frac{E_b}{N_0} \ge \min\left\{\frac{E_b}{N_0}\right\} = \frac{2^\gamma - 1}{\gamma}. \tag{2.4}$$

The rightmost expression – that is, the minimum required E_b/N_0 at the receiver as a function of the bandwidth utilization – is illustrated in Figure 2.1. As can be seen, for bandwidth utilizations significantly less than 1 – that is, for information rates substantially smaller than the utilized bandwidth – the minimum required E_b/N_0 is relatively constant, regardless of γ. For a given noise power density, any increase of the information data rate then implies a similar relative increase in the minimum required signal power $S = E_b \cdot R$ at the receiver. On the other hand, for bandwidth utilizations larger than 1, the minimum required E_b/N_0 increases rapidly with γ. Thus, in the case of data rates of the same order as or larger than the communication bandwidth, any further increase of the information data rate, without a corresponding increase in the available bandwidth, implies a larger, eventually much larger, relative increase in the minimum required received signal power.

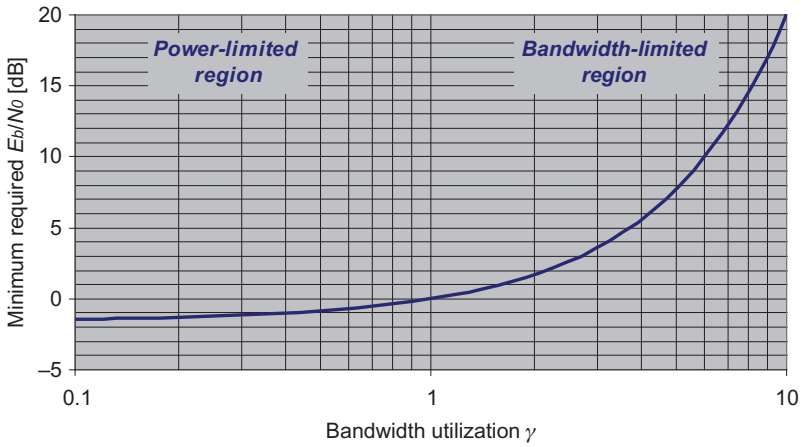


FIGURE 2.1

Minimum required E_b/N_0 at the receiver as a function of bandwidth utilization.

2.1.1 High Data Rates in Noise-Limited Scenarios

From the discussion above, some basic conclusions can be drawn regarding the provisioning of higher data rates in a mobile-communication system when noise is the main source of radio-link impairment (a *noise-limited* scenario):

- The data rates that can be provided in such scenarios are always limited by the available received signal power or, in the general case, the received signal-power-to-noise-power ratio. Furthermore, any increase of the achievable data rate within a given bandwidth will require *at least* the same relative increase of the received signal power. At the same time, if sufficient received signal power can be made available, basically any data rate can, at least in theory, be provided within a given limited bandwidth.
- In the case of low-bandwidth utilization – that is, as long as the radio-link data rate is substantially lower than the available bandwidth – any further increase of the data rate requires *approximately the same* relative increase in the received signal power. This can be referred to as *power-limited* operation (in contrast to *bandwidth-limited* operation; see below) as, in this case, an increase in the available bandwidth does not substantially impact what received signal power is required for a certain data rate.
- On the other hand, in the case of high-bandwidth utilization – that is, in the case of data rates of the same order as or exceeding the available bandwidth – any further increase in the data rate requires a *much larger* relative increase in the received signal power unless the bandwidth is increased in proportion to the increase in data rate. This can be referred to as *bandwidth-limited operation* as, in this case, an increase in the bandwidth will reduce the received signal power required for a certain data rate.

Thus, to make efficient use of the available received signal power or, in the general case, the available signal-to-noise ratio, the transmission bandwidth should at least be of the same order as the data rates to be provided.

Assuming a constant transmit power, the received signal power can always be increased by reducing the distance between the transmitter and the receiver, thereby reducing the attenuation of the signal as it propagates from the transmitter to the receiver. Thus, in a noise-limited scenario it is, at least in theory, always possible to increase the achievable data rates, assuming that one is prepared to accept a reduction in the transmitter/receiver distance – that is, a reduced range. In a mobile-communication system this would correspond to a reduced cell size and thus the need for more cell sites to cover the same overall area. In particular, providing data rates of the same order as or larger than the available bandwidth – that is, with a high-bandwidth utilization – would require a significant cell-size reduction. Alternatively, one has to accept that the high data rates are only available for terminals in the center of the cell and not over the entire cell area.

Another means to increase the overall received signal power for a given transmit power is the use of additional antennas at the receiver side, also known as *receive-antenna diversity*. Multiple receive antennas can be applied at the base station (that is, for the uplink) or at the terminal (that is, for the downlink). By proper combination of the signals received at the different antennas, the signal-to-noise ratio after the antenna combination can be increased in proportion to the number of receive antennas, thereby allowing for higher data rates for a given transmitter/receiver distance.

Multiple antennas can also be applied at the transmitter side, typically at the base station, and be used to focus a given total transmit power in the direction of the receiver – that is, toward the target terminal. This will increase the received signal power and thus, once again, allow for higher data rates for a given transmitter/receiver distance.

Petitioners' Exhibit 1003, p. 376
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

However, providing higher data rates by the use of multiple transmit or receive antennas is only efficient up to a certain level – that is, as long as the data rates are power limited rather than bandwidth limited. Beyond this point, the achievable data rates start to saturate and any further increase in the number of transmit or receive antennas, although leading to a correspondingly improved signal-to-noise ratio at the receiver, will only provide a marginal increase in the achievable data rates. This saturation in achievable data rates can be avoided though, by the use of multiple antennas at both the transmitter *and* the receiver, enabling what can be referred to as *spatial multiplexing*, often also referred to as *MIMO* (Multiple-Input Multiple-Output). Different types of multi-antenna techniques, including spatial multiplexing, will be discussed in more detail in Chapter 5. Multi-antenna techniques for the specific case of LTE are discussed in Chapters 10 and 11.

An alternative to increasing the received signal power is to reduce the noise power, or more exactly the noise power density, at the receiver. This can, at least to some extent, be achieved by more advanced receiver RF design, allowing for a reduced receiver noise figure.

2.1.2 Higher Data Rates in Interference-Limited Scenarios

The discussion above assumed communication over a radio link only impaired by noise. However, in actual mobile-communication scenarios, interference from transmissions in neighboring cells, also referred to as *inter-cell interference*, is often the dominant source of radio-link impairment, more so than noise. This is especially the case in small-cell deployments with a high traffic load. Furthermore, in addition to inter-cell interference there may in some cases also be interference from other transmissions *within the current cell*, also referred to as *intra-cell interference*.

In many respects the impact of interference on a radio link is similar to that of noise. In particular, the basic principles discussed above apply also to a scenario where interference is the main radio-link impairment:

- The maximum data rate that can be achieved in a given bandwidth is limited by the available signal-power-to-interference-power ratio.
- Providing data rates larger than the available bandwidth (high-bandwidth utilization) is costly in the sense that it requires a disproportionately high signal-to-interference ratio.

Also, similar to a scenario where noise is the dominant radio-link impairment, reducing the cell size as well as the use of multi-antenna techniques are key means to increase the achievable data rates in an interference-limited scenario:

- Reducing the cell size will obviously reduce the number of users, and thus also the overall traffic, per cell. This will reduce the relative interference level and thus allow for higher data rates.
- Similar to the increase in signal-to-noise ratio, proper combination of the signals received at multiple antennas will also increase the signal-to-interference ratio after the antenna combination.
- The use of beam-forming by means of multiple transmit antennas will focus the transmit power in the direction of the target receiver, leading to reduced interference to other radio links and thus improving the overall signal-to-interference ratio in the system.

One important difference between interference and noise is that interference, in contrast to noise, typically has a certain structure which makes it, at least to some extent, predictable and thus possible to further suppress or even remove completely. As an example, a dominant interfering signal

Petitioners' Exhibit 1003, p. 377
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

may arrive from a certain direction, in which case the corresponding interference can be further suppressed, or even completely removed, by means of *spatial processing* using multiple antennas at the receiver. This will be further discussed in Chapter 5. Also, any differences in the spectral properties between the target signal and an interfering signal can be used to suppress the interferer and thus reduce the overall interference level.

2.2 HIGHER DATA RATES WITHIN A LIMITED BANDWIDTH: HIGHER-ORDER MODULATION

As discussed in the previous section, providing data rates larger than the available bandwidth is fundamentally inefficient in the sense that it requires disproportionately high signal-to-noise and signal-to-interference ratios at the receiver. Still, bandwidth is often a scarce and expensive resource and, at least in some mobile-communication scenarios, high signal-to-noise and signal-to-interference ratios can be made available, for example in small-cell environments with a low traffic load or for terminals close to the cell site. Mobile-communication systems should preferably be designed to be able to take advantage of such scenarios – that is, they should be able to offer very high data rates within a limited bandwidth when the radio conditions so allow.

A straightforward means to provide higher data rates within a given transmission bandwidth is the use of *higher-order modulation*, implying that the modulation alphabet is extended to include additional signaling alternatives and thus allowing for more bits of information to be communicated per modulation symbol.

In the case of QPSK modulation, which is the modulation scheme used for the downlink in the first releases of the 3G mobile-communication standards (WCDMA and CDMA2000), the modulation alphabet consists of four different signaling alternatives. These four signaling alternatives can be illustrated as four different points in a two-dimensional plane (see Figure 2.2a). With four different signaling alternatives, QPSK allows for up to 2 bits of information to be communicated during each modulation-symbol interval. By extending to 16QAM modulation (Figure 2.2b), 16 different signaling alternatives are available. The use of 16QAM thus allows for up to 4 bits of information to be communicated per symbol interval. Further extension to 64QAM (Figure 2.2c), with 64 different signaling alternatives, allows for up to 6 bits of information to be communicated per symbol interval. At the same time, the bandwidth of the transmitted signal is, at least in principle, independent of the size of the modulation alphabet and mainly depends on the modulation rate – that is, the number of modulation symbols per second. The maximum bandwidth utilization, expressed in bits/s/Hz, of 16QAM and 64QAM are thus, at least in principle, two and three times that of QPSK respectively.

It should be pointed out that there are many other possible modulation schemes, in addition to those illustrated in Figure 2.2. One example is 8PSK, consisting of eight signaling alternatives and thus providing up to 3 bits of information per modulation symbol. Readers are referred to [12] for a more thorough discussion on different modulation schemes.

The use of higher-order modulation provides the possibility for higher bandwidth utilization – that is, the possibility to provide higher data rates within a given bandwidth. However, the higher bandwidth utilization comes at the cost of reduced robustness to noise and interference. Alternatively expressed, higher-order modulation schemes, such as 16QAM or 64QAM, require a higher E_b/N_0 at the receiver for a given bit-error probability, compared to QPSK. This is in line with the discussion in

Petitioners' Exhibit 1003, p. 378
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

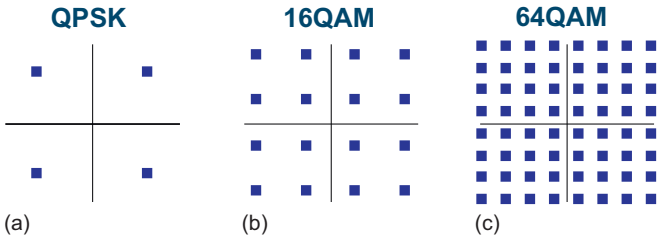


FIGURE 2.2

Signal constellations for: (a) QPSK; (b) 16QAM; (c) 64QAM.

the previous section, where it was concluded that high-bandwidth utilization – that is, a high information rate within a limited bandwidth – in general requires a higher receiver E_b/N_0.

2.2.1 Higher-Order Modulation in Combination with Channel Coding

Higher-order modulation schemes such as 16QAM and 64QAM require, in themselves, a higher receiver E_b/N_0 for a given error rate, compared to QPSK. However, in combination with channel coding the use of higher-order modulation will sometimes be more efficient – that is, require a lower receiver E_b/N_0 for a given error rate – compared to the use of lower-order modulation such as QPSK. This may, for example, occur when the target bandwidth utilization implies that, with lower-order modulation, no or very little channel coding can be applied. In such a case, the additional channel coding that can be applied by using a higher-order modulation scheme such as 16QAM may lead to an overall gain in power efficiency compared to the use of QPSK.

As an example, if a bandwidth utilization of close to 2 information bits per modulation symbol is required, QPSK modulation would allow for very limited channel coding (channel-coding rate close to 1). On the other hand, the use of 16QAM modulation would allow for a channel-coding rate of the order of one-half. Similarly, if a bandwidth efficiency close to 4 information bits per modulation symbol is required, the use of 64QAM may be more efficient than 16QAM modulation, taking into account the possibility for lower-rate channel coding and corresponding additional coding gain in the case of 64QAM. It should be noted that this does not contradict the general discussion in Section 2.1, where it was concluded that transmission with high-bandwidth utilization is inherently power inefficient. The use of rate 1/2 channel coding for 16QAM obviously reduces the information data rate, and thus also the bandwidth utilization, to the same level as uncoded QPSK.

From the discussion above it can be concluded that, for a given signal-to-noise/interference ratio, a certain combination of modulation scheme and channel-coding rate is optimal in the sense that it can deliver the highest-bandwidth utilization (the highest data rate within a given bandwidth) for that signal-to-noise/interference ratio.

2.2.2 Variations in Instantaneous Transmit Power

A general drawback of higher-order modulation schemes such as 16QAM and 64QAM, where information is also encoded in the instantaneous amplitude of the modulated signal, is that the modulated signal will have larger variations, and thus also larger peaks, in its instantaneous power. This can be

Petitioners' Exhibit 1003, p. 379
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

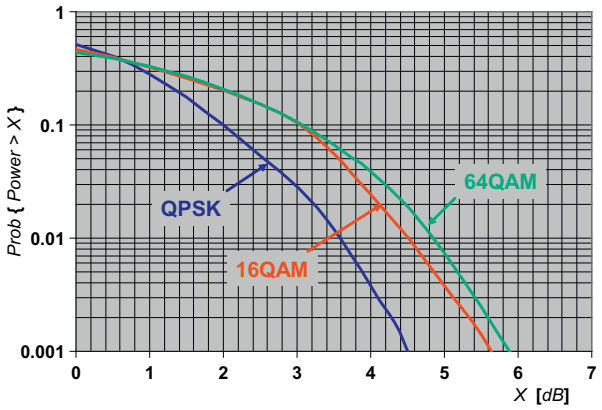


FIGURE 2.3

Distribution of instantaneous power for different modulation schemes. Average power is the same in all cases.

seen in Figure 2.3, which illustrates the distribution of the instantaneous power, more specifically the probability that the instantaneous power is above a certain value, for QPSK, 16QAM, and 64QAM respectively. Clearly, the probability for large peaks in the instantaneous power is higher in the case of higher-order modulation.

Larger peaks in the instantaneous signal power imply that the transmitter power amplifier must be over-dimensioned to avoid power-amplifier nonlinearities, occurring at high instantaneous power levels, causing corruption to the signal to be transmitted. As a consequence, the power-amplifier efficiency will be reduced, leading to increased power consumption. In addition, there will be a negative impact on the power-amplifier cost. Alternatively, the average transmit power must be reduced, implying a reduced range for a given data rate. High power-amplifier efficiency is especially important for the terminal – that is, in the uplink direction – due to the importance of low mobile-terminal power consumption and cost. For the base station, high power-amplifier efficiency, although far from irrelevant, is still somewhat less important. Thus, large peaks in the instantaneous signal power are less of an issue for the downlink compared to the uplink and, consequently, higher-order modulation is more suitable for the downlink compared to the uplink.

2.3 WIDER BANDWIDTH INCLUDING MULTI-CARRIER TRANSMISSION

As was shown in Section 2.1, transmission with a high-bandwidth utilization is fundamentally power inefficient in the sense that it will require disproportionately high signal-to-noise and signal-to-interference ratios for a given data rate. Providing very high data rates within a limited bandwidth, for example by means of higher-order modulation, is thus only possible in situations where relatively high signal-to-noise and signal-to-interference ratios can be made available, for example in small-cell environments with low traffic load or for terminals close to the cell site.

Instead, to provide high data rates as efficiently as possible in terms of required signal-to-noise and signal-to-interference ratios, implying as good coverage as possible for high data rates, the transmission bandwidth should be at least of the same order as the data rates to be provided.

Petitioners' Exhibit 1003, p. 380
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Having in mind that the provisioning of higher data rates with good coverage is one of the main targets for mobile communication, it can thus be concluded that support for even wider transmission bandwidth is an important part of this evolution.

However, there are several critical issues related to the use of wider transmission bandwidths in a mobile-communication system:

- Spectrum is, as already mentioned, often a scarce and expensive resource, and it may be difficult to find spectrum allocations of sufficient size to allow for very wideband transmission, especially at lower-frequency bands.
- The use of wider transmission and reception bandwidths has an impact on the complexity of the radio equipment, both at the base station and at the terminal. As an example, a wider transmission bandwidth has a direct impact on the transmitter and the receiver sampling rates, and thus on the complexity and power consumption of digital-to-analog and analog-to-digital converters, as well as front-end digital signal processing. RF components are also, in general, more complicated to design and more expensive to produce, the wider the bandwidth they have to handle.

The two issues above are mainly outside the scope of this book. However, a more specific technical issue related to wider-band transmission is the increased corruption of the transmitted signal due to time dispersion on the radio channel. Time dispersion occurs when the transmitted signal propagates to the receiver via multiple paths with different delays (see Figure 2.4a). In the frequency domain, a time-dispersive channel corresponds to a non-constant channel frequency response, as illustrated in Figure 2.4b. This radio-channel *frequency selectivity* will corrupt the frequency-domain structure of the transmitted signal and lead to higher error rates for given signal-to-noise/interference ratios. Every radio channel is subject to frequency selectivity, at least to some extent. However, the extent to which the frequency selectivity impacts the radio communication depends on the bandwidth of the transmitted signal with, in general, larger impact for wider-band transmission. The amount of radio-channel frequency selectivity also depends on the environment, with typically less frequency selectivity (less time dispersion) in the case of small cells and in environments with few obstructions and potential reflectors, such as rural environments.

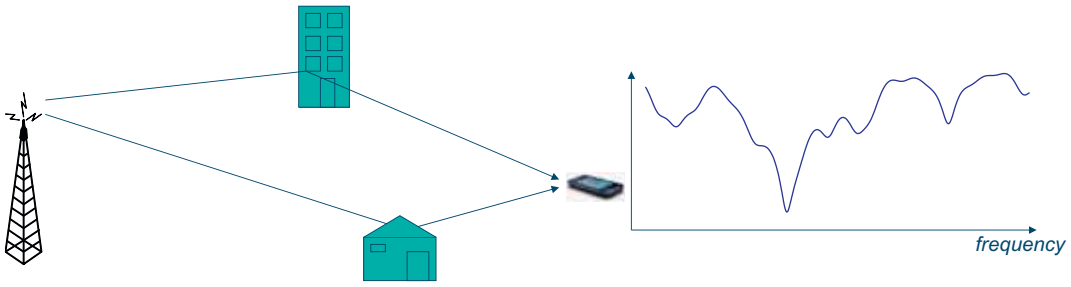


FIGURE 2.4

Multi-path propagation causing time dispersion and radio-channel frequency selectivity.

Petitioners' Exhibit 1003, p. 381
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

It should be noted that Figure 2.4b illustrates a "snapshot" of the channel frequency response. As a terminal is moving through the environment, the detailed structure of the multi-path propagation, and thus also the detailed structure of the channel frequency response, may vary rapidly with time. The rate of the variations in the channel frequency response is related to the channel *Doppler spread*, f_D, defined as $f_D = v/c \cdot fc$, where v is the speed of the terminal, fc is the carrier frequency (for example, 2 GHz), and c is the speed of light.

Receiver-side *equalization* [12] has for many years been used to counteract signal corruption due to radio-channel frequency selectivity. Equalization has been shown to provide satisfactory performance with reasonable complexity at least up to bandwidths corresponding to the WCDMA bandwidth of 5 MHz (see, for example, [13]). However, if the transmission bandwidth is further increased up to, for example, 20 MHz, as is done in LTE, the complexity of straightforward high-performance equalization starts to become a serious issue. One option is then to apply less optimal equalization, with a corresponding negative impact on the equalizer capability to counteract the signal corruption due to radio-channel frequency selectivity and thus a corresponding negative impact on the radio-link performance.

An alternative approach is to consider specific transmission schemes and signal designs that allow for good radio-link performance also in the case of substantial radio-channel frequency selectivity without a prohibitively large receiver complexity. In the following, two such approaches to wider-band transmission will be discussed:

1. The use of different types of *multi-carrier transmission* – that is, transmitting an overall wider-band signal as several more narrowband frequency-multiplexed signals (see below). One special case of multi-carrier transmission is *OFDM transmission*, to be discussed in more detail in Chapter 3.
2. The use of specific *single-carrier* transmission schemes, especially designed to allow for efficient but still reasonably low-complexity equalization. This is further discussed in Chapter 4.

2.3.1 Multi-Carrier Transmission

One way to increase the overall transmission bandwidth, without suffering from increased signal corruption due to radio-channel frequency selectivity, is the use of so-called *multi-carrier transmission*. As illustrated in Figure 2.5, multi-carrier transmission implies that, instead of transmitting a single more wideband signal, multiple more narrowband signals, often referred to as *subcarriers*, are frequency multiplexed and jointly transmitted over the same radio link to the same receiver. By transmitting M signals in parallel over the same radio link, the overall data rate can be increased up to M times. At the same time, the impact in terms of signal corruption due to radio-channel frequency selectivity depends on the bandwidth of each subcarrier. Thus, the impact from a frequency-selective channel is essentially the same as for a more narrowband transmission scheme with a bandwidth that corresponds to the bandwidth of each subcarrier.

A drawback of the kind of multi-carrier evolution outlined in Figure 2.5, where an existing more narrowband radio-access technology is extended to a wider overall transmission bandwidth by the parallel transmission of M more narrowband carriers, is that the spectrum of each subcarrier typically does not allow for very tight subcarrier "packing". This is illustrated by the "valleys" in the overall multi-carrier spectrum outlined in the lower part of Figure 2.5. This has a somewhat negative impact on the overall bandwidth efficiency of this kind of multi-carrier transmission.

Petitioners' Exhibit 1003, p. 382
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

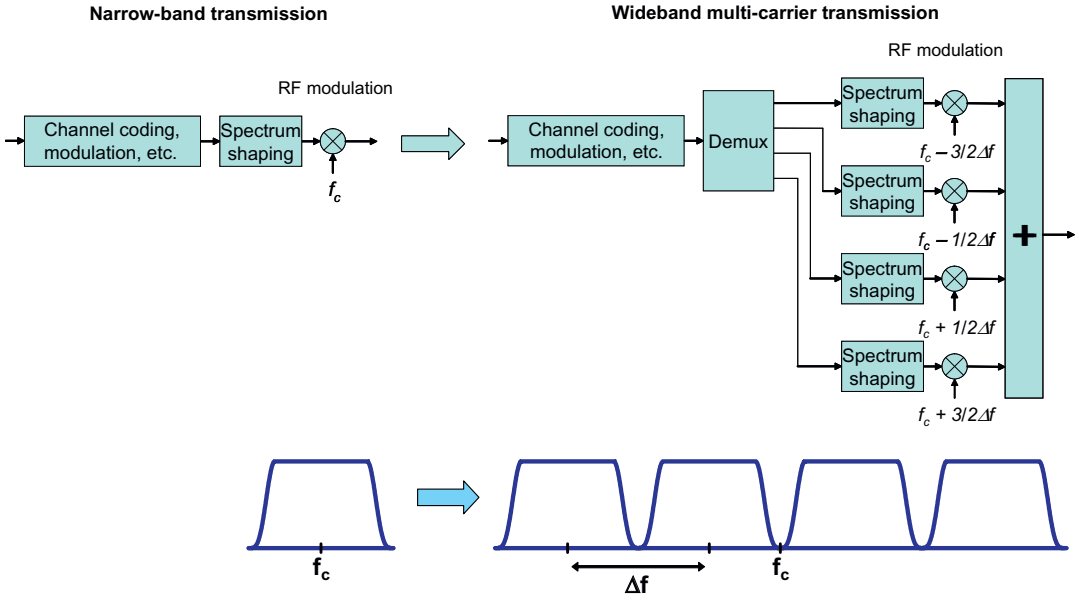


FIGURE 2.5

Extension to wider transmission bandwidth by means of multi-carrier transmission.

As an example, consider the multi-carrier evolution of WCDMA/HSPA towards wider bandwidth. WCDMA has a modulation rate, also referred to as the *WCDMA chip rate*, of $f_{cr} = 3.84$ Mchips/s. However, due to spectrum shaping, even the theoretical WCDMA spectrum, not including spectrum widening due to transmitter imperfections, has a bandwidth that significantly exceeds 3.84 MHz. More specifically, as can be seen in Figure 2.6, the theoretical WCDMA spectrum has a *raised-cosine* shape with roll-off $\alpha = 0.22$. As a consequence, the bandwidth outside of which the WCDMA theoretical spectrum equals zero is approximately 4.7 MHz (see right part of Figure 2.6).

For a straightforward multi-carrier extension of WCDMA, the subcarriers must thus be spaced approximately 4.7 MHz from each other to completely avoid inter-subcarrier interference. It should be noted, though, that a smaller subcarrier spacing can be used with only limited inter-subcarrier interference.

A second drawback of multi-carrier transmission is that, similar to the use of higher-order modulation, the parallel transmission of multiple carriers will lead to larger variations in the instantaneous transmit power. Thus, similar to the use of higher-order modulation, multi-carrier transmission will have a negative impact on the transmitter power-amplifier efficiency, implying increased transmitter power consumption and increased power-amplifier cost. Alternatively, the average transmit power must be reduced, implying a reduced range for a given data rate. For this reason, similar to the use of higher-order modulation, multi-carrier transmission is more suitable for the downlink (base-station transmission), compared to the uplink (mobile-terminal transmission), due to the higher importance of high power-amplifier efficiency at the terminal.

Petitioners' Exhibit 1003, p. 383
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

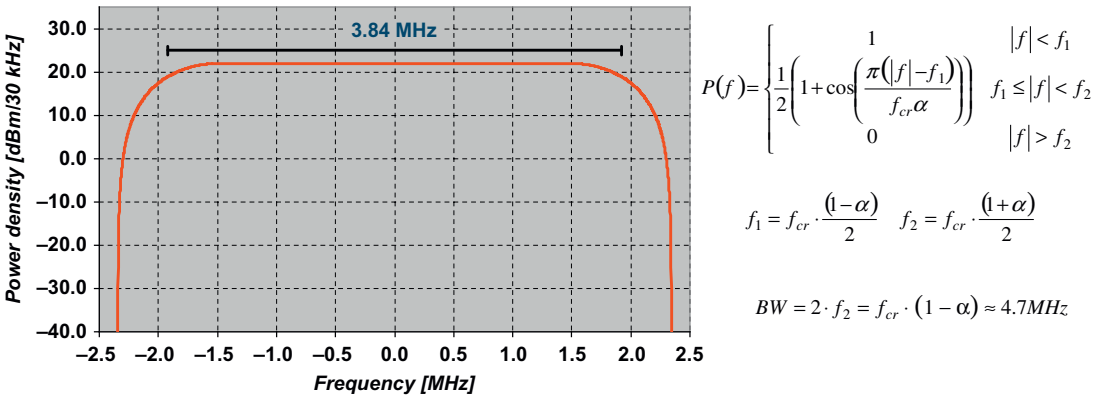


FIGURE 2.6

Theoretical WCDMA spectrum. Raised-cosine shape with roll-off $\alpha = 0.22$.

The main advantage with the kind of multi-carrier extension outlined in Figure 2.5 is that it provides a very smooth evolution, in terms of both radio equipment and spectrum, of an already existing radio-access technology to wider transmission bandwidth and a corresponding possibility for higher data rates, especially for the downlink. In essence this kind of multi-carrier evolution to wider bandwidth can be designed so that, for legacy terminals not capable of multi-carrier reception, each downlink "subcarrier" will appear as an original, more narrowband carrier, while, for a multi-carrier-capable terminal, the network can make use of the full multi-carrier bandwidth to provide higher data rates.

The next chapter will discuss, in more detail, a different approach to multi-carrier transmission, based on the so-called OFDM technique.

CHAPTER

OFDM Transmission

3

In this chapter, a more detailed overview of OFDM or *Orthogonal Frequency-Division Multiplexing* will be given. OFDM is the transmission scheme used for 3GPP LTE and is also used for several other radio-access technologies, for example WiMAX [14] and the DVB broadcast technologies [15].

3.1 BASIC PRINCIPLES OF OFDM

Transmission by means of OFDM can be seen as a kind of multi-carrier transmission. The basic characteristics of OFDM transmission, which distinguish it from a straightforward multi-carrier extension of a more narrowband transmission scheme as outlined in Figure 2.5 in the previous chapter, are:

- The use of a typically very large number of relatively narrowband subcarriers. In contrast, a straightforward multi-carrier extension as outlined in Figure 2.5 would typically consist of only a few subcarriers, each with a relatively wide bandwidth. As an example, the HSPA multi-carrier evolution to a 20 MHz overall transmission bandwidth consists of four (sub)carriers, each with a bandwidth of the order of 5 MHz. In comparison, OFDM transmission may imply that several hundred subcarriers are transmitted over the same radio link to the same receiver.
- Simple rectangular pulse shaping is illustrated in Figure 3.1a. This corresponds to a sinc-square-shaped per-subcarrier spectrum, as illustrated in Figure 3.1b.
- Tight frequency-domain packing of the subcarriers with a subcarrier spacing $\Delta f = 1/T_u$, where T_u is the per-subcarrier modulation-symbol time (see Figure 3.2). The subcarrier spacing is thus equal to the per-subcarrier modulation rate $1/T_u$.[1]

An illustrative description of a basic OFDM modulator is provided in Figure 3.3. It consists of a bank of N_c complex modulators, where each modulator corresponds to one OFDM subcarrier.

In complex baseband notation, a basic OFDM signal $x(t)$ during the time interval $mT_u \leq t < (m+1)T_u$ can thus be expressed as:

$$x(t) = \sum_{k=0}^{N_c-1} x_k(t) = \sum_{k=0}^{N_c-1} a_k^{(m)} e^{j2\pi k\Delta f t}, \tag{3.1}$$

where $x_k(t)$ is the kth modulated subcarrier with frequency $f_k = k \cdot \Delta f$ and $a_k^{(m)}$ is the, generally complex, modulation symbol applied to the kth subcarrier during the mth OFDM symbol interval – that is, during the time interval $mT_u \leq t < (m+1)T_u$. OFDM transmission is thus block based, implying

[1] This ignores a possible *cyclic prefix*, see Section 3.4.

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 386
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

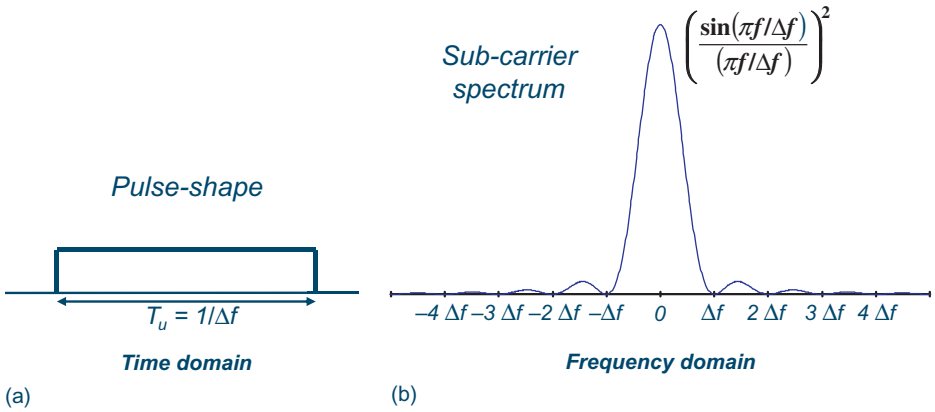


FIGURE 3.1

(a) Per-subcarrier pulse shape. (b) Spectrum for basic OFDM transmission.

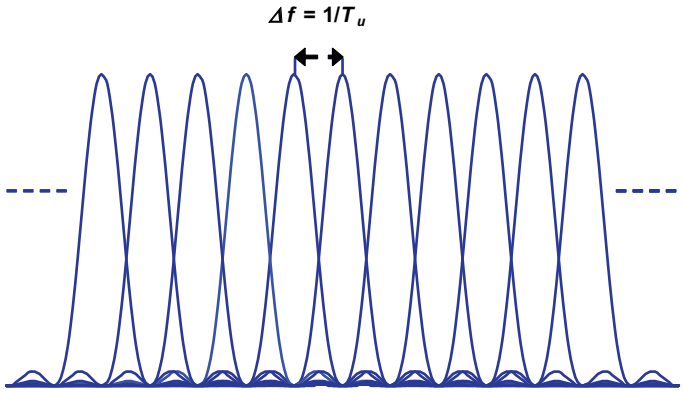


FIGURE 3.2

OFDM subcarrier spacing.

that, during each OFDM symbol interval, N_c modulation symbols are transmitted in parallel. The modulation symbols can be from any modulation alphabet, such as QPSK, 16QAM, or 64QAM.

The number of OFDM subcarriers can range from less than hundred to several thousand, with the subcarrier spacing ranging from several hundred kHz down to a few kHz. What subcarrier spacing to use depends on what types of environments the system is to operate in, including such aspects as the maximum expected radio-channel frequency selectivity (maximum expected time dispersion) and the maximum expected rate of channel variations (maximum expected Doppler spread). Once the subcarrier spacing has been selected, the number of subcarriers can be decided based on the assumed overall transmission bandwidth, taking into account acceptable out-of-band emission, etc.

Petitioners' Exhibit 1003, p. 387
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

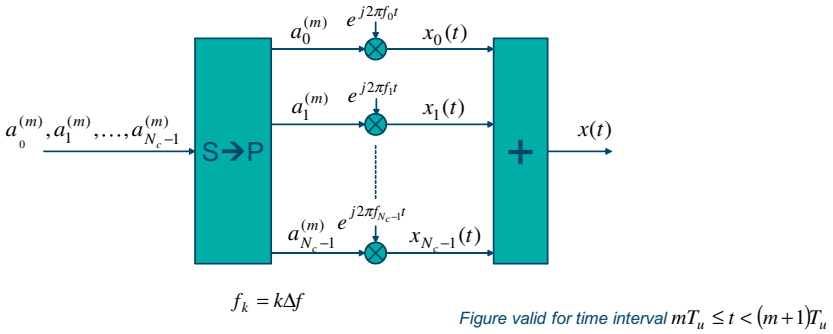


FIGURE 3.3

Principles for OFDM modulation.

The selection of OFDM subcarrier spacing and number of subcarriers is discussed in somewhat more detail in Section 3.8.

As an example, for 3GPP LTE the basic subcarrier spacing equals 15 kHz. On the other hand, the number of subcarriers depends on the transmission bandwidth, with of the order of 600 subcarriers in the case of operation in a 10 MHz spectrum allocation and correspondingly fewer/more subcarriers in the case of smaller/larger overall transmission bandwidths.

The term *Orthogonal Frequency-Division Multiplex* is due to the fact that two modulated OFDM subcarriers x_{k_1} and x_{k_2} are mutually *orthogonal* over the time interval $mT_u \le t < (m+1)T_u$, that is:

$$\int_{mT_u}^{(m+1)T_u} x_{k_1}(t)x_{k_2}^*(t)\,dt = \int_{mT_u}^{(m+1)T_u} a_{k_1}a_{k_2}^* e^{j2\pi k_1 \Delta f t} e^{-j2\pi k_2 \Delta f t}\,dt = 0 \quad \text{for } k_1 \neq k_2. \tag{3.2}$$

Thus, basic OFDM transmission can be seen as the modulation of a set of orthogonal functions $\varphi_k(t)$, where

$$\varphi_k(t) = \begin{cases} e^{j2\pi k \Delta f t} & 0 \le t < T_u \\ 0 & \text{otherwise} \end{cases}. \tag{3.3}$$

The "physical resource" in the case of OFDM transmission is often illustrated as a time–frequency grid according to Figure 3.4, where each "column" corresponds to one OFDM symbol and each "row" corresponds to one OFDM subcarrier.

3.2 OFDM DEMODULATION

Figure 3.5 illustrates the basic principle of OFDM demodulation consisting of a bank of correlators, one for each subcarrier. Taking into account the orthogonality between subcarriers according to Eqn (3.2), it is clear that, in the ideal case, two OFDM subcarriers do not cause any interference to

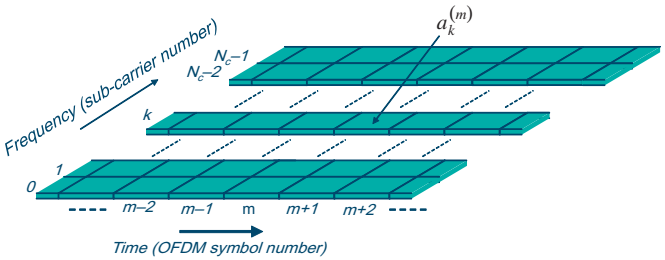


FIGURE 3.4

OFDM time–frequency grid.

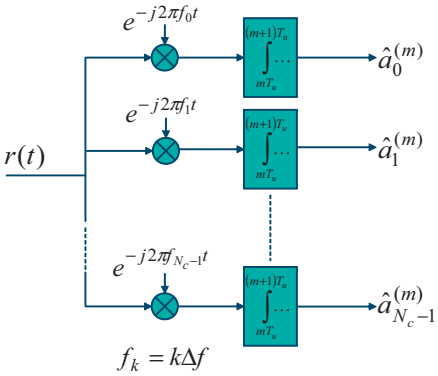


FIGURE 3.5

Basic principle of OFDM demodulation.

each other after demodulation. Note that this is the case despite the fact that the spectrum of neighbor subcarriers clearly overlaps, as can be seen from Figure 3.2. Thus, the avoidance of interference between OFDM subcarriers is not simply due to a subcarrier spectrum separation, which is, for example, the case for the kind of straightforward multi-carrier extension outlined in Figure 2.5 in the previous chapter. Rather, the subcarrier orthogonality is due to the *specific* frequency-domain structure of each subcarrier in combination with the *specific* choice of a subcarrier spacing Δf equal to the per-subcarrier symbol rate $1/T_u$. However, this also implies that, in contrast to the kind of multi-carrier transmission outlined in Section 2.3.1 of the previous chapter, any corruption of the frequency-domain structure of the OFDM subcarriers, for example due to a frequency-selective radio channel, may lead to a loss of inter-subcarrier orthogonality and thus to interference between subcarriers. To handle this and to make an OFDM signal truly robust to radio-channel frequency selectivity, *cyclic-prefix insertion* is typically used, as will be further discussed in Section 3.4.

3.3 OFDM IMPLEMENTATION USING IFFT/FFT PROCESSING

Although a bank of modulators/correlators according to Figures 3.3 and 3.5 can be used to illustrate the basic principles of OFDM modulation and demodulation respectively, these are not the most appropriate modulator/demodulator structures for actual implementation. Actually, due to its specific structure and the selection of a subcarrier spacing Δf equal to the per-subcarrier symbol rate $1/T_u$, OFDM allows for low-complexity implementation by means of computationally efficient *Fast Fourier Transform* (FFT) processing.

To confirm this, consider a time-discrete (sampled) OFDM signal where it is assumed that the sampling rate f_s is a multiple of the subcarrier spacing Δf – that is, $f_s = 1/T_s = N \cdot \Delta f$. The parameter N should be chosen so that the sampling theorem [12] is sufficiently fulfilled.[2] As $N_c \cdot \Delta f$ can be seen

[2]An OFDM signal defined according to Eqn (3.1) in theory has an infinite bandwidth and thus the sampling theorem can never be fulfilled completely.

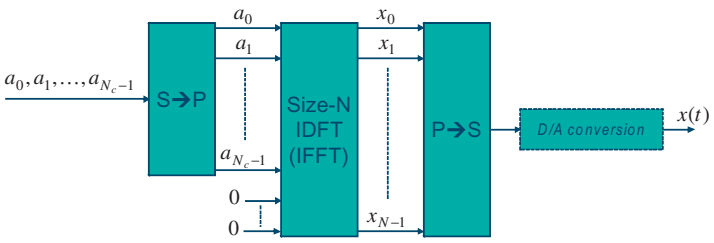


FIGURE 3.6

OFDM modulation by means of IFFT processing.

as the nominal bandwidth of the OFDM signal, this implies that N should exceed N_c with a sufficient margin.

With these assumptions, the time-discrete OFDM signal can be expressed as:[3]

$$x_n = x(nT_s) = \sum_{k=0}^{N_c-1} a_k e^{j2\pi k\Delta f n T_s} = \sum_{k=0}^{N_c-1} a_k e^{j2\pi kn/N} = \sum_{k=0}^{N-1} a'_k e^{j2\pi kn/N}, \tag{3.4}$$

where

$$a'_k = \begin{cases} a_k & 0 \le k < N_c \\ 0 & N_c \le k < N \end{cases}. \tag{3.5}$$

Thus, the sequence x_n, or, in other words, the sampled OFDM signal, is the size-N Inverse Discrete Fourier Transform (IDFT) of the block of modulation symbols a_0, a_1, …, a_{N_c-1} extended with zeros to length N. OFDM modulation can thus be implemented by means of IDFT processing followed by digital-to-analog conversion, as illustrated in Figure 3.6. In particular, by selecting the IDFT size N equal to 2^m for some integer m, the OFDM modulation can be implemented by means of implementation-efficient radix-2 Inverse Fast Fourier Transform (IFFT) processing. It should be noted that the ratio N/N_c, which could be seen as the *over-sampling* of the time-discrete OFDM signal, could very well be, and typically is, a non-integer number. As an example and as already mentioned, for 3GPP LTE the number of subcarriers N_c is approximately 600 in the case of a 10 MHz spectrum allocation. The IFFT size can then, for example, be selected as $N = 1024$. This corresponds to a sampling rate $f_s = N \cdot \Delta f = 15.36$ MHz, where $\Delta f = 15$ kHz is the LTE subcarrier spacing.

It is important to understand that IDFT/IFFT-based implementation of an OFDM modulator, and even more so the exact IDFT/IFFT size, are just transmitter-implementation choices and not something that would be mandated by any radio-access specification. As an example, nothing forbids the implementation of an OFDM modulator as a set of parallel modulators, as illustrated in Figure 3.3. Also, nothing prevents the use of a larger IFFT size, for example a size-2048 IFFT size, even in the case of a smaller number of OFDM subcarriers.

[3]From now on the index m on the modulation symbols, indicating the OFDM symbol number, will be ignored unless especially needed.

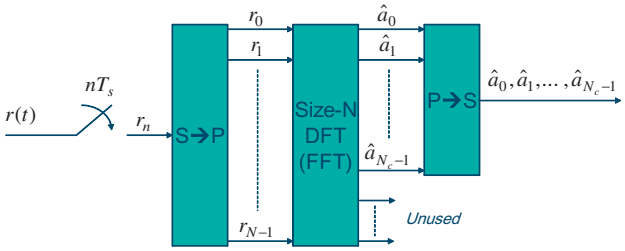


FIGURE 3.7

OFDM demodulation by means of FFT processing.

Similar to OFDM modulation, efficient FFT processing can be used for OFDM demodulation, replacing the bank of N_c parallel demodulators of Figure 3.5 with sampling with some sampling rate $f_s = 1/T_s$, followed by a size-N DFT/FFT, as illustrated in Figure 3.7.

3.4 CYCLIC-PREFIX INSERTION

As described in Section 3.2, an uncorrupted OFDM signal can be demodulated without any interference between subcarriers. One way to understand this *subcarrier orthogonality* is to recognize that a modulated subcarrier $x_k(t)$ in Eqn (3.1) consists of an integer number of periods of complex exponentials during the demodulator integration interval $T_u = 1/\Delta f$.

However, in case of a time-dispersive channel the orthogonality between the subcarriers will, at least partly, be lost. The reason for this loss of subcarrier orthogonality in the case of a time-dispersive channel is that, in this case, the demodulator correlation interval for one path will overlap with the symbol boundary of a different path, as illustrated in Figure 3.8. Thus, the integration interval will not necessarily correspond to an integer number of periods of complex exponentials of that path as the modulation symbols a_k may differ between consecutive symbol intervals. As a consequence, in the case of a time-dispersive channel there will not only be inter-symbol interference within a subcarrier, but also interference between subcarriers.

Another way to explain the interference between subcarriers in the case of a time-dispersive channel is to have in mind that time dispersion on the radio channel is equivalent to a frequency-selective channel frequency response. As clarified in Section 3.2, orthogonality between OFDM subcarriers is not simply due to frequency-domain separation but due to the *specific* frequency-domain structure of each subcarrier. Even if the frequency-domain channel is constant over a bandwidth corresponding to the main lobe of an OFDM subcarrier and only the subcarrier side lobes are corrupted due to the radio-channel frequency selectivity, the orthogonality between subcarriers will be lost with inter-subcarrier interference as a consequence. Due to the relatively large side lobes of each OFDM subcarrier, already a relatively limited amount of time dispersion or, equivalently, a relatively modest radio-channel frequency selectivity may cause substantial interference between subcarriers.

To deal with this problem and to make an OFDM signal truly insensitive to time dispersion on the radio channel, so-called *cyclic-prefix insertion* is typically used in OFDM transmission. As illustrated

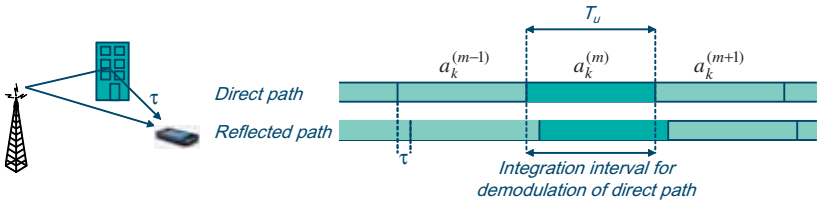


FIGURE 3.8

Time dispersion and corresponding received-signal timing.

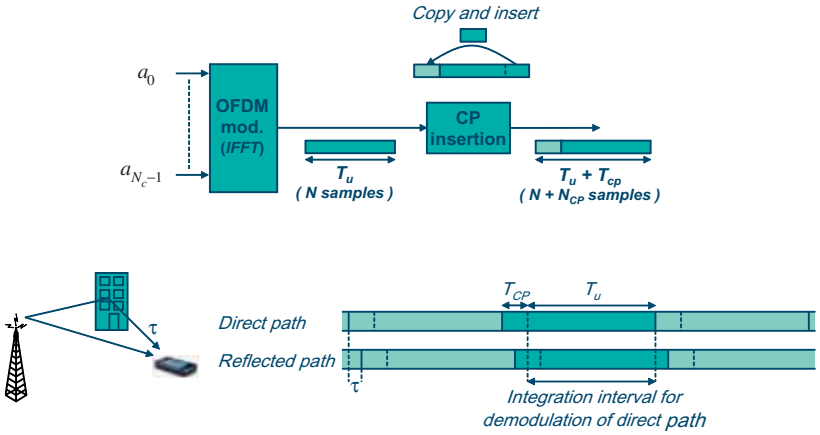


FIGURE 3.9

Cyclic-prefix insertion.

in Figure 3.9, cyclic-prefix insertion implies that the last part of the OFDM symbol is copied and inserted at the beginning of the OFDM symbol. Cyclic-prefix insertion thus increases the length of the OFDM symbol from T_u to $T_u + T_{CP}$, where T_{CP} is the length of the cyclic prefix, with a corresponding reduction in the OFDM symbol rate as a consequence. As illustrated in the lower part of Figure 3.9, if the correlation at the receiver side is still only carried out over a time interval $T_u = 1/\Delta f$, subcarrier orthogonality will then also be preserved in the case of a time-dispersive channel, as long as the span of the time dispersion is shorter than the cyclic-prefix length.

In practice, cyclic-prefix insertion is carried out on the time-discrete output of the transmitter IFFT. Cyclic-prefix insertion then implies that the last N_{CP} samples of the IFFT output block of length N are copied and inserted at the beginning of the block, increasing the block length from N to $N + N_{CP}$. At the receiver side, the corresponding samples are discarded before OFDM demodulation by means of, for example, DFT/FFT processing.

Cyclic-prefix insertion is beneficial in the sense that it makes an OFDM signal insensitive to time dispersion as long as the span of the time dispersion does not exceed the length of the cyclic prefix. The drawback of cyclic-prefix insertion is that only a fraction $T_u/(T_u + T_{CP})$ of the received signal

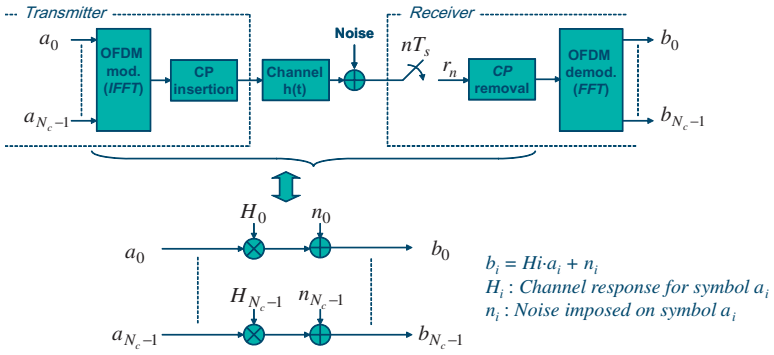


FIGURE 3.10

Frequency-domain model of OFDM transmission/reception.

power is actually utilized by the OFDM demodulator, implying a corresponding power loss in the demodulation. In addition to this power loss, cyclic-prefix insertion also implies a corresponding loss in terms of bandwidth as the OFDM symbol rate is reduced without a corresponding reduction in the overall signal bandwidth.

One way to reduce the relative overhead due to cyclic-prefix insertion is to reduce the subcarrier spacing Δf, with a corresponding increase in the symbol time T_u as a consequence. However, this will increase the sensitivity of the OFDM transmission to fast channel variations – that is, high Doppler spread – as well as different types of frequency errors (see further Section 3.8).

It is also important to understand that the cyclic prefix does not necessarily have to cover the entire length of the channel time dispersion. In general, there is a trade-off between the power loss due to the cyclic prefix and the signal corruption (inter-symbol and inter-subcarrier interference) due to residual time dispersion not covered by the cyclic prefix and, at a certain point, further reduction of the signal corruption due to further increase of the cyclic-prefix length will not justify the corresponding additional power loss. This also means that, although the amount of time dispersion typically increases with the cell size, beyond a certain cell size there is often no reason to increase the cyclic prefix further as the corresponding power loss due to a further increase of the cyclic prefix would have a larger negative impact, compared to the signal corruption due to the residual time dispersion not covered by the cyclic prefix [16].

3.5 FREQUENCY-DOMAIN MODEL OF OFDM TRANSMISSION

Assuming a sufficiently large cyclic prefix, the linear convolution of a time-dispersive radio channel will appear as a circular convolution during the demodulator integration interval T_u. The combination of OFDM modulation (IFFT processing), a time-dispersive radio channel, and OFDM demodulation (*FFT* processing) can then be seen as a *frequency-domain* channel as illustrated in Figure 3.10, where

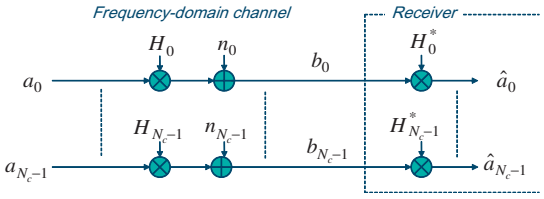


FIGURE 3.11

Frequency-domain model of OFDM transmission/reception with "one-tap equalization" at the receiver.

the frequency-domain channel taps $H_0, \ldots, H_{N_c-1}$ can be directly derived from the channel impulse response.

The demodulator output b_k in Figure 3.10 is the transmitted modulation symbol a_k scaled and phase rotated by the complex frequency-domain channel tap H_k and impaired by noise n_k. To properly recover the transmitted symbol for further processing, for example data demodulation and channel decoding, the receiver should multiply b_k by the complex conjugate of H_k, as illustrated in Figure 3.11. This is often expressed as a *one-tap equalizer* being applied to each received subcarrier.

3.6 CHANNEL ESTIMATION AND REFERENCE SYMBOLS

As described above, to demodulate the transmitted modulation symbol a_k and allow for proper decoding of the transmitted information at the receiver side, scaling with the complex conjugate of the frequency-domain channel tap H_k should be applied after OFDM demodulation (*FFT* processing) (see Figure 3.11). To be able to do this, the receiver obviously needs an estimate of the frequency-domain channel taps $H_0, \ldots, H_{N_c-1}$.

The frequency-domain channel taps can be estimated indirectly by first estimating the channel impulse response and, from that, calculating an estimate of H_k. However, a more straightforward approach is to estimate the frequency-domain channel taps directly. This can be done by inserting known *reference symbols*, sometimes also referred to as *pilot symbols*, at regular intervals within the OFDM time–frequency grid, as illustrated in Figure 3.12. Using knowledge about the reference symbols, the receiver can estimate the frequency-domain channel around the location of the reference symbol. The reference symbols should also have a sufficiently high density in both the time and the frequency domains to be able to provide estimates for the entire time–frequency grid in the case of radio channels subject to high frequency and/or time selectivity.

Different more or less advanced algorithms can be used for the channel estimation, ranging from simple averaging in combination with linear interpolation to Minimum-Mean-Square-Error (MMSE) estimation relying on more detailed knowledge of the channel time/frequency-domain characteristics. Readers are referred to, for example, [17] for a more in-depth discussion on channel estimation for OFDM.

Petitioners' Exhibit 1003, p. 394
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

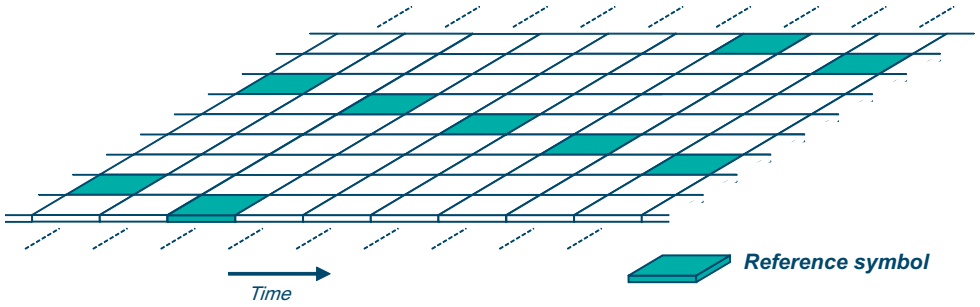


FIGURE 3.12

Time–frequency grid with known reference symbols.

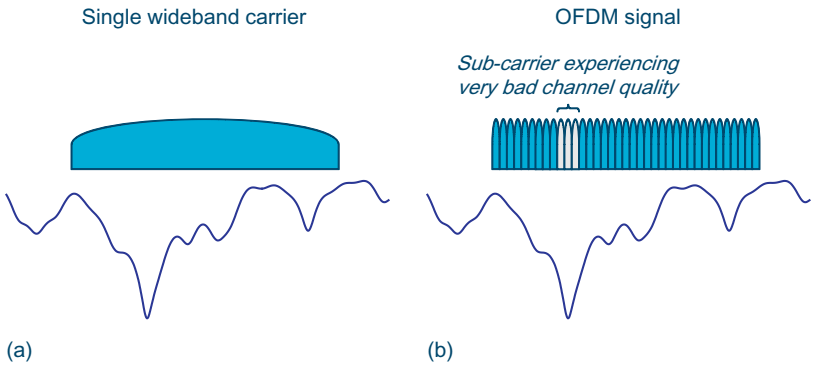


FIGURE 3.13

(a) Transmission of single wideband carrier. (b) OFDM transmission over a frequency-selective channel.

3.7 FREQUENCY DIVERSITY WITH OFDM: IMPORTANCE OF CHANNEL CODING

As discussed in Section 2.3 in the previous chapter, a radio channel is always subject to some degree of frequency selectivity, implying that the channel quality will vary in the frequency domain. In the case of a single wideband carrier, such as a WCDMA carrier, each modulation symbol is transmitted over the entire signal bandwidth. Thus, in the case of the transmission of a single wideband carrier over a highly frequency-selective channel (see Figure 3.13a), each modulation symbol will be transmitted both over frequency bands with relatively good quality (relatively high signal strength) and frequency bands with low quality (low signal strength). Such transmission of information over multiple frequency bands with different instantaneous channel quality is also referred to as *frequency diversity*.

On the other hand, in the case of OFDM transmission each modulation symbol is mainly confined to a relatively narrow bandwidth. Thus, for OFDM transmission over a frequency-selective channel, certain modulation symbols may be fully confined to a frequency band with very low instantaneous

Petitioners' Exhibit 1003, p. 395
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

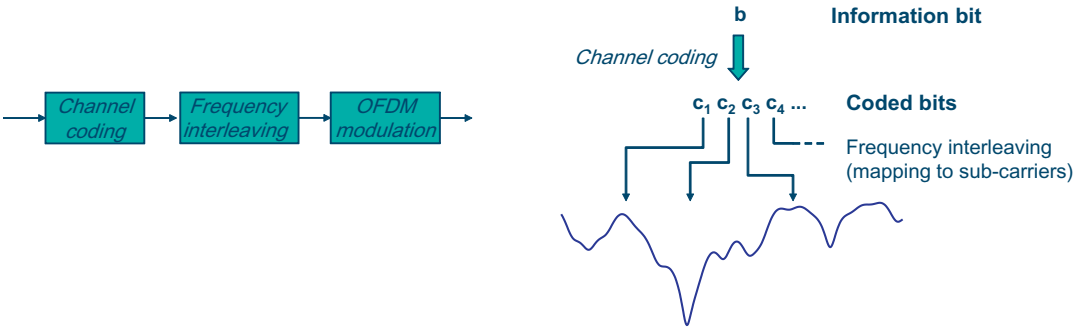


FIGURE 3.14

Channel coding in combination with frequency-domain interleaving to provide frequency diversity in the case of OFDM transmission.

signal strength, as illustrated in Figure 3.13b. Thus, the individual modulation symbols will typically not experience any substantial frequency diversity even if the channel is highly frequency selective over the overall OFDM transmission bandwidth. As a consequence, the basic error-rate performance of OFDM transmission over a frequency-selective channel is relatively poor and especially much worse than the basic error rate in the case of a single wideband carrier.

However, in practice channel coding is used in most cases of digital communication and especially in mobile communication. Channel coding implies that each bit of information to be transmitted is spread over several, often very many, code bits. If these coded bits are then, via modulation symbols, mapped to a set of OFDM subcarriers that are well distributed over the overall transmission bandwidth of the OFDM signal, as illustrated in Figure 3.14, each information bit will experience frequency diversity in the case of transmission over a radio channel that is frequency selective over the transmission bandwidth, despite the fact that the subcarriers, and thus also the code bits, will not experience any frequency diversity. Distributing the code bits in the frequency domain, as illustrated in Figure 3.14, is sometimes referred to as *frequency interleaving*. This is similar to the use of time-domain interleaving to benefit from channel coding in the case of fading that varies in time.

Thus, in contrast to the transmission of a single wideband carrier, channel coding (combined with frequency interleaving) is an essential component in order for OFDM transmission to be able to benefit from frequency diversity on a frequency-selective channel. As channel coding is typically used in most cases of mobile communication this is not a very serious drawback, especially taking into account that a significant part of the available frequency diversity can be captured already with a relatively high code rate.

3.8 SELECTION OF BASIC OFDM PARAMETERS

If OFDM is to be used as the transmission scheme in a mobile-communication system, the following basic OFDM parameters need to be decided upon:

- The subcarrier spacing Δf.
- The number of subcarriers N_c, which, together with the subcarrier spacing, determines the overall transmission bandwidth of the OFDM signal.

Petitioners' Exhibit 1003, p. 396
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

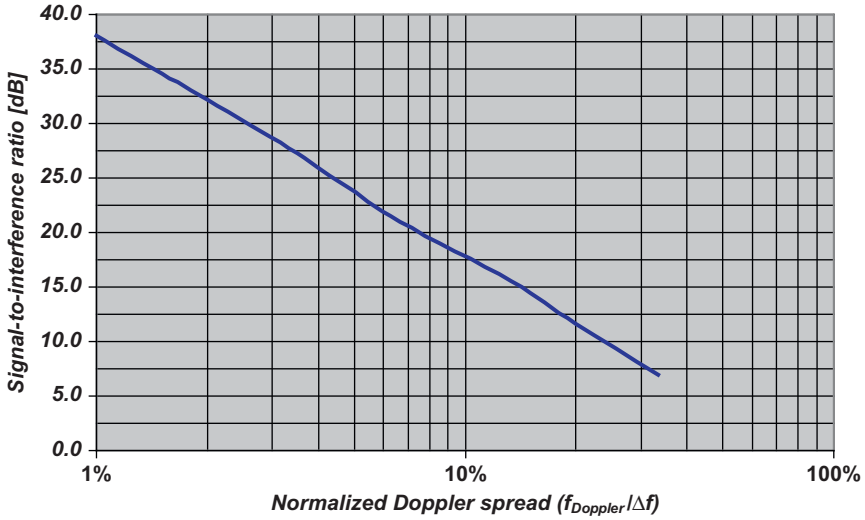


FIGURE 3.15

Subcarrier interference as a function of the normalized Doppler spread $f_{\text{Doppler}}/\Delta f$.

- The cyclic-prefix length T_{CP}. Together with the subcarrier spacing $\Delta f = 1/T_{\text{u}}$, the cyclic-prefix length determines the overall OFDM symbol time $T = T_{\text{CP}} + T_{\text{u}}$ or, equivalently, the OFDM symbol rate.

3.8.1 OFDM Subcarrier Spacing

There are two factors that constrain the selection of the OFDM subcarrier spacing:

- The OFDM subcarrier spacing should be as small as possible (T_{u} as large as possible) to minimize the relative cyclic-prefix overhead $T_{\text{CP}}/(T_{\text{u}} + T_{\text{CP}})$ – see further Section 3.8.3.
- A too small subcarrier spacing increases the sensitivity of the OFDM transmission to Doppler spread and different kinds of frequency inaccuracies.

A requirement for the OFDM subcarrier orthogonality (3.2) to hold at the receiver side – that is, after the transmitted signal has propagated over the radio channel – is that the instantaneous channel does not vary noticeably during the demodulator correlation interval T_{u} (see Figure 3.5). In the case of such channel variations, for example due to very high Doppler spread, the orthogonality between subcarriers will be lost, with inter-subcarrier interference as a consequence. Figure 3.15 illustrates the subcarrier signal-to-interference ratio due to inter-subcarrier interference between two neighboring subcarriers, as a function of the normalized Doppler spread. When considering Figure 3.15, it should be borne in mind that a subcarrier will be subject to interference from multiple subcarriers on both sides[4] – that is, the overall inter-subcarrier interference from all subcarriers will be higher than what is illustrated in Figure 3.15.

[4]Except for the subcarrier at the edge of the spectrum.

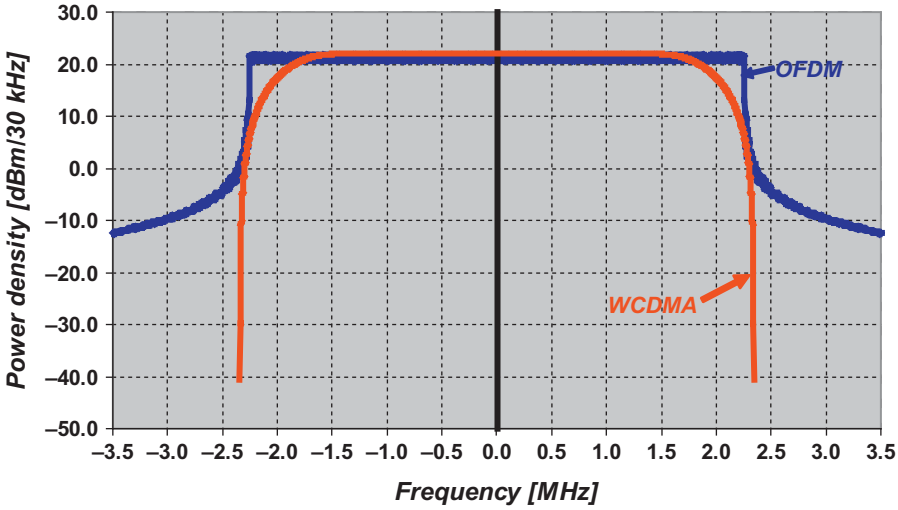


FIGURE 3.16

Spectrum of a basic 5 MHz OFDM signal compared with WCDMA spectrum.

In practice, the amount of inter-subcarrier interference that can be accepted very much depends on the service to be provided and to what extent the received signal is anyway corrupted due to noise and other impairments. As an example, on the cell border of large cells the signal-to-noise/interference ratio will anyway be relatively low, with relatively low achievable data rates as a consequence. A small amount of additional inter-subcarrier interference, for example due to Doppler spread, may then be more or less negligible. At the same time, in high signal-to-noise/interference scenarios, for example in small cells with low traffic or close to the base station, where high data rates are to be provided, the same amount of inter-subcarrier interference may have a much more negative impact.

It should also be noted that, in addition to Doppler spread, inter-subcarrier interference will also be due to different transmitter and receiver inaccuracies, such as frequency errors and phase noise.

3.8.2 Number of Subcarriers

Once the subcarrier spacing has been selected based on environment, expected Doppler spread and time dispersion, etc., the number of subcarriers can be determined based on the amount of spectrum available and the acceptable out-of-band emissions.

The basic bandwidth of an OFDM signal equals $N_c \cdot \Delta f$ – that is, the number of subcarriers multiplied by the subcarrier spacing. However, as can be seen in Figure 3.16, the spectrum of a basic OFDM signal falls off very slowly outside the basic OFDM bandwidth and especially much slower than for a WCDMA signal. The reason for the large *out-of-band emission* of a basic OFDM signal is the use of rectangular pulse shaping (Figure 3.1), leading to per-subcarrier side lobes that fall off relatively slowly. However, in practice, straightforward filtering or *time-domain windowing* [18] will be used to suppress a main part of the OFDM out-of-band emissions. Thus, in practice, typically of the

order of 10% guard-band is needed for an OFDM signal implying, as an example, that in a spectrum allocation of 5 MHz, the basic OFDM bandwidth $N_c \cdot \Delta f$ could be of the order of 4.5 MHz. Assuming, for example, a subcarrier spacing of 15 kHz as selected for LTE, this corresponds to approximately 300 subcarriers in 5 MHz.

3.8.3 Cyclic-Prefix Length

In principle, the cyclic-prefix length T_{CP} should cover the maximum length of the time dispersion expected to be experienced. However, as already discussed, increasing the length of the cyclic prefix, without a corresponding reduction in the subcarrier spacing Δf, implies an additional overhead in terms of power as well as bandwidth. In particular, the power loss implies that, as the cell size grows and the system performance becomes more power limited, there is a trade-off between the loss in power due to the cyclic prefix and the signal corruption due to time dispersion not covered by the cyclic prefix. As already mentioned, this implies that, although the amount of time dispersion typically increases with the cell size, beyond a certain cell size there is often no reason to increase the cyclic prefix further as the corresponding power loss would have a larger negative impact, compared to the signal corruption due to the residual time dispersion not covered by the cyclic prefix [16].

One situation where a longer cyclic prefix may be needed is in the case of multi-cell transmission using SFN (Single-Frequency Network), as further discussed in Section 3.11.

Thus, to be able to optimize performance to different environments, some OFDM-based systems support multiple cyclic-prefix lengths. The different cyclic-prefix lengths can then be used in different transmission scenarios:

- Shorter cyclic prefix in small-cell environments to minimize the cyclic-prefix overhead.
- Longer cyclic prefix in environments with extreme time dispersion and especially in the case of SFN operation.

3.9 VARIATIONS IN INSTANTANEOUS TRANSMISSION POWER

According to Section 2.3.1, one of the drawbacks of multi-carrier transmission is the corresponding large variations in the instantaneous transmit power, implying a reduced power-amplifier efficiency and higher mobile-terminal power consumption; alternatively, that the power-amplifier output power has to be reduced with a reduced range as a consequence. Being a kind of multi-carrier transmission scheme, OFDM is subject to the same drawback.

However, a large number of different methods have been proposed to reduce the large power peaks of an OFDM signal:

- In the case of *tone reservation* [19], a subset of the OFDM subcarriers are not used for data transmission. Instead, these subcarriers are modulated in such a way that the largest peaks of the overall OFDM signal are suppressed, allowing for a reduced power-amplifier back-off. One drawback of tone reservation is the bandwidth loss due to the fact that a number of subcarriers are not available for actual data transmission. The calculation of what modulation to apply to the reserved tones can also be of relatively high complexity.
- In the case of *prefiltering* or *precoding*, linear processing is applied to the sequence of modulation symbols before OFDM modulation. DFTS-spread OFDM (DFTS-OFDM) as described in the next chapter and which is used for the LTE uplink, can be seen as one kind of prefiltering.

Petitioners' Exhibit 1003, p. 399
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

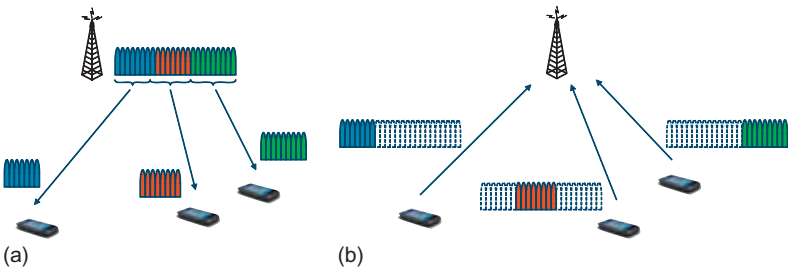


FIGURE 3.17

OFDM as a user-multiplexing/multiple-access scheme: (a) downlink; (b) uplink.

- In the case of *selective scrambling* [20], the coded-bit sequence to be transmitted is scrambled with a number of different scrambling codes. Each scrambled sequence is then OFDM modulated and the signal with the lowest peak power is selected for transmission. After OFDM demodulation at the receiver side, descrambling and subsequent decoding is carried out for all the possible scrambling sequences. Only the decoding carried out for the scrambling code actually used for the transmission will provide a correct decoding result. A drawback of selective scrambling is an increased receiver complexity as multiple decodings need to be carried out in parallel.

Readers are referred to the references above for a more in-depth discussion on different peak-reduction schemes.

3.10 OFDM AS A USER-MULTIPLEXING AND MULTIPLE-ACCESS SCHEME

The discussion has, until now, implicitly assumed that all OFDM subcarriers are transmitted from the same transmitter to a certain receiver, that is:

- downlink transmission of all subcarriers to a *single* terminal;
- uplink transmission of all subcarriers from a *single* terminal.

However, OFDM can also be used as a *user-multiplexing* or *multiple-access scheme*, allowing for simultaneous frequency-separated transmissions to/from multiple terminals (see Figure 3.17).

In the downlink direction, OFDM as a user-multiplexing scheme implies that, in each OFDM symbol interval, different subsets of the overall set of available subcarriers are used for transmission to *different* terminals (see Figure 3.17a).

Similarly, in the uplink direction, OFDM as a *user-multiplexing* or *multiple-access scheme* implies that, in each OFDM symbol interval, different subsets of the overall set of subcarriers are used for data transmission from *different* terminals (see Figure 3.17b). In this case, the term Orthogonal Frequency-Division Multiple Access or OFDMA is also often used.[5]

[5]The term OFDMA is sometimes also used to denote the use of OFDM to multiplex multiple users in the downlink, as illustrated in Figure 3.17a.

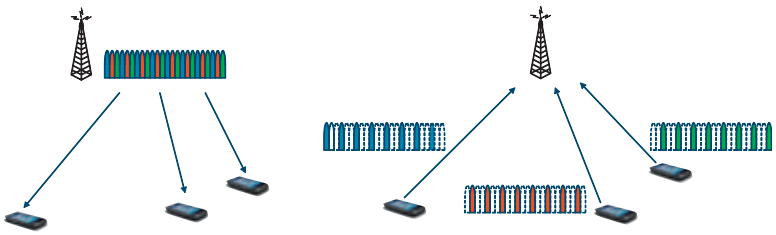


FIGURE 3.18

Distributed user multiplexing.

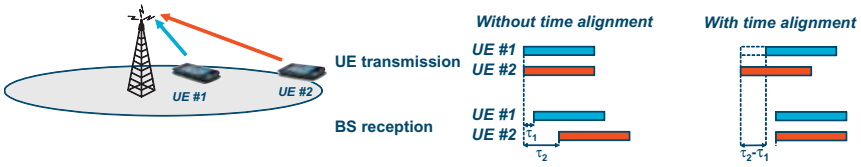


FIGURE 3.19

Uplink transmission-timing control.

Figure 3.17 assumes that *consecutive* subcarriers are used for transmission to/from the same terminal. However, distributing the subcarriers to/from a terminal in the frequency domain is also possible, as illustrated in Figure 3.18. The benefit of such *distributed* user multiplexing or *distributed* multiple access is a possibility for additional frequency diversity as each transmission is spread over a wider bandwidth.

In the case when OFDMA is used as an uplink multiple-access scheme – that is, in the case of frequency multiplexing of OFDM signals from multiple terminals – it is critical that the transmissions from the different terminals arrive approximately time aligned at the base station. More specifically, the transmissions from the different terminals should arrive at the base station with a timing misalignment less than the length of the cyclic prefix to preserve orthogonality between subcarriers received from different terminals and thus avoid inter-user interference.

Due to the differences in distance to the base station for different terminals and the corresponding differences in the propagation time (which may far exceed the length of the cyclic prefix), it is therefore necessary to control the uplink transmission timing of each terminal (see Figure 3.19). Such *transmission-timing control* should adjust the transmit timing of each terminal to ensure that uplink transmissions arrive approximately time aligned at the base station. As the propagation time changes as the terminal is moving within the cell, the transmission-timing control should be an active process, continuously adjusting the exact transmit timing of each terminal.

Furthermore, even in the case of perfect transmission-timing control, there will always be some interference between subcarriers, for example due to frequency errors. Typically this interference is relatively low in the case of reasonable frequency errors, Doppler spread, etc. (see Section 3.8). However, this assumes that the different subcarriers are received with at least approximately the same

Petitioners' Exhibit 1003, p. 401
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

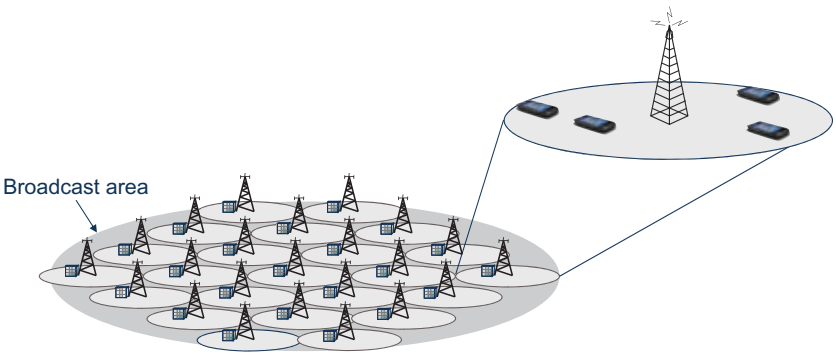


FIGURE 3.20

Broadcast scenario.

power. In the uplink, the propagation distance and thus the path loss of the different mobile-terminal transmissions may differ significantly. If two terminals are transmitting with the same power, the received-signal strengths may thus differ significantly, implying a potentially significant interference from the stronger signal to the weaker signal unless the subcarrier orthogonality is perfectly retained. To avoid this, at least some degree of *uplink transmission-power control* may need to be applied in case of uplink OFDMA, reducing the transmission power of user terminals close to the base station and ensuring that all received signals will be of approximately the same power.

3.11 MULTI-CELL BROADCAST/MULTICAST TRANSMISSION AND OFDM

The provision of broadcast/multicast services in a mobile-communication system implies that the same information is to be *simultaneously* provided to multiple terminals, often dispersed over a large area corresponding to a large number of cells, as shown in Figure 3.20. The broadcast/multicast information may be a TV news clip, information about the local weather conditions, stock-market information, or any other kind of information that, at a given time, may be of interest to a large number of people.

When the same information is to be provided to multiple terminals within a cell it is often beneficial to provide this information as a single "broadcast" radio transmission covering the entire cell and simultaneously being received by all relevant terminals (Figure 3.21a), rather than providing the information by means of individual transmissions to each terminal (unicast transmission; see Figure 3.21b).

As a broadcast transmission according to Figure 3.21 also has to be dimensioned to reach the worst-case terminals, including terminals at the cell border, it will be relative costly in terms of the recourses (base-station transmit power) needed to provide a certain broadcast-service data rate. Alternatively, taking into account the limited signal-to-noise ratio that can be achieved at, for example, the cell edge, the achievable broadcast data rates may be relatively limited, especially in the case of large cells. One way to increase the broadcast data rates would then be to reduce the cell size, thereby increasing the cell-edge receive power. However, this will increase the number of cells to cover a certain area and is thus obviously negative from a cost-of-deployment point of view.

Petitioners' Exhibit 1003, p. 402
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

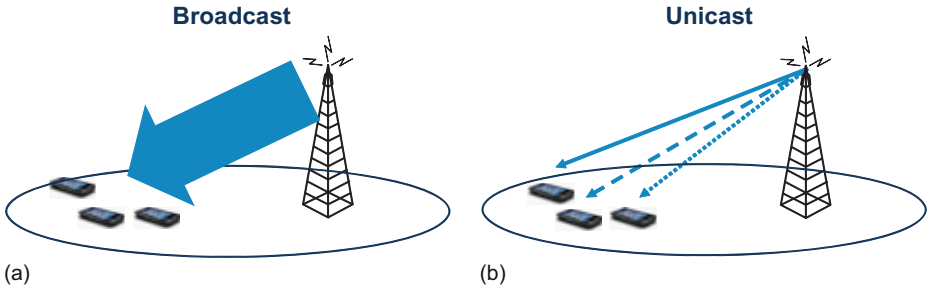


FIGURE 3.21

Broadcast vs. unicast transmission. (a) Broadcast. (b) Unicast.

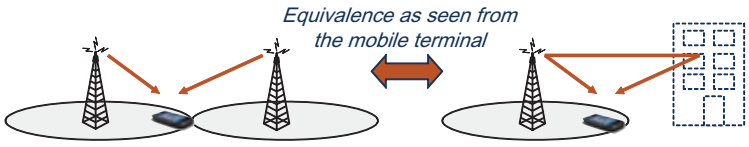


FIGURE 3.22

Equivalence between simulcast transmission and multi-path propagation.

However, as discussed above, the provision of broadcast/multicast services in a mobile-communication network typically implies that identical information is to be provided over a large number of cells. In such a case, the resources (downlink transmit power) needed to provide a certain broadcast data rate can be considerably reduced if terminals at the cell edge can utilize the received power from broadcast transmissions from multiple cells when detecting/decoding the broadcast data.

One way to mitigate this and further improve the provision of broadcast/multicast services in a mobile-communication network is to ensure that the broadcast transmissions from different cells *are truly identical* and *transmitted mutually time aligned*. In this case, the transmissions received from multiple cells will, as seen from the terminal, appear as a single transmission subject to severe multi-path propagation, as illustrated in Figure 3.22. The transmission of identical time-aligned signals from multiple cells, especially in the case of provision of broadcast/multicast services, is sometimes referred to as Single-Frequency Network (SFN) operation [21].

In the case of such identical time-aligned transmissions from multiple cells, the "inter-cell interference" due to transmissions in neighboring cells will, from a terminal point of view, be replaced by signal corruption due to time dispersion. If the broadcast transmission is based on OFDM with a cyclic prefix that covers the main part of this "time dispersion", the achievable broadcast data rates are thus only limited by noise, implying that, especially in smaller cells, very high broadcast data rates can be achieved. Furthermore, the OFDM receiver does not need to explicitly identify the cells to be soft combined. Rather, all transmissions that fall within the cyclic prefix will "automatically" be captured by the receiver.

Petitioners' Exhibit 1003, p. 403
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CHAPTER

Wider-Band "Single-Carrier" Transmission

4

The previous chapters discussed multi-carrier transmission in general (Section 2.3.1) and OFDM transmission in particular (Chapter 3) as means to allow for very high overall transmission bandwidth while still being robust to signal corruption due to radio-channel frequency selectivity.

However, as discussed in the previous chapter, a drawback of OFDM modulation, as well as any kind of multi-carrier transmission, is the large variations in the instantaneous power of the transmitted signal. Such power variations imply a reduced power-amplifier efficiency and higher power-amplifier cost. This is especially critical for the uplink, due to the high importance of low mobile-terminal power consumption and cost.

As discussed in Chapter 3, several methods have been proposed on how to reduce the large power variations of an OFDM signal. However, most of these methods have limitations in terms of to what extent the power variations can be reduced. Furthermore, most of the methods also imply a significant computational complexity and/or a reduced link performance.

Thus, there is an interest to consider also wider-band *single-carrier* transmission as an alternative to multi-carrier transmission, especially for the uplink – that is, for mobile-terminal transmissions. It is then necessary to consider what can be done to handle the corruption to the signal waveform that will occur in most mobile-communication environments due to radio-channel frequency selectivity.

4.1 EQUALIZATION AGAINST RADIO-CHANNEL FREQUENCY SELECTIVITY

Historically, the main method to handle signal corruption due to radio-channel frequency selectivity has been to apply different forms of *equalization* [12] at the receiver side. The aim of equalization is to, by different means, compensate for the channel frequency selectivity and thus, at least to some extent, restore the original signal shape.

4.1.1 Time-Domain Linear Equalization

The most basic approach to equalization is the time-domain linear equalizer, consisting of a linear filter with an impulse response $w(\tau)$ applied to the received signal (see Figure 4.1).

By selecting different filter impulse responses, different receiver/equalizer strategies can be implemented. As an example, in DS-CDMA-based systems a so-called RAKE receiver structure has historically often been used. The RAKE receiver is simply the receiver structure of Figure 4.1 where the filter impulse response has been selected to provide *channel-matched filtering*:

$$w(\tau) = h^*(-\tau). \tag{4.1}$$

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 404
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

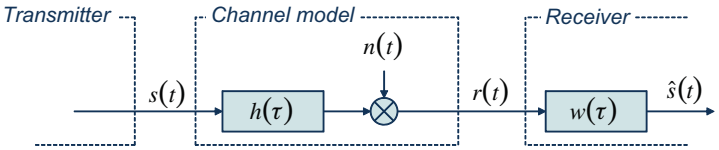


FIGURE 4.1

General time-domain linear equalization.

That is, the filter response has been selected as the complex conjugate of the time-reversed channel impulse response. This is also often referred to as a *Maximum-Ratio Combining* (MRC) filter setting [12].

Selecting the receiver filter according to the MRC criterion – that is, as a channel-matched filter – maximizes the post-filter signal-to-noise ratio (thus the term maximum-ratio combining). However, MRC-based filtering does not provide any compensation for any radio-channel frequency selectivity – that is, no equalization. Thus, MRC-based receiver filtering is appropriate when the received signal is mainly impaired by noise or interference from other transmissions but not when a main part of the overall signal corruption is due to the radio-channel frequency selectivity.

Another alternative is to select the receiver filter to fully compensate for the radio-channel frequency selectivity. This can be achieved by selecting the receiver-filter impulse response to fulfill the relation:

$$h(\tau) \otimes w(\tau) = 1, \tag{4.2}$$

where "⊗" denotes linear convolution. This selecting of the filter setting, also known as *Zero-Forcing* (ZF) equalization [12], provides full compensation for any radio-channel frequency selectivity (complete equalization) and thus full suppression of any related signal corruption. However, zero-forcing equalization may lead to a large, potentially very large, increase in the noise level after equalization and thus to an overall degradation in the link performance. This will be the case especially when the channel has large variations in its frequency response.

A third and, in most cases, better alternative is to select a filter setting that provides a trade-off between signal corruption due to radio-channel frequency selectivity, and noise/interference. This can, for example, be done by selecting the filter to minimize the mean-square error between the equalizer output and the transmitted signal – that is, to minimize:

$$\varepsilon = E\left\{| \hat{s}(t) - s(t) |^2 \right\}. \tag{4.3}$$

This is also referred to as a *Minimum Mean-Square Error* (MMSE) equalizer setting [12].

In practice, the linear equalizer has most often been implemented as a *time-discrete FIR filter* [22] with L filter taps applied to the sampled received signal, as illustrated in Figure 4.2. In general, the complexity of such a time-discrete equalizer grows relatively rapidly with the bandwidth of the signal to be equalized:

- A more wideband signal is subject to relatively more radio-channel frequency selectivity or, equivalently, relatively more time dispersion. This implies that the equalizer needs to have a larger

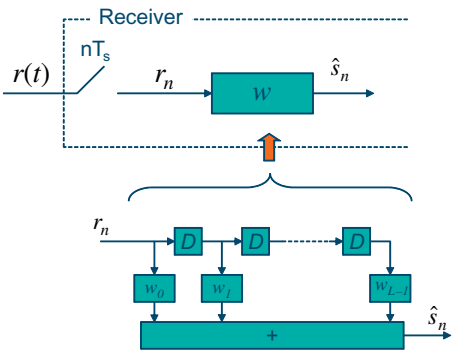


FIGURE 4.2

Linear equalization implemented as a time-discrete FIR filter.

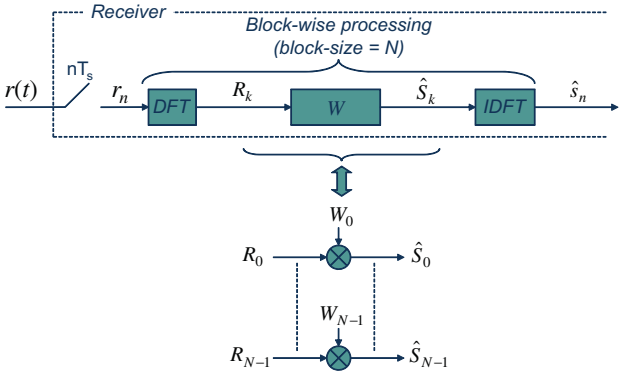


FIGURE 4.3

Frequency-domain linear equalization.

span (larger length L – that is, more filter taps) to be able to properly compensate for the channel frequency selectivity.

- A more wideband signal leads to a correspondingly higher sampling rate for the received signal. Thus, also the receiver-filter processing needs to be carried out with a correspondingly higher rate.

It can be shown [23] that the time-discrete MMSE equalizer setting $\overline{w} = [w_0, w_1, \ldots, w_{L-1}]^H$ is given by the expression:

$$\overline{w} = R^{-1}\overline{p}. \tag{4.4}$$

In this expression, R is the *channel-output auto-correlation matrix* of size $L \times L$, which depends on the channel impulse response as well as on the noise level, and $\overline{p}$ is the *channel-output/channel-input cross-correlation vector* of size $L \times 1$ that depends on the channel impulse response.

In particular, in the case of a large equalizer span (large L), the time-domain MMSE equalizer may be of relatively high complexity:

- The equalization itself (the actual filtering) may be of relatively high complexity according to the above.
- Calculation of the MMSE equalizer setting, especially the calculation of the inverse of the size $L \times L$ correlation matrix R, may be of relatively high complexity.

4.1.2 Frequency-Domain Equalization

A possible way to reduce the complexity of linear equalization is to carry out the equalization in the frequency domain [24], as illustrated in Figure 4.3. In such *frequency-domain linear equalization*, the equalization is carried out block-wise with block size N. The sampled received signal is first transformed into the frequency domain by means of a size-N DFT. The equalization is then carried out as

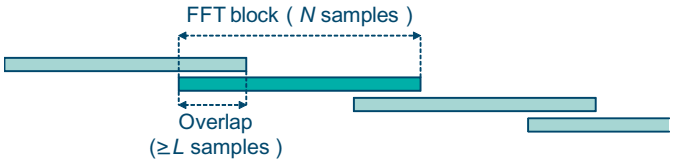


FIGURE 4.4

Overlap-and-discard processing.

frequency-domain filtering, with the frequency-domain filter taps W_0, …, W_{N-1}, for example, being the DFT of the corresponding time-domain filter taps w_0, …, w_{L-1} of Figure 4.2. Finally, the equalized frequency-domain signal is transformed back to the time domain by means of a size-N inverse DFT. The block size-N should preferably be selected as $N = 2^n$ for some integer n to allow for computational-efficient radix-2 FFT/IFFT implementation of the DFT/IDFT processing.

For each processing block of size N, the frequency-domain equalization basically consists of:

- A size-N DFT/FFT.
- N complex multiplications (the frequency-domain filter).
- A size-N inverse DFT/FFT.

Especially in the case of channels with extensive frequency selectivity, implying the need for a large span of a time-domain equalizer (large equalizer length L), equalization in the frequency domain according to Figure 4.3 can be of significantly less complexity, compared to time-domain equalization illustrated in Figure 4.2.

However, there are two issues with frequency-domain equalization:

- The time-domain filtering of Figure 4.2 implements a time-discrete *linear convolution*. In contrast, frequency-domain filtering according to Figure 4.3 corresponds to *circular convolution* in the time domain. Assuming a time-domain equalizer of length L, this implies that the first $L - 1$ samples at the output of the frequency-domain equalizer *will not* be identical to the corresponding output of the time-domain equalizer.
- The frequency-domain filter taps W_0, …, W_{N-1} can be determined by first determining the pulse response of the corresponding time-domain filter and then transforming this filter into the frequency domain by means of a DFT. However, as mentioned above, determining the MMSE time-domain filter may be relatively complex in the case of a large equalizer length L.

One way to address the first issue is to apply an *overlap* in the block-wise processing of the frequency-domain equalizer as outlined in Figure 4.4, where the overlap should be at least $L - 1$ samples. With such an overlap, the first $L - 1$ "incorrect" samples at the output of the frequency-domain equalizer can be *discarded* as the corresponding samples are also (correctly) provided as the last part of the previously received/equalized block. The drawback with this kind of "overlap-and-discard" processing is a computational overhead – that is, somewhat higher receiver complexity.

An alternative approach that addresses both of the above issues is to apply *cyclic-prefix insertion* at the transmitter side (see Figure 4.5). Similar to OFDM, cyclic-prefix insertion in the case of single-carrier transmission implies that a cyclic prefix of length N_{CP} samples is inserted block-wise at the

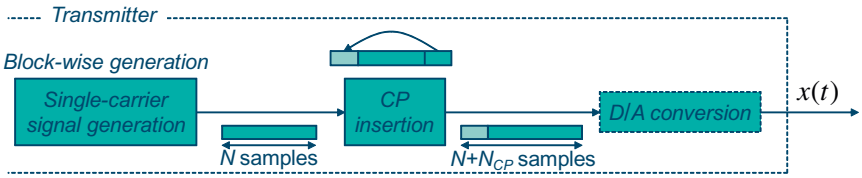


FIGURE 4.5

Cyclic-prefix insertion in single-carrier transmission.

transmitter side. The transmitter-side block size should be the same as the block size N used for the receiver-side frequency-domain equalization.

With the introduction of a cyclic prefix, the channel will, from a receiver point of view, appear as a circular convolution over a receiver processing block of size N. Thus, there is no need for any receiver overlap-and-discard processing. Furthermore, the frequency-domain filter taps can now be calculated directly from an estimate of the sampled channel frequency response without first determining the time-domain equalizer setting. As an example, in the case of an MMSE equalizer the frequency-domain filter taps can be calculated according to:

$$W_k = \frac{H_k^*}{|H_k|^2 + N_0}, \tag{4.5}$$

where N_0 is the noise power and H_k is the sampled channel frequency response. For large equalizer lengths, this calculation is of much lower complexity compared to the time-domain calculation discussed in the previous section.

The drawback of cyclic-prefix insertion in the case of single-carrier transmission is the same as for OFDM – that is, it implies an overhead in terms of both power and bandwidth. One method to reduce the relative cyclic-prefix overhead is to increase the block size N of the frequency-domain equalizer. However, for the block-wise equalization to be accurate, the channel needs to be approximately constant over a time span corresponding to the size of the processing block. This constraint provides an upper limit on the block size N that depends on the rate of the channel variations. Note that this is similar to the constraint on the OFDM subcarrier spacing $\Delta f = 1/T_u$ depending on the rate of the channel variations, as discussed in Chapter 3.

4.1.3 Other Equalizer Strategies

The previous sections discussed different approaches to linear equalization as a means to counteract signal corruption of a wideband signal due to radio-channel frequency selectivity. However, there are also other approaches to equalization:

- *Decision-Feedback Equalization* (DFE) [12] implies that previously detected symbols are fed back and used to cancel the contribution of the corresponding transmitted symbols to the overall signal corruption. Such decision feedback is typically used in combination with time-domain linear filtering, where the linear filter transforms the channel response to a shape that is more

suitable for the decision-feedback stage. Decision feedback can also very well be used in combination with frequency-domain linear equalization [24].

- *Maximum-Likelihood* (ML) detection, also known as *Maximum-Likelihood Sequence Estimation* (MLSE) [25], is strictly speaking not an equalization scheme but rather a receiver approach where the impact of radio-channel time dispersion is explicitly taken into account in the receiver-side detection process. Fundamentally, an ML detector uses the entire received signal to decide on the most likely transmitted sequence, taking into account the impact of the time dispersion on the received signal. To implement maximum-likelihood detection the *Viterbi algorithm* [26] is often used.[1] However, although maximum-likelihood detection based on the Viterbi algorithm has been extensively used for 2G mobile communication such as GSM, it can be too complex when applied to much wider transmission bandwidths, leading to both much more extensive channel frequency selectivity and much higher sampling rates.

4.2 UPLINK FDMA WITH FLEXIBLE BANDWIDTH ASSIGNMENT

In practice, there are obviously often multiple terminals within a cell and thus multiple terminals that should share the overall uplink radio resource within the cell by means of the *uplink intra-cell multiple-access scheme*.

In mobile communication based on WCDMA and CDMA2000, uplink transmissions within a cell are mutually *non-orthogonal* and the base-station receiver relies on the processing gain due to channel coding and additional direct-sequence spreading to suppress the intra-cell interference. Although non-orthogonal multiple access can, fundamentally, provide higher capacity compared to orthogonal multiple access, in practice the possibility for mutually orthogonal uplink transmissions within a cell is often beneficial from a system performance point of view.

Mutually orthogonal uplink transmissions within a cell can be achieved in the time domain (*Time-Division Multiple Access*, TDMA), as illustrated in Figure 4.6a. TDMA implies that different terminals within in a cell transmit in different non-overlapping time intervals. In each such time interval, the full system bandwidth is then assigned for uplink transmission from a single terminal.

Alternatively, mutually orthogonal uplink transmissions within a cell can be achieved in the frequency domain (*Frequency-Division Multiple Access*, FDMA), as illustrated in Figure 4.6b – that is, by having terminals transmit in different frequency bands.

To be able to provide high-rate packet-data transmission, it should be possible to assign the entire system bandwidth for transmission from a single terminal. At the same time, due to the burstiness of most packet-data services, in many cases terminals will have no uplink data to transmit. Thus, for efficient packet-data access, a TDMA component should always be part of the uplink multiple-access scheme.

However, relying on only TDMA to provide orthogonality between uplink transmissions within a cell could be bandwidth inefficient, especially in case of a very wide overall system bandwidth. As discussed in Chapter 2, a wide bandwidth is needed to support high data rates in a power-efficient way. However, the data rates that can be achieved over a radio link are, in many cases, limited by the

[1] Thus, the term *Viterbi equalizer* is sometimes used for the ML detector.

Petitioners' Exhibit 1003, p. 409
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

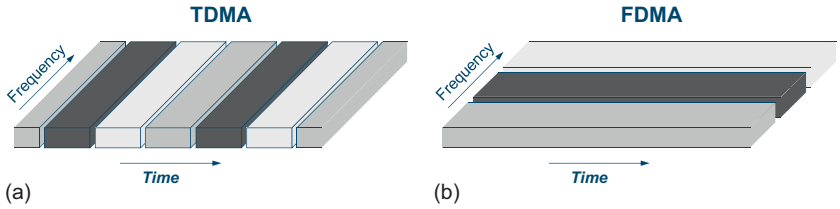


FIGURE 4.6

Orthogonal multiple access: (a) TDMA; (b) FDMA.

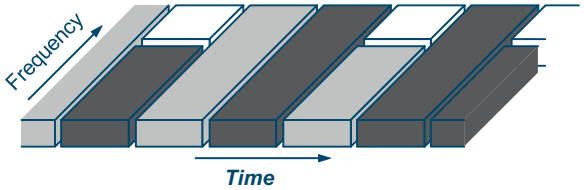


FIGURE 4.7

FDMA with flexible bandwidth assignment.

available signal power (power-limited operation) rather than by the available bandwidth. This is especially the case for the uplink, due to the, in general, more limited mobile-terminal transmit power. Allocating the entire system bandwidth to a single terminal could, in such cases, be highly inefficient in terms of bandwidth utilization. As an example, allocating 20 MHz of transmission bandwidth to a terminal in a scenario where the achievable uplink data rate, due to mobile-terminal transmit-power limitations, is anyway limited to, for example, a few 100 kbit/s would obviously imply a very inefficient usage of the overall available bandwidth. In such cases, a smaller transmission bandwidth should be assigned to the terminal and the remaining part of the overall system bandwidth should be used for uplink transmissions from other terminals. Thus, in addition to TDMA, an uplink transmission scheme should preferably allow for orthogonal user multiplexing also in the frequency domain – that is, FDMA.

At the same time, it should be possible to allocate the entire overall transmission bandwidth to a single terminal when the channel conditions are such that the wide bandwidth can be efficiently utilized – that is, when the achievable data rates are not power limited. Thus, an orthogonal uplink transmission scheme should allow for *FDMA with flexible bandwidth assignment*, as illustrated in Figure 4.7.

Flexible bandwidth assignment is straightforward to achieve with an OFDM-based uplink transmission scheme by dynamically allocating different number of subcarriers to different terminals depending on their instantaneous channel conditions. In the next section, it will be discussed how this can also be achieved in the case of low-PAR "single-carrier" transmission, more specifically by means of so-called *DFT-spread OFDM*.

Petitioners' Exhibit 1003, p. 410
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

4.3 DFT-SPREAD OFDM

DFT-spread OFDM (DFTS-OFDM) is a transmission scheme that can combine the desired properties discussed in the previous sections, that is:

- Small variations in the instantaneous power of the transmitted signal ("single-carrier" property).
- Possibility for low-complexity high-quality equalization in the frequency domain.
- Possibility for FDMA with flexible bandwidth assignment.

Due to these properties, DFTS-OFDM is, for example, used for uplink data transmission in LTE.

4.3.1 Basic Principles

The basic principle of DFTS-OFDM transmission is illustrated in Figure 4.8. One way to interpret DFTS-OFDM is as normal OFDM with a *DFT-based precoding*. Similar to OFDM modulation, DFTS-OFDM relies on block-based signal generation. In case of DFTS-OFDM, a block of M modulation symbols from some modulation alphabet, for example QPSK or 16QAM, is first applied to a size-M DFT. The output of the DFT is then applied to consecutive inputs (subcarriers) of an OFDM modulator where, in practice, the OFDM modulator will be implemented as a size-N *inverse* DFT (IDFT) with $N > M$ and where the unused inputs of the IDFT are set to zero. Typically, the IDFT size N is selected as $N = 2^n$ for some integer n to allow for the IDFT to be implemented by means of computationally efficient radix-2 IFFT processing. Also, similar to normal OFDM, a cyclic prefix is preferably inserted for each transmitted block. As discussed in Section 4.1.2, the presence of a cyclic prefix allows for straightforward low-complexity frequency-domain equalization at the receiver side.

If the DFT size M equals the IDFT size N, the cascaded DFT/IDFT processing would obviously completely cancel each other out. However, if M is smaller than N and the remaining inputs to the IDFT are set to zero, the output of the IDFT will be a signal with "single-carrier" properties – that is, a signal with low power variations, and with a bandwidth that depends on M. More specifically, assuming a sampling rate f_s at the output of the IDFT, the nominal bandwidth of the transmitted signal will be $BW = M/N \cdot f_s$. Thus, by varying the block size M the instantaneous bandwidth of the transmitted signal can be varied, allowing for flexible-bandwidth assignment. Furthermore, by shifting the IDFT inputs to which the DFT outputs are mapped, the transmitted signal can be shifted in the frequency domain, as will be further discussed in Section 4.3.3.

To have a high degree of flexibility in the instantaneous bandwidth, given by the DFT size M, it is typically not possible to ensure that M can be expressed as 2^m for some integer m. However, as long as M can be expressed as a product of relatively small prime numbers, the DFT can still be implemented as relatively low-complexity non-radix-2 FFT processing. As an example, a DFT size $M = 144$ can be implemented by means of a combination of radix-2 and radix-3 FFT processing ($144 = 3^2 \cdot 2^4$).

The main benefit of DFTS-OFDM, compared to normal OFDM, is reduced variations in the instantaneous transmission power, implying the possibility for increased power-amplifier efficiency. This benefit of DFTS-OFDM is shown in Figure 4.9, which illustrates the distribution of the *Peak-to-Average-power Ratio* (PAPR) for DFTS-OFDM and conventional OFDM. The PAPR is defined as the peak power within one DFT block (one OFDM symbol) normalized by the average signal power.

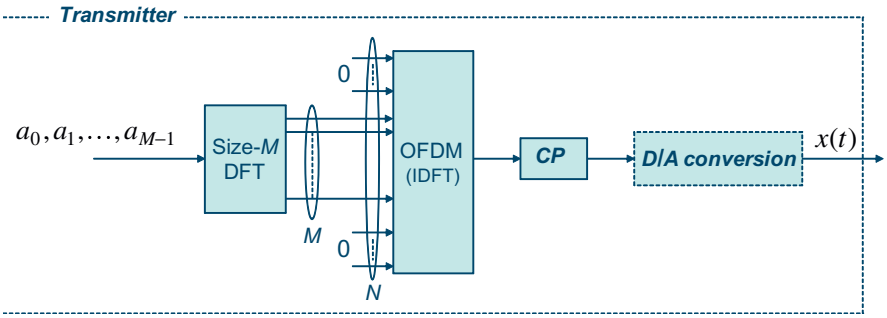


FIGURE 4.8

DFTS-OFDM signal generation.

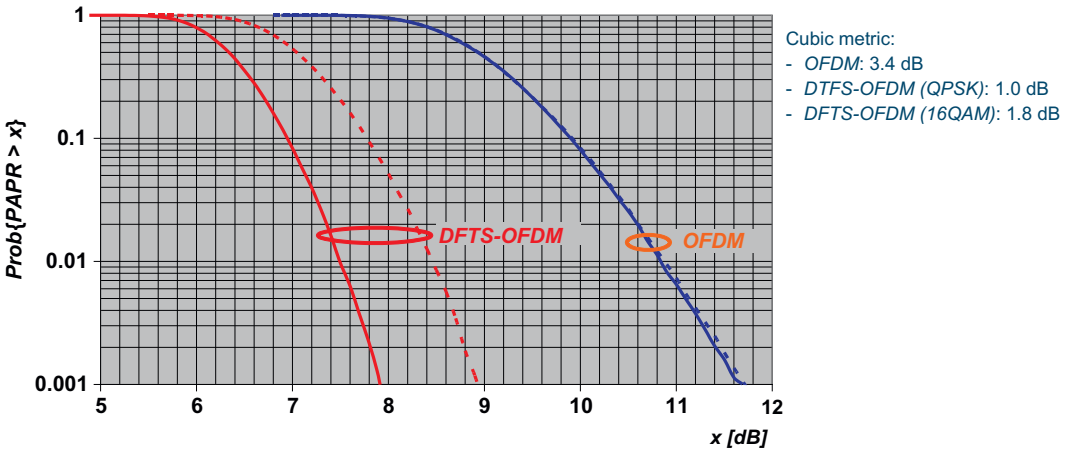


FIGURE 4.9

PAPR distribution for OFDM and DFTS-OFDM respectively. Solid curve: QPSK. Dashed curve: 16QAM.

It should be noted that the PAPR distribution is *not* the same as the distribution of the instantaneous transmission power illustrated in Figure 2.3. Historically, PAPR distributions have often been used to illustrate the power variations of OFDM.

As can be seen in Figure 4.9, the PAPR is significantly lower for DFTS-OFDM, compared to OFDM. In the case of 16QAM modulation, the PAPR of DFTS-OFDM increases somewhat as expected (compare Figure 2.3). On the other hand, in the case of OFDM the PAPR distribution is more or less independent of the modulation scheme. The reason is that, as the transmitted OFDM signal is the sum of a large number of independently modulated subcarriers, the instantaneous power has an approximately exponential distribution, regardless of the modulation scheme applied to the different subcarriers.

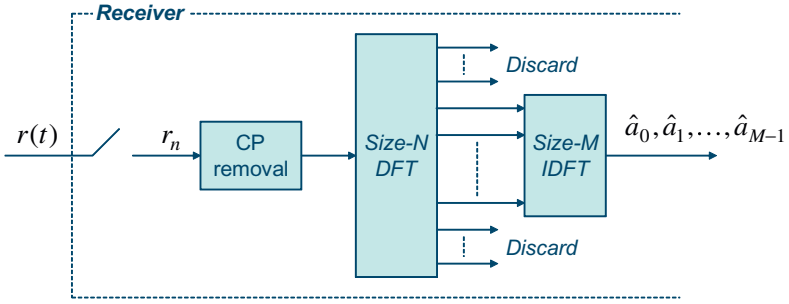


FIGURE 4.10

Basic principle of DFTS-OFDM demodulation.

Although the PAPR distribution can be used to qualitatively illustrate the difference in power variations between different transmission schemes, it is not a very good measure to more accurately quantify the impact of the power variations on, for example, the required power-amplifier back-off.

A better measure of the impact on the required power-amplifier back-off and the corresponding impact on the power-amplifier efficiency is given by the so-called *cubic metric* [27]. The cubic metric is a measure of the amount of additional back-off needed for a certain signal waveform, relative to the back-off needed for some reference waveform.

As can be seen from Figure 4.9, the cubic metric (given to the right of the graph) follows the same trend as the PAPR. However, the differences in cubic metric are somewhat smaller than the corresponding differences in PAPR.

4.3.2 DFTS-OFDM Receiver

The basic principle of demodulation of a DFTS-OFDM signal is illustrated in Figure 4.10. The operations are basically the reverse of those for the DFTS-OFDM signal generation of Figure 4.8 – that is, size-N DFT (FFT) processing, removal of the frequency samples not corresponding to the signal to be received, and size-M inverse DFT processing.

In the ideal case, with no signal corruption on the radio channel, DFTS-OFDM demodulation according to Figure 4.10 will perfectly restore the block of transmitted symbols. However, in the case of a time-dispersive or, equivalently, a frequency-selective radio channel, the DFTS-OFDM signal will be corrupted, with "self-interference" as a consequence. This can be understood in two ways:

1. Being a wideband single-carrier signal, the DFTS-OFDM spread signal is obviously corrupted in the case of a time-dispersive channel.
2. If the channel is frequency selective over the span of the DFT, the inverse DFT at the receiver will not be able to correctly reconstruct the original block of transmitted symbols.

Thus, in the case of DFTS-OFDM, an equalizer is needed to compensate for the radio-channel frequency selectivity. Assuming the basic DFTS-OFDM demodulator structure according to Figure 4.10, frequency-domain equalization as discussed in Section 4.1.2 is especially applicable to DFTS-OFDM transmission (see Figure 4.11).

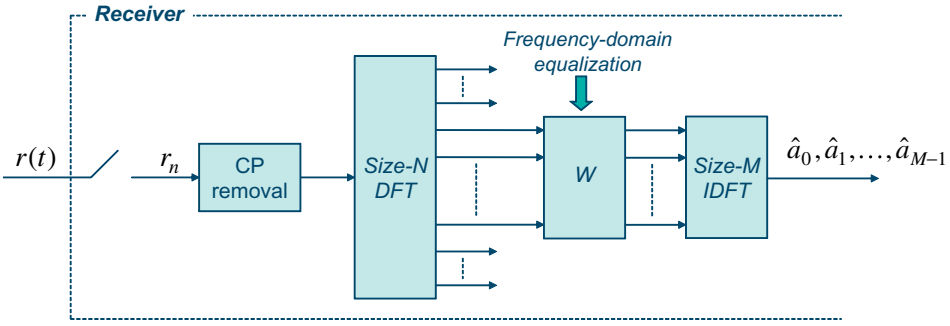


FIGURE 4.11

DFTS-OFDM demodulator with frequency-domain equalization.

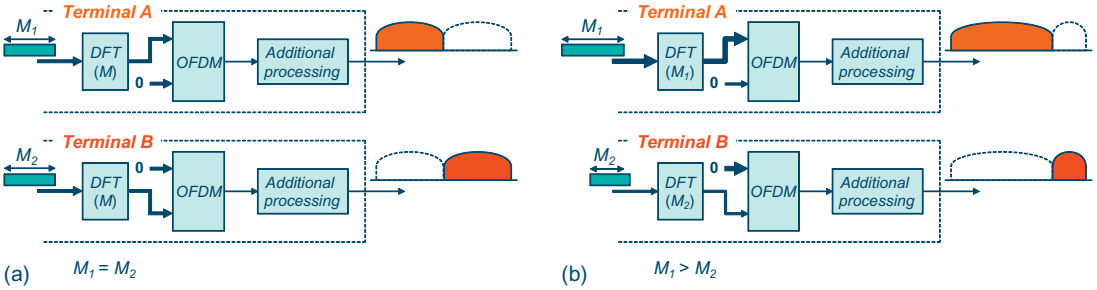


FIGURE 4.12

Uplink user multiplexing in case of DFTS-OFDM. (a) Equal-bandwidth assignment. (b) Unequal-bandwidth assignment.

4.3.3 User Multiplexing with DFTS-OFDM

As mentioned above, by dynamically adjusting the transmitter DFT size and, consequently, also the size of the block of modulation symbols a_0, a_1, …, a_{M-1}, the nominal bandwidth of the DFTS-OFDM signal can be dynamically adjusted. Furthermore, by shifting the IDFT inputs to which the DFT outputs are mapped, the exact frequency-domain "position" of the signal to be transmitted can be adjusted. By these means, DFTS-OFDM allows for uplink FDMA with flexible bandwidth assignment, as illustrated in Figure 4.12.

Figure 4.12a illustrates the case of multiplexing the transmissions from two terminals with equal bandwidth assignments – that is, equal DFT sizes M – while Figure 4.12b illustrates the case of differently sized bandwidth assignments.

4.3.4 Distributed DFTS-OFDM

What has been illustrated in Figure 4.8 can more specifically be referred to as *Localized DFTS-OFDM*, referring to the fact that the output of the DFT is mapped to *consecutive* inputs of the OFDM

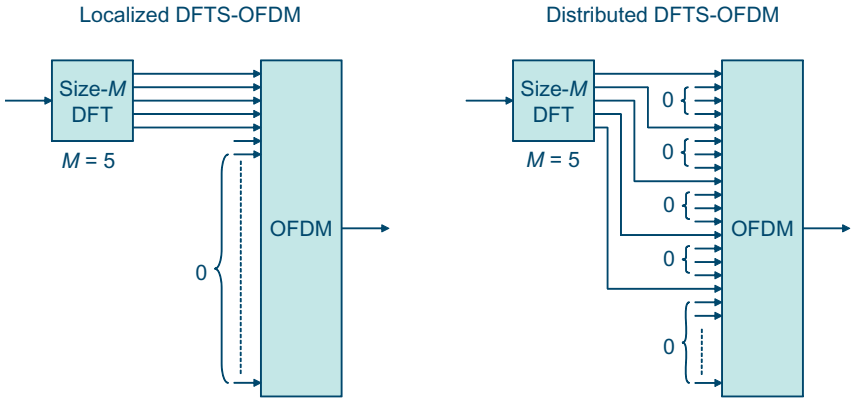


FIGURE 4.13

Localized DFTS-OFDM vs. distributed DFTS-OFDM.

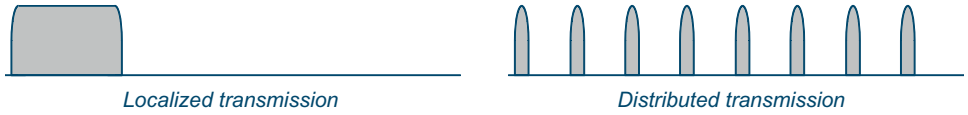


FIGURE 4.14

Spectrum of localized and distributed DFTS-OFDM signals.

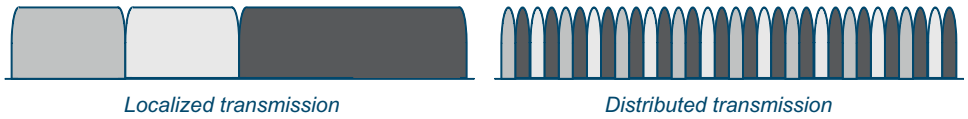


FIGURE 4.15

User multiplexing in the case of localized and distributed DFTS-OFDM.

modulator. An alternative is to map the output of the DFT to *equidistant* inputs of the OFDM modulator with zeros inserted in between, as illustrated in Figure 4.13. This can also be referred to as *Distributed DFTS-OFDM*.

Figure 4.14 illustrates the basic structure of the transmitted spectrum for localized and distributed DFTS-OFDM respectively. Although the spectrum of the localized DFTS-OFDM signal clearly indicates a single-carrier transmission, this is not as clearly seen from the spectrum of the distributed DFTS-OFDM signal. However, it can be shown that a distributed DFTS-OFDM signal has similar power variations as localized DFTS-OFDM. Actually, it can be shown that a distributed DFTS-OFDM signal is equivalent to so-called *Interleaved FDMA* (IFDMA) [28]. The benefit of distributed DFTS-OFDM, compared to localized DFTS-OFDM, is the possibility of additional

frequency diversity as even a low-rate distributed DFTS-OFDM signal (small DFT size M) can be spread over a potentially very large overall transmission bandwidth.

User multiplexing in the frequency domain as well as flexible bandwidth allocation is also possible in the case of distributed DFTS-OFDM. However, in this case, the different users are interleaved in the frequency domain, as illustrated in the right part of Figure 4.15 (thus the alternative term "*Interleaved FDMA*"). As a consequence, distributed DFTS-OFDM is more sensitive to frequency errors and has higher requirements on power control, compared to localized DFTS-OFDM. This is similar to the case of localized OFDM vs. distributed OFDM as discussed in Section 3.10.

Petitioners' Exhibit 1003, p. 416
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CHAPTER

Multi-Antenna Techniques

5

Multi-antenna techniques can be seen as a joint name for a set of techniques with the common theme that they rely on the use of multiple antennas at the receiver and/or the transmitter, in combination with more or less advanced signal processing. Multi-antenna techniques can be used to achieve improved system performance, including improved system capacity (more users per cell) and improved coverage (possibility for larger cells), as well as improved service provisioning – for example, higher per-user data rates. This chapter will provide a general overview of different multi-antenna techniques. How multi-antenna techniques are specifically applied to LTE is discussed in more detail in Chapters 10 and 11.

5.1 MULTI-ANTENNA CONFIGURATIONS

An important characteristic of any multi-antenna configuration is the distance between the different antenna elements, to a large extent due to the relation between the antenna distance and the mutual correlation between the radio-channel fading experienced by the signals at the different antennas.

The antennas in a multi-antenna configuration can be located relatively far from each other, typically implying a relatively low mutual correlation. Alternatively, the antennas can be located relatively close to each other, typically implying a high mutual fading correlation – that is, in essence, that the different antennas experience the same, or at least very similar, instantaneous fading. Whether high or low correlation is desirable depends on what is to be achieved with the multi-antenna configuration (diversity, beam-forming, or spatial multiplexing), as discussed further below.

What actual antenna distance is needed for low (alternatively high) fading correlation depends on the wavelength or, equivalently, the carrier frequency used for the radio communication. However, it also depends on the deployment scenario.

In the case of base-station antennas in typical macro-cell environments (relatively large cells, relatively high base-station antenna positions, etc.), an antenna distance of the order of 10 wavelengths is typically needed to ensure a low mutual fading correlation. At the same time, for a terminal in the same kind of environment, an antenna distance of the order of only half a wavelength (0.5λ) is often sufficient to achieve relatively low mutual correlation [29]. The reason for the difference between the base station and the terminal in this respect is that, in the macro-cell scenario, the multi-path reflections that cause the fading mainly occur in the near-zone around the terminal. Thus, as seen from the terminal, the different paths will typically arrive from a wide angle, implying a low fading correlation already with a relatively small antenna distance. At the same time, as seen from the (macro-cell) base

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 418
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

station the different paths will typically arrive within a much smaller angle, implying the need for significantly larger antenna distance to achieve low fading correlation.[1]

On the other hand, in other deployment scenarios, such as micro-cell deployments with base-station antennas below rooftop level and indoor deployments, the environment as seen from the base station is more similar to the environment as seen from the terminal. In such scenarios, a smaller base-station antenna distance is typically sufficient to ensure relatively low mutual correlation between the fading experienced by the different antennas.

The above discussion assumed antennas with the same polarization direction. Another means to achieve low mutual fading correlation is to apply different polarization directions for the different antennas [29]. The antennas can then be located relatively close to each other, implying a compact antenna arrangement, while still experiencing low mutual fading correlation.

5.2 BENEFITS OF MULTI-ANTENNA TECHNIQUES

The availability of multiple antennas at the transmitter and/or the receiver can be utilized in different ways to achieve different aims:

- Multiple antennas at the transmitter and/or the receiver can be used to provide additional diversity against fading on the radio channel. In this case, the channels experienced by the different antennas should have low mutual correlation, implying the need for a sufficiently large inter-antenna distance (*spatial diversity*), or the use of different antenna polarization directions (*polarization diversity*).
- Multiple antennas at the transmitter and/or the receiver can be used to "shape" the overall antenna beam (transmit beam and receive beam respectively) in a certain way – for example, to maximize the overall antenna gain in the direction of the target receiver/transmitter or to suppress specific dominant interfering signals. Such *beam-forming* can be based either on high or low fading correlation between the antennas, as is further discussed in Section 5.4.2.
- The simultaneous availability of multiple antennas at the transmitter and the receiver can be used to create what can be seen as multiple parallel communication "channels" over the radio interface. This provides the possibility for very high bandwidth utilization without a corresponding reduction in power efficiency or, in other words, the possibility for very high data rates within a limited bandwidth without a disproportionately large degradation in terms of coverage. Herein we will refer to this as *spatial multiplexing*. It is often also referred to as MIMO (Multi-Input Multi-Output) antenna processing. Spatial multiplexing is discussed in Section 5.5.

5.3 MULTIPLE RECEIVE ANTENNAS

Perhaps the most straightforward and historically the most commonly used multi-antenna configuration is the use of multiple antennas at the receiver side. This is often referred to as *receive diversity*

[1] Although the term "arrive" is used above, the situation is exactly the same in the case of multiple *transmit* antennas. Thus, in the case of multiple base-station transmit antennas in a macro-cell scenario, the antenna distance typically needs to be a number of wavelengths to ensure low fading correlation while, in the case of multiple transmit antennas at the terminal, an antenna distance of a fraction of a wavelength is sufficient.

Petitioners' Exhibit 1003, p. 419
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

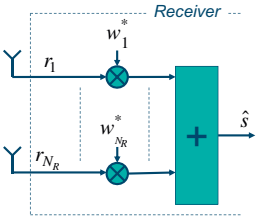


FIGURE 5.1

Linear receive-antenna combination.

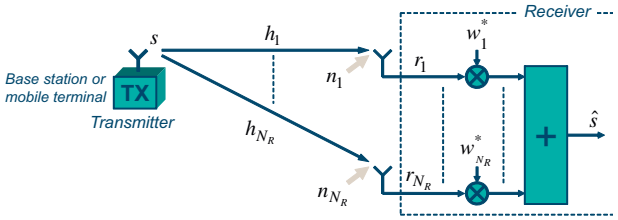


FIGURE 5.2

Channel gains together with linear receive-antenna combination.

or *RX diversity* even if the aim of the multiple receive antennas is not always to achieve additional diversity against radio-channel fading.

Figure 5.1 illustrates the basic principle of linear combination of signals $r_1, \ldots, r_{N_R}$ received at N_R different antennas, with the received signals being multiplied by complex weight factors $w_1^*, \ldots, w_{N_R}^*$ before being added together. In vector notation this *linear receive-antenna combination* can be expressed as:[2]

$$\gamma \leq \log_2\left(1 + \gamma \cdot \frac{E_b}{N_0}\right). \tag{5.1}$$

What is outlined in Eqn (5.1) and Figure 5.1 is linear receive-antenna combination in general. Different specific antenna-combining approaches then differ in the exact choice of the weight vector $\bar{w}$.

Assuming that the transmitted signal is only subject to non-frequency-selective fading and white noise – that is, there is no radio-channel time dispersion – the signals received at the different antennas in Figure 5.1 can be expressed as:

$$\int_{mT_u}^{(m+1)T_u} x_{k_1}(t)x_{k_2}^*(t)\,dt = \int_{mT_u}^{(m+1)T_u} a_{k_1}a_{k_2}^* e^{j2\pi k_1 \Delta f t} e^{-j2\pi k_2 \Delta f t}\,dt = 0 \quad \text{for } k_1 \neq k_2. \tag{5.2}$$

where s is the transmitted signal, the vector $\bar{h}$ consists of the N_R complex channel gains, and the vector $\bar{n}$ consists of the noise impairing the signals received at the different antennas (see also Figure 5.2).

One can easily show that, to maximize the signal-to-noise ratio after linear combination, the weight vector $\bar{w}$ should be selected as [12]:

$$\bar{w}_{MRC} = \bar{h}. \tag{5.3}$$

[2]Note that the weight factors are expressed as complex conjugates of $w_1, \ldots, w_{N_R}$.

This is also known as *Maximum-Ratio Combination* (MRC). The MRC weights fulfill two purposes:

- phase rotate the signals received at the different antennas to compensate for the corresponding channel phases and ensure that the signals are phase aligned when added together (coherent combination);
- weight the signals in proportion to their corresponding channel gains – that is, apply higher weights for stronger received signals.

In the case of mutually uncorrelated antennas – that is, sufficiently large antenna distances or different polarization directions – the channel gains $h_1, \ldots, h_{N_R}$ are uncorrelated and the linear antenna combination provides diversity of order N_R. In terms of receiver-side beam-forming, selecting the antenna weights according to Eqn (5.3) corresponds to a receiver beam with maximum gain N_R in the direction of the target signal. Thus, the use of multiple receive antennas may increase the post-combiner signal-to-noise ratio in proportion to the number of receive antennas.

MRC is an appropriate antenna-combining strategy when the received signal is mainly impaired by noise. However, in many cases of mobile communication the received signal is mainly impaired by interference from other transmitters within the system, rather than by noise. In a situation with a relatively large number of interfering signals of approximately equal strength, maximum-ratio combination is typically still a good choice as, in this case, the overall interference will appear relatively "noise-like" with no specific direction of arrival. However, in situations where there is a single dominating interferer (or, in the general case, a limited number of dominating interferers), as illustrated in Figure 5.3, improved performance can be achieved if, instead of selecting the antenna weights to maximize the received signal-to-noise ratio after antenna combination (MRC), the antenna weights are selected so that the interferer is suppressed. In terms of receiver-side beam-forming this corresponds to a receiver beam with high attenuation in the direction of the interferer, rather than focusing the receiver beam in the direction of the target signal. Applying receive-antenna combination with a target to suppress specific interferers is often referred to as *Interference Rejection Combination* (IRC) [30].

In the case of a single dominating interferer as outlined in Figure 5.3, expression (5.2) can be extended according to:

$$\bar{r} = \begin{pmatrix} r_1 \\ \vdots \\ r_{N_R} \end{pmatrix} = \begin{pmatrix} h_1 \\ \vdots \\ h_{N_R} \end{pmatrix} \cdot s + \begin{pmatrix} h_{I,1} \\ \vdots \\ h_{I,N_R} \end{pmatrix} \cdot s_I + \begin{pmatrix} n_1 \\ \vdots \\ n_{N_R} \end{pmatrix} = \bar{h} \cdot s + \bar{h}_I \cdot s_I + \bar{n}, \tag{5.4}$$

where s_I is the transmitted interferer signal and the vector $\bar{h}_I$ consists of the complex channel gains from the interferer to the N_R receive antennas. By applying expressions (5.1)–(5.4) it is clear that the interfering signal will be completely suppressed if the weight vector $\bar{w}$ is selected to fulfill the expression:

$$\bar{w}^H \cdot \bar{h}_I = 0. \tag{5.5}$$

In the general case, Eqn (5.5) has $N_R - 1$ non-trivial solutions, indicating flexibility in the weight-vector selection. This flexibility can be used to suppress additional dominating interferers. More specifically, in the general case of N_R receive antennas there is a possibility to, at least in theory,

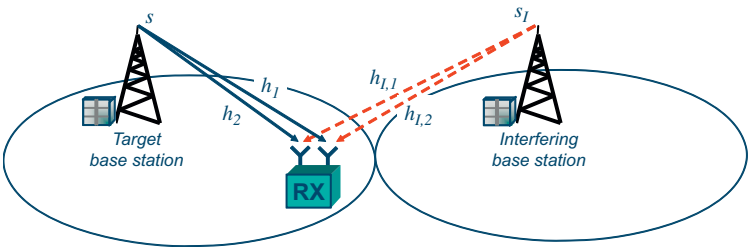


FIGURE 5.3

Downlink scenario with a single dominating interferer (special case of only two receive antennas).

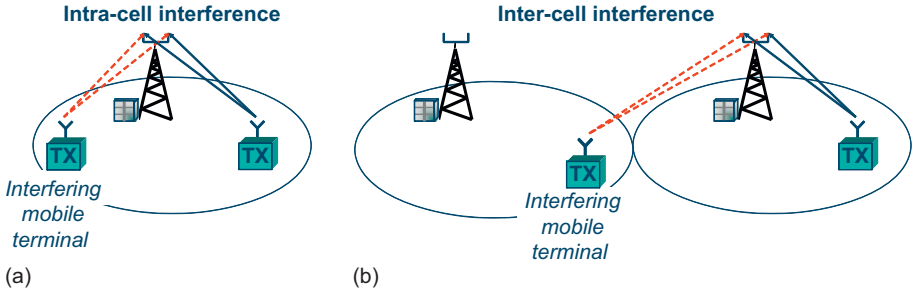


FIGURE 5.4

Receiver scenario with one strong interfering terminal. (a) Intra-cell interference. (b) Inter-cell interference.

completely suppress up to $N_R - 1$ separate interferers. However, such a choice of antenna weights, providing complete suppression of a number of dominating interferers, may lead to a large, potentially very large, increase in the noise level after the antenna combination. This is similar to the potentially large increase in the noise level in the case of a Zero-Forcing equalizer as discussed in Chapter 4.

Thus, similar to the case of linear equalization, a better approach is to select the antenna weight vector $\bar{w}$ to minimize the mean square error:

$$\varepsilon = E\{|\hat{s} - s|^2\}, \tag{5.6}$$

also known as *Minimum Mean Square Error* (MMSE) combination [22,29].

Although Figure 5.3 illustrates a downlink scenario with a dominating interfering base station, IRC can also be applied to the uplink to suppress interference from specific terminals. In this case, the interfering terminal may either be in the same cell as the target terminal (*intra-cell interference*) or in a neighboring cell (*inter-cell interference*) (see Figure 5.4a and b respectively). Suppression of intra-cell interference is relevant in the case of a non-orthogonal uplink – that is, when multiple terminals are transmitting simultaneously using the same time–frequency resource. Uplink intra-cell-interference suppression by means of IRC is sometimes also referred to as *Spatial-Division Multiple Access* (SDMA) [31,32].

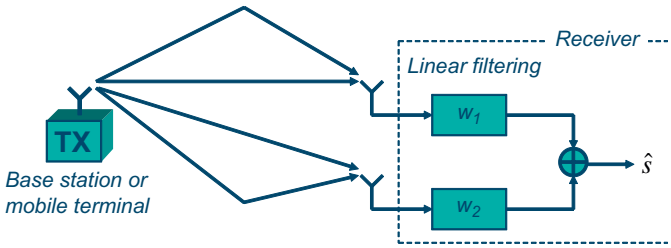


FIGURE 5.5

Two-dimensional space–time linear processing (two receive antennas).

As discussed in Chapter 2, in practice a radio channel is always subject to at least some degree of time dispersion or, equivalently, frequency selectivity, causing corruption to a wideband signal. As discussed in Chapter 4, one method to counteract such signal corruption is to apply linear equalization, either in the time or frequency domain.

It should be clear from the discussion above that linear receive-antenna combination has many similarities to linear equalization:

- Linear time-domain (frequency-domain) filtering/equalization as described in Chapter 4 implies that linear processing is applied to signals received at different time instances (different frequencies) with a target to maximize the post-equalizer SNR (MRC-based equalization), or to suppress signal corruption due to radio-channel frequency selectivity (zero-forcing equalization, MMSE equalization, etc.).
- Linear receive-antenna combination implies that linear processing is applied to signals received at different antennas – that is, processing in the spatial domain – with a target to maximize the post-combiner SNR (MRC-based combination), or to suppress specific interferers (IRC based on e.g. MMSE).

Thus, in the general case of frequency-selective channel and multiple receive antennas, two-dimensional time/space linear processing/filtering can be applied as illustrated in Figure 5.5, where the linear filtering can be seen as a generalization of the antenna weights of Figure 5.1. The filters should be jointly selected to minimize the overall impact of noise, interference, and signal corruption due to radio-channel frequency selectivity.

Alternatively, especially in the case when cyclic-prefix insertion has been applied at the transmitter side, two-dimensional frequency/space linear processing can be applied, as illustrated in Figure 5.6. The frequency-domain weights should then be jointly selected to minimize the overall impact of noise, interference, and signal corruption due to radio-channel frequency selectivity.

The frequency/space processing outlined in Figure 5.6, without the IDFT, is also applicable if receive diversity is to be applied to OFDM transmission. In the case of OFDM transmission, there is no signal corruption due to radio-channel frequency selectivity. Thus, the frequency-domain coefficients of Figure 5.6 can be selected taking into account only noise and interference. In principle,

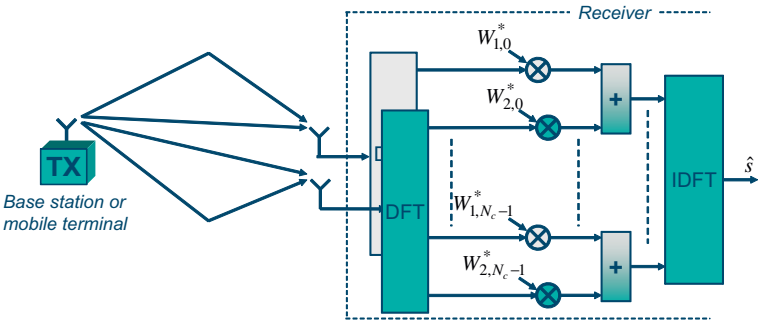


FIGURE 5.6

Two-dimensional space–frequency linear processing (two receive antennas).

this means the antenna-combining schemes discussed above (MRC and IRC) are applied on a *per-subcarrier* basis.

Note that, although Figures 5.5 and 5.6 assume two receive antennas, the corresponding receiver structures can straightforwardly be extended to more than two antennas.

5.4 MULTIPLE TRANSMIT ANTENNAS

As an alternative, or complement, to multiple receive antennas, diversity and beam-forming can also be achieved by applying multiple antennas at the transmitter side. The use of multiple transmit antennas is primarily of interest for the downlink – that is, at the base station. In this case, the use of multiple transmit antennas provides an opportunity for diversity and beam-forming without the need for additional receive antennas and corresponding additional receiver chains at the terminal. On the other hand, due to complexity the use of multiple transmit antennas for the uplink – that is, at the terminal – is less attractive. In this case, it is typically preferred to apply additional receive antennas and corresponding receiver chains at the base station.

5.4.1 Transmit-Antenna Diversity

If no knowledge of the downlink channels of the different transmit antennas is available at the transmitter, multiple transmit antennas cannot provide beam-forming but only diversity. For this to be possible, there should be low mutual correlation between the channels of the different antennas. As discussed in Section 5.1, this can be achieved by means of sufficiently large distance between the antennas, or by the use of different antenna polarization directions. Assuming such antenna configurations, different approaches can be taken to realize the diversity offered by the multiple transmit antennas.

5.4.1.1 Delay Diversity

As discussed in Chapter 2, a radio channel subject to time dispersion, with the transmitted signal propagating to the receiver via multiple, independently fading paths with different delays, provides

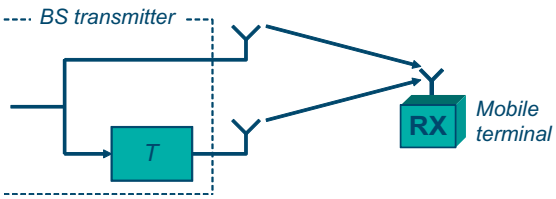


FIGURE 5.7

Two-antenna delay diversity.

the possibility for multi-path diversity or, equivalently, frequency diversity. Thus, multi-path propagation is actually beneficial in terms of radio-link performance, assuming that the amount of multi-path propagation is not too extensive and that the transmission scheme includes tools to counteract signal corruption due to the radio-channel frequency selectivity – for example, by means of OFDM transmission or the use of advanced receiver-side equalization.

If the channel in itself is not time dispersive, the availability of multiple transmit antennas can be used to create *artificial time dispersion* or, equivalently, *artificial frequency selectivity* by transmitting identical signals with different relative delays from the different antennas. In this way, the antenna diversity – that is, the fact that the fading experienced by the different antennas have low mutual correlation – can be transformed into frequency diversity. This kind of *delay diversity* is illustrated in Figure 5.7 for the special case of two transmit antennas. The relative delay T should be selected to ensure a suitable amount of frequency selectivity over the bandwidth of the signal to be transmitted. It should be noted that, although Figure 5.7 assumes two transmit antennas, delay diversity can straightforwardly be extended to more than two transmit antennas with different relative delays for each antenna.

Delay diversity is in essence invisible to the terminal, which will simply see a single radio channel subject to additional time dispersion. Delay diversity can thus straightforwardly be introduced in an existing mobile-communication system without requiring any specific support in a corresponding radio-interface standard. Delay diversity is also applicable to basically any kind of transmission scheme that is designed to handle and benefit from frequency-selective fading.

5.4.1.2 Cyclic-Delay Diversity

Cyclic-Delay Diversity (CDD) [33] is similar to delay diversity with the main difference that cyclic-delay diversity operates block-wise and applies *cyclic shifts*, rather than linear delays, to the different antennas (see Figure 5.8). Thus, cyclic-delay diversity is applicable to block-based transmission schemes such as OFDM and DFTS-OFDM.

In the case of OFDM transmission, a cyclic shift of the time-domain signal corresponds to a frequency-dependent phase shift before OFDM modulation, as illustrated in Figure 5.8b. Similar to delay diversity, this will create artificial frequency selectivity as seen by the receiver.

Also similar to delay diversity, CDD can straightforwardly be extended to more than two transmit antennas with different cyclic shifts for each antenna.

5.4.1.3 Diversity by Means of Space–Time Coding

Space–time coding is a general term used to indicate multi-antenna transmission schemes where modulation symbols are mapped in the time and spatial (transmit-antenna) domain to capture the

Petitioners' Exhibit 1003, p. 425
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

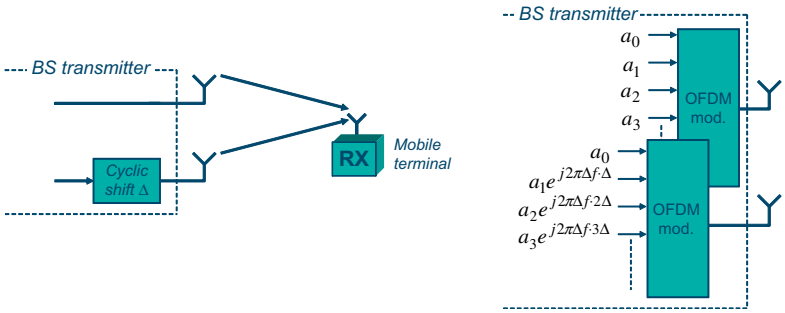


FIGURE 5.8

Two-antenna Cyclic-Delay Diversity (CDD).

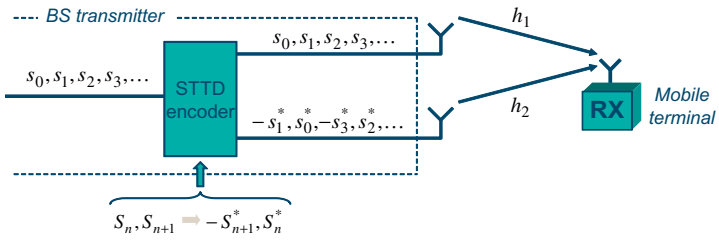


FIGURE 5.9

Space–Time Transmit Diversity (STTD).

diversity offered by the multiple transmit antennas. Two-antenna space–time block coding (STBC), more specifically a scheme referred to as *Space–Time Transmit Diversity* (STTD), has been part of the 3G WCDMA standard already from its first release [34].

As shown in Figure 5.9, STTD operates on pairs of modulation symbols. The modulation symbols are directly transmitted on the first antenna. However, on the second antenna the order of the modulation symbols within a pair is reversed. Furthermore, the modulation symbols are sign-reversed and complex-conjugated, as illustrated in Figure 5.9.

In vector notation, STTD transmission can be expressed as:

$$\bar{r} = \begin{pmatrix} r_{2n} \\ r_{2n+1}^* \end{pmatrix} = \begin{pmatrix} h_1 & -h_2 \\ h_2^* & h_1^* \end{pmatrix} \cdot \begin{pmatrix} s_{2n} \\ s_{2n+1}^* \end{pmatrix} = H \cdot \bar{s}, \tag{5.7}$$

where r_{2n} and r_{2n+1} are the received symbols during the symbol intervals $2n$ and $2n + 1$ respectively.[3] It should be noted that this expression assumes that the channel coefficients h_1 and h_2 are constant over the time corresponding to two consecutive symbol intervals, an assumption that is typically

[3]Note that, for convenience, complex conjugates have been applied for the second elements of $\bar{r}$ and $\bar{s}$.

Petitioners' Exhibit 1003, p. 426
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

valid. As the matrix H is a scaled unitary matrix, the sent symbols s_{2n} and s_{2n+1} can be recovered from the received symbols r_{2n} and r_{2n+1}, without any interference between the symbols, by applying the matrix $W = H^{-1}$ to the vector $\bar{r}$.

The two-antenna space–time coding of Figure 5.9 can be said to be of rate one, implying that the input symbol rate is the same as the symbol rate at each antenna, corresponding to a bandwidth utilization of 1. Space–time coding can also be extended to more than two antennas. However, in the case of complex-valued modulation, such as QPSK or 16/64QAM, space–time codes of rate one without any inter-symbol interference (*orthogonal space–time codes*) only exist for two antennas [35]. If inter-symbol interference is to be avoided in the case of more than two antennas, space–time codes with rate less than one must be used, corresponding to reduced bandwidth utilization.

5.4.1.4 *Diversity by Means of Space–Frequency Coding*

Space–frequency block coding (SFBC) is similar to space–time block coding, with the difference that the encoding is carried out in the antenna/frequency domains rather than in the antenna/time domains. Thus, space–frequency coding is applicable to OFDM and other "frequency-domain" transmission schemes. The space–frequency equivalence to STTD (which could also be referred to as Space–Frequency Transmit Diversity, SFTD) is illustrated in Figure 5.10. As can be seen, the block of (frequency-domain) modulation symbols a_0, a_1, a_2, a_3, … is directly mapped to OFDM carriers of the first antenna, while the block of symbols $-a_1^*, a_0^*, -a_3^*, a_2^*$ is mapped to the corresponding subcarriers of the second antenna.

Similar to space–time coding, the drawback of space–frequency coding is that there is no straightforward extension to more than two antennas unless a rate reduction is acceptable.

Comparing Figure 5.10 with the right-hand side of Figure 5.8, it can be noted that the difference between SFBC and two-antenna cyclic-delay diversity in essence lies in how the block of frequency-domain modulation symbols are mapped to the second antenna. The benefit of SFBC compared to CDD is that SFBC provides diversity at modulation-symbol level while CDD, in the case of OFDM, must rely on channel coding in combination with frequency-domain interleaving to provide diversity.

5.4.2 Transmitter-Side Beam-Forming

If some knowledge of the downlink channels of the different transmit antennas (more specifically, some knowledge of the relative channel phases) is available at the transmitter side, multiple transmit antennas can, in addition to diversity, also provide beam-forming – that is, the shaping of the overall antenna beam in the direction of a target receiver. In general, such beam-forming can increase the signal strength at the receiver with up to a factor N_T – that is, in proportion to the number of transmit antennas. When discussing transmission schemes relying on multiple transmit antennas to provide beam-forming one can distinguish between the cases of *high* and *low mutual antenna correlation* respectively.

High mutual antenna correlation typically implies an antenna configuration with a small inter-antenna distance, as illustrated in Figure 5.11a. In this case, the channels between the different antennas and a specific receiver are essentially the same, including the same radio-channel fading, except for a direction-dependent phase difference. The overall transmission beam can then be steered in

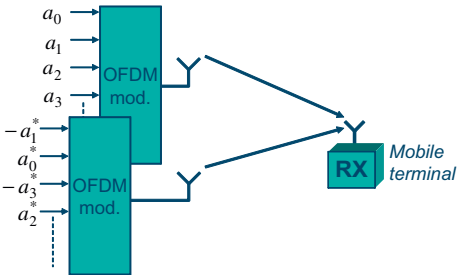


FIGURE 5.10

Space–Frequency Block Coding (SFBC) assuming two transmit antennas.

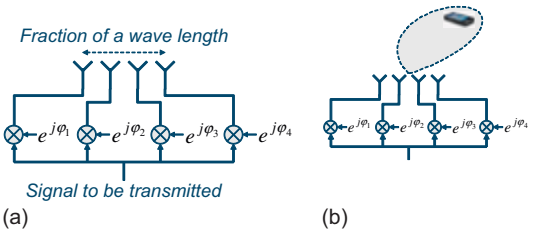


FIGURE 5.11

Classical beam-forming with high mutual antennas correlation: (a) antenna configuration; (b) beam-structure.

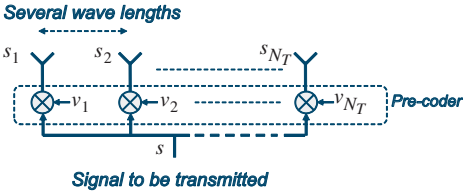


FIGURE 5.12

Pre-coder-based beam-forming in the case of low mutual antenna correlation.

different directions by applying *different phase shifts* to the signals to be transmitted on the different antennas, as illustrated in Figure 5.11b.

This approach to transmitter-side beam-forming, with different phase shifts applied to highly correlated antennas, is sometimes referred to as "classical" beam-forming. Due to the small antenna distance, the overall transmission beam will be relatively wide and any adjustments of the beam direction – in practice, adjustments of the antenna phase shifts – will typically be carried out on a relatively slow basis. The adjustments could, for example, be based on estimates of the direction to the target terminal derived from uplink measurements. Furthermore, due to the assumption of high correlation between the different transmit antennas, classical beam-forming cannot provide any diversity against radio-channel fading but only an increase of the received signal strength.

Low mutual antenna correlation typically implies either a sufficiently large antenna distance, as illustrated in Figure 5.12, or different antenna polarization directions. With low mutual antenna correlation, the basic beam-forming principle is similar to that of Figure 5.11 – that is, the signals to be transmitted on the different antennas are multiplied by different complex weights. However, in contrast to classical beam-forming, the antenna weights should now take general complex values and both the phase and the amplitude of the signals to be transmitted on the different antennas can be adjusted. This reflects the fact that, due to the low mutual antenna correlation, both the phase and the instantaneous gain of the channels of each antenna may differ.

Petitioners' Exhibit 1003, p. 428
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Applying different complex weights to the signals to be transmitted on the different antennas can be expressed, in vector notation, as applying a *precoding vector* $\overline{v}$ to the signal to be transmitted, according to:

$$\overline{s} = \begin{pmatrix} s_1 \\ \vdots \\ s_{N_T} \end{pmatrix} = \begin{pmatrix} v_1 \\ \vdots \\ v_{N_T} \end{pmatrix} \cdot s = \overline{v} \cdot s. \tag{5.8}$$

It should be noted that classical beam-forming according to Figure 5.11 can also be described according to Eqn (5.8) – that is, as *transmit-antenna precoding* – with the constraint that the antenna weights are limited to unit gain and only provide phase shifts to the different transmit antennas.

Assuming that the signals transmitted from the different antennas are only subject to non-frequency-selective fading and white noise – that is, there is no radio-channel time dispersion – it can be shown [36] that, in order to maximize the received signal power, the precoding weights should be selected according to:

$$v_i = \frac{h_i^*}{\sqrt{\sum_{k=1}^{N_T} |h_k|^2}}. \tag{5.9}$$

That is, as the complex conjugate of the corresponding channel coefficient h_i and with a normalization to ensure a fixed overall transmit power. The precoding vector thus:

- phase rotates the transmitted signals to compensate for the instantaneous channel phase and ensure that the received signals are received phase aligned;
- allocates power to the different antennas with, in general, more power being allocated to antennas with good instantaneous channel conditions (high channel gain $|h_i|$);
- ensures an overall unit (or any other constant) transmit power.

A key difference between classical beam-forming according to Figure 5.11, assuming high mutual antenna correlation, and beam-forming according to Figure 5.12, assuming low mutual antenna correlation, is that, in the latter case, there is a need for more detailed channel knowledge, including estimates of the instantaneous channel fading. Updates to the precoding vector are thus typically done on a relatively short time scale to capture the fading variations. As the adjustment of the precoder weights also takes into account the instantaneous fading, including the instantaneous channel gain, fast beam-forming according to Figure 5.12 also provides diversity against radio-channel fading.

Furthermore, at least in the case of communication based on *Frequency-Division Duplex* (FDD), with uplink and downlink communication taking place in different frequency bands, the fading is typically uncorrelated between the downlink and uplink. Thus, in the case of FDD, only the terminal can determine the downlink fading. The terminal would then report an estimate of the downlink channel to the base station by means of uplink signaling. Alternatively, the terminal may, in itself, select a suitable precoding vector from a limited set of possible precoding vectors, the so-called precoder codebook, and report this to the base station.

On the other hand, in the case of *Time-Division Duplex* (TDD), with uplink and downlink communication taking place in the same frequency band but in separate non-overlapping time slots, there

Petitioners' Exhibit 1003, p. 429
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

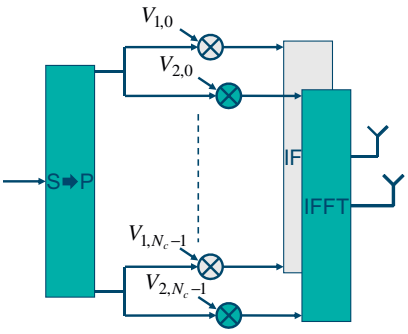


FIGURE 5.13

Per-subcarrier precoding in the case of OFDM (two transmit antennas).

is typically a high fading correlation between the downlink and uplink. In this case, the base station could, at least in theory, determine the instantaneous downlink fading from measurements on the uplink, thus avoiding the need for any feedback. Note, however, that this assumes that the terminal is continuously transmitting on the uplink.

The above discussion assumed that the channel gain was constant in the frequency domain – that is, there was no radio-channel frequency selectivity. In the case of a frequency-selective channel there is obviously not a single channel coefficient per antenna, based on which the antennas weights can be selected according to Eqn (5.9). However, in the case of OFDM transmission, each subcarrier will typically experience a frequency-non-selective channel. Thus, in the case of OFDM transmission, the precoding of Figure 5.12 can be carried out on a per-subcarrier basis as outlined in Figure 5.13, where the precoding weights of each subcarrier should be selected according to Eqn (5.9).

It should be pointed out that in the case of single-carrier transmission the one-weight-per-antenna approach outlined in Figure 5.12 can be extended to also take into account a time-dispersive/frequency-selective channel [37].

5.5 SPATIAL MULTIPLEXING

The use of multiple antennas at both the transmitter and the receiver can simply be seen as a tool to further improve the signal-to-noise/interference ratio and/or achieve additional diversity against fading, compared to the use of only multiple receive antennas or multiple transmit antennas. However, in the case of multiple antennas at both the transmitter and the receiver there is also the possibility for so-called *spatial multiplexing*, allowing for more efficient utilization of high signal-to-noise/interference ratios and significantly higher data rates over the radio interface.

5.5.1 Basic Principles

It should be clear from the previous sections that multiple antennas at the receiver and the transmitter can be used to improve the receiver signal-to-noise ratio in proportion to the number of antennas by applying beam-forming at the receiver and the transmitter. In the general case of N_T transmit antennas

Petitioners' Exhibit 1003, p. 430
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

and N_R receive antennas, the receiver signal-to-noise ratio can be made to increase in proportion to the product $N_T \times N_R$. As discussed in Chapter 2, such an increase in the receiver signal-to-noise ratio allows for a corresponding increase in the achievable data rates, assuming that the data rates are power limited rather than bandwidth limited. However, once the bandwidth-limited range of operation is reached, the achievable data rates start to saturate unless the bandwidth is also allowed to increase.

One way to understand this saturation in achievable data rates is to consider the basic expression for the normalized channel capacity:

$$\frac{C}{BW} = \log_2\left(1 + \frac{S}{N}\right), \tag{5.10}$$

where, by means of beam-forming, the signal-to-noise ratio S/N can be made to grow proportionally to $N_T \times N_R$. In general, $\log_2(1 + x)$ is proportional to x for small x, implying that, for low signal-to-noise ratios, the capacity grows approximately proportionally to the signal-to-noise ratio. However, for larger x, $\log_2(1 + x) \approx \log_2(x)$, implying that, for larger signal-to-noise ratios, capacity grows only logarithmically with the signal-to-noise ratio.

However, in the case of multiple antennas at the transmitter *and* the receiver it is, *under certain conditions*, possible to create up to $N_L = \min\{N_T, N_R\}$ parallel "channels" each with N_L times lower signal-to-noise ratio (the signal power is "split" between the channels) – that is, with a channel capacity:

$$\frac{C}{BW} = \log_2\left(1 + \frac{N_R}{N_L} \cdot \frac{S}{N}\right). \tag{5.11}$$

As there are now N_L parallel channels, each with a channel capacity given by Eqn (5.11), the overall channel capacity for such a multi-antenna configuration is thus given by:

$$\begin{aligned}\frac{C}{BW} &= N_L \cdot \log_2\left(1 + \frac{N_R}{N_L} \cdot \frac{S}{N}\right) \\ &= \min\{N_T, N_R\} \cdot \log_2\left(1 + \frac{N_R}{\min\{N_T, N_R\}} \cdot \frac{S}{N}\right).\end{aligned} \tag{5.12}$$

Thus, *under certain conditions*, the channel capacity can be made to grow essentially linearly with the number of antennas, avoiding the saturation in the data rates. We will refer to this as *Spatial Multiplexing*. The term MIMO (Multiple-Input/Multiple-Output) antenna processing is also very often used, although the term strictly speaking refers to all cases of multiple transmit antennas and multiple receive antennas, also including the case of combined transmit and receive diversity.[4]

To understand the basic principles how multiple parallel channels can be created in the case of multiple antennas at the transmitter and the receiver, consider a 2×2 antenna configuration – that is, two transmit antennas and two receive antennas – as outlined in Figure 5.14. Furthermore, assume that the transmitted signals are only subject to non-frequency-selective fading and white noise – that is, there is no radio-channel time dispersion.

[4]The case of a single transmit antenna and multiple receive antennas is, consequently, often referred to as SIMO (Single-Input/Multiple-Output). Similarly, the case of multiple transmit antennas and a single receiver antenna can be referred to as MISO (Multiple-Input/Single-Output).

Petitioners' Exhibit 1003, p. 431
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

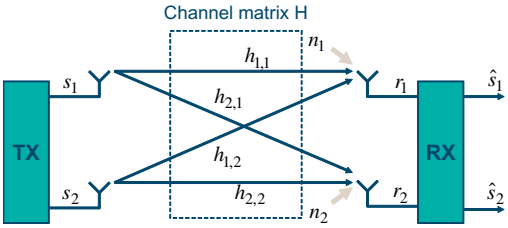


FIGURE 5.14

2 × 2 antenna configuration.

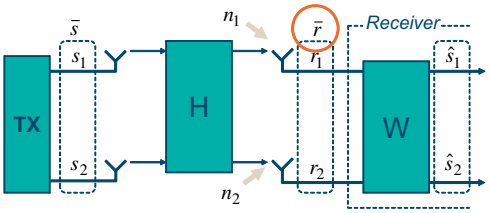


FIGURE 5.15

Linear reception/demodulation of spatially multiplexed signals.

Based on Figure 5.14, the received signals can be expressed as:

$$\bar{r} = \begin{pmatrix} r_1 \\ r_2 \end{pmatrix} = \begin{pmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{2,2} \end{pmatrix} \cdot \begin{pmatrix} s_1 \\ s_2 \end{pmatrix} + \begin{pmatrix} n_1 \\ n_2 \end{pmatrix} = H \cdot \bar{s} + \bar{n}, \tag{5.13}$$

where H is the 2 × 2 *channel matrix*. This expression can be seen as a generalization of Eqn (5.2) in Section 5.3 to multiple transmit antennas, with different signals being transmitted from the different antennas.

Assuming no noise and that the channel matrix H is invertible, the vector $\bar{s}$, and thus both signals s_1 and s_2, can be perfectly recovered at the receiver, with no residual interference between the signals, by multiplying the received vector $\bar{r}$ with a matrix $W = H^{-1}$ (see also Figure 5.15):

$$\begin{pmatrix} \hat{s}_1 \\ \hat{s}_2 \end{pmatrix} = W \cdot \bar{r} = \begin{pmatrix} s_1 \\ s_2 \end{pmatrix} + H^{-1} \cdot \bar{n}. \tag{5.14}$$

This is illustrated in Figure 5.15.

Although the vector $\bar{s}$ can be perfectly recovered in the case of no noise, as long as the channel matrix H is invertible, Eqn (5.14) also indicates that the properties of H will determine to what extent the joint demodulation of the two signals will increase the noise level. More specifically, the closer the channel matrix is to being a singular matrix, the larger the increase in the noise level.

One way to interpret the matrix W is to realize that the signals transmitted from the two transmit antennas are two signals causing interference to each other. The two receive antennas can then be used to carry out IRC, in essence completely suppressing the interference from the signal transmitted on the second antenna when detecting the signal transmitted at the first antenna and vice versa. The rows of the receiver matrix W simply implement such IRC.

In the general case, a multiple-antenna configuration will consist of N_T transmit antennas and N_R receive antennas. As discussed above, in such a case, the number of parallel signals that can be spatially multiplexed is, at least in practice, upper limited by $N_L = \min\{N_T, N_R\}$. This can intuitively be understood from the fact that:

- Obviously no more than N_T different signals can be transmitted from N_T transmit antennas, implying a maximum of N_T spatially multiplexed signals.
- With N_R receive antennas, a maximum of $N_R - 1$ interfering signals can be suppressed, implying a maximum of N_R spatially multiplexed signals.

Petitioners' Exhibit 1003, p. 432
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

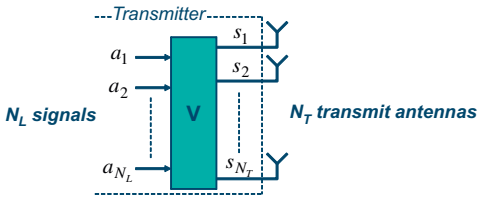


FIGURE 5.16

Pre-coder-based spatial multiplexing.

However, in many cases, the number of spatially multiplexed signals, or the *order of the spatial multiplexing*, will be less than N_L given above:

- In the case of very bad channel conditions (low signal-to-noise ratio) there is no gain of spatial multiplexing as the channel capacity is anyway a linear function of the signal-to-noise ratio. In such a case, the multiple transmit and receive antennas should be used for beam-forming to improve the signal-to-noise ratio, rather than for spatial multiplexing.
- In the more general case, the spatial-multiplexing order should be determined based on the properties of the size $N_R \times N_T$ channel matrix. Any excess antennas should then be used to provide beam-forming. Such combined beam-forming and spatial multiplexing can be achieved by means of *precoder-based* spatial multiplexing, as discussed below.

5.5.2 Precoder-Based Spatial Multiplexing

Linear precoding in the case of spatial multiplexing implies that linear processing by means of a size $N_T \times N_L$ precoding matrix is applied at the transmitter side, as illustrated in Figure 5.16. In line with the discussion above, in the general case N_L is equal or smaller than N_T, implying that N_L signals are spatially multiplexed and transmitted using N_T transmit antennas.

It should be noted that precoder-based spatial multiplexing can be seen as a generalization of precoder-based beam-forming as described in Section 5.4.2, with the precoding vector of size $N_T \times 1$ replaced by a precoding matrix of size $N_T \times N_L$.

The precoding of Figure 5.16 can serve two purposes:

- In the case when the number of signals to be spatially multiplexed equals the number of transmit antennas ($N_L = N_T$), the precoding can be used to "orthogonalize" the parallel transmissions, allowing for improved signal isolation at the receiver side.
- In the case when the number of signals to be spatially multiplexed is less than the number of transmit antennas ($N_L < N_T$), the precoding also provides the mapping of the N_L spatially multiplexed signals to the N_T transmit antennas, including the combination of spatially multiplexing and beam-forming.

To confirm that precoding can improve the isolation between the spatially multiplexed signals, express the channel matrix H as its singular-value decomposition [38]:

$$H = W \cdot \Sigma \cdot V^H, \tag{5.15}$$

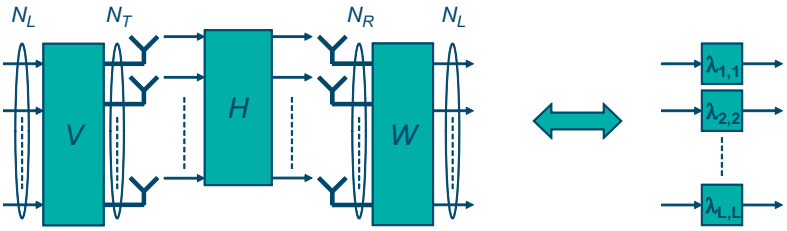


FIGURE 5.17

Orthogonalization of spatially multiplexed signals by means of precoding. $\lambda_{i,i}$ is the ith eigenvalue of the matrix $H^{\mathrm{H}}H$.

where the columns of V and W each form an orthonormal set and Σ is an $N_{\mathrm{L}} \times N_{\mathrm{L}}$ diagonal matrix with the N_{L} strongest eigenvalues of $H^{\mathrm{H}}H$ as its diagonal elements. By applying the matrix V as precoding matrix at the transmitter side and the matrix W^{H} at the receiver side, one arrives at an equivalent channel matrix $H' = \Sigma$ (see Figure 5.17). As H' is a diagonal matrix, there is thus no interference between the spatially multiplexed signals at the receiver. At the same time, as both V and W have orthonormal columns, the transmit power as well as the demodulator noise level (assuming spatially white noise) are unchanged.

Clearly, in the case of precoding each received signal will have a certain "quality", depending on the eigenvalues of the channel matrix (see right part of Figure 5.17). This indicates potential benefits of applying dynamic link adaptation in the *spatial domain* – that is, the adaptive selection of the coding rates and/or modulation schemes for each signal to be transmitted.

As the precoding matrix will never perfectly match the channel matrix in practice, there will always be some residual interference between the spatially multiplexed signals. This interference can be taken care of by means of additional receiver-size linear processing according to Figure 5.15 or nonlinear processing as discussed in Section 5.5.3 below.

To determine the precoding matrix V, knowledge about the channel matrix H is obviously needed. Similar to precoder-based beam-forming, a common approach is to have the receiver estimate the channel and decide on a suitable precoding matrix from a set of available precoding matrices (the precoder *codebook*). The receiver then feeds back information about the selected precoding matrix to the transmitter.

5.5.3 Nonlinear Receiver Processing

The previous sections discussed the use of linear receiver processing to jointly recover spatially multiplexed signals. However, improved demodulation performance can be achieved if nonlinear receiver processing can be applied in the case of spatial multiplexing.

The "optimal" receiver approach for spatially multiplexed signals is to apply *Maximum-Likelihood* (ML) detection [25]. However, in many cases ML detection is too complex to use. Thus, several different proposals have been made for reduced complexity, almost ML, schemes (see, for example, [39]).

Another nonlinear approach to the demodulation of spatially multiplexed signals is to apply *Successive Interference Cancellation* (SIC) [40]. Successive Interference Cancellation is based on an assumption that the spatially multiplexed signals are separately coded before the spatial multiplexing.

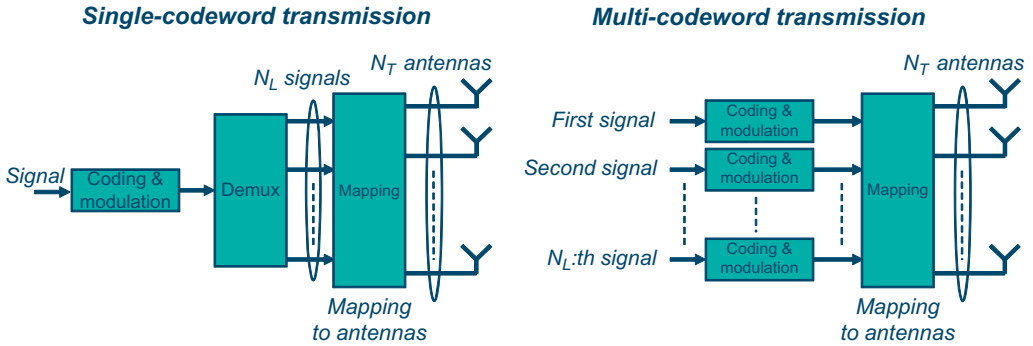


FIGURE 5.18

Single-codeword transmission (a) vs. multi-codeword transmission (b).

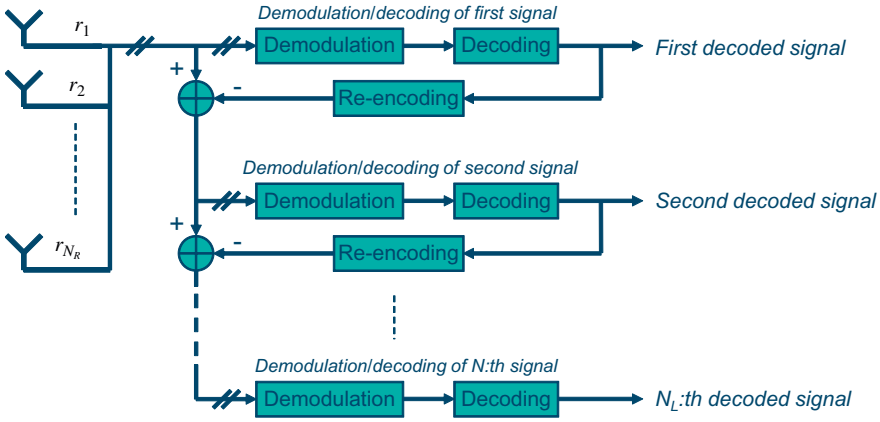


FIGURE 5.19

Demodulation/decoding of spatially multiplexed signals based on Successive Interference Cancellation.

This is often referred to as *Multi-Codeword* transmission, in contrast to *Single-Codeword* transmission where the spatially multiplexed signals are assumed to be jointly coded (Figure 5.18). It should be understood that, also in the case of multi-codeword transmission, the data may originate from the same source but is then demultiplexed into different signals to be spatially multiplexed before channel coding.

As shown in Figure 5.19, in the case of successive interference cancellation the receiver first demodulates and decodes one of the spatially multiplexed signals. The corresponding decoded data is then, if correctly decoded, re-encoded and subtracted from the received signals. A second spatially multiplexed signal can then be demodulated and decoded without, at least in the ideal case, any interference from the first signal – that is, with an improved signal-to-interference ratio. The decoded data of the second signal is then, if correctly decoded, re-encoded and subtracted from the received signal

Petitioners' Exhibit 1003, p. 435
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

before decoding of a third signal. These iterations continue until all spatially multiplexed signals have been demodulated and decoded.

Clearly, in the case of Successive Interference Cancellation, the first signals to be decoded are subject to higher interference level, compared to later decoded signals. To work properly, there should thus be a differentiation in the robustness of the different signals with, at least in principle, the first signal to be decoded being more robust than the second signal, the second signal being more robust than the third signal, etc. Assuming multi-codeword transmission according to Figure 5.18b, this can be achieved by applying different modulation schemes and coding rates to the different signals with, typically, lower-order modulation and lower coding rate, implying a lower data rate, for the first signals to be decoded. This is often referred to as *Per-Antenna Rate Control* (PARC) [41].

Petitioners' Exhibit 1003, p. 436
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CHAPTER

Scheduling, Link Adaptation, and Hybrid ARQ

6

One key characteristic of mobile radio communication is the typically rapid and significant variations in the instantaneous channel conditions. There are several reasons for these variations. Frequency-selective fading will result in rapid and random variations in the channel attenuation. Shadow fading and distance-dependent path loss will also significantly affect the average received signal strength. Finally, the interference at the receiver due to transmissions in other cells and by other terminals will also impact the interference level. Hence, to summarize, there will be rapid, and to some extent random, variations in the experienced quality of each radio link in a cell, variations that must be taken into account and preferably exploited.

In this chapter, some of the techniques for handling variations in the instantaneous radio-link quality will be discussed. *Channel-dependent scheduling* in a mobile-communication system deals with the question of how to share, between different users (different terminals), the radio resource(s) available in the system to achieve as efficient resource utilization as possible. Typically, this implies minimizing the amount of resources needed per user and thus allowing for as many users as possible in the system, while still satisfying whatever quality-of-service requirements that may exist. Closely related to scheduling is *link adaptation*, which deals with how to set the transmission parameters of a radio link to handle variations of the radio-link quality.

Both channel-dependent scheduling and link adaptation try to exploit the channel variations through appropriate processing *prior* to transmission of the data. However, due to the random nature of the variations in the radio-link quality, perfect adaptation to the instantaneous radio-link quality is never possible. *Hybrid ARQ,* which requests retransmission of erroneously received data packets, is therefore useful. This can be seen as a mechanism for handling variations in the instantaneous radio-link quality *after* transmission and nicely complements channel-dependent scheduling and link adaptation. Hybrid ARQ also serves the purpose of handling random errors due to, for example, noise in the receiver.

6.1 LINK ADAPTATION: POWER AND RATE CONTROL

Historically, *dynamic transmit-power control* has been used in CDMA-based mobile-communication systems such as WCDMA and CDMA2000 to compensate for variations in the instantaneous channel conditions.[1] As the name suggests, dynamic power control dynamically adjusts the radio-link transmit

[1]Power control is also used in GSM, but operating on a much slower basis than in CDMA-based systems. In CDMA-based systems, power control is also essential to handle the near–far problem and the associated performance impact from non-orthogonal uplink transmissions.

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 438
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

power to compensate for variations and differences in the instantaneous channel conditions. The aim of these adjustments is to maintain a (near) constant E_b/N_0 at the receiver to successfully transmit data without the error probability becoming too high. In principle, transmit-power control increases the power at the transmitter when the radio link experiences poor radio conditions (and vice versa). Thus, the transmit power is in essence inversely proportional to the channel quality, as illustrated in Figure 6.1a. This results in a basically constant data rate, regardless of the channel variations. For services such as circuit-switched voice, this is a desirable property. Transmit-power control can be seen as one type of link adaptation – that is, the adjustment of transmission parameters, in this case the transmit power – to adapt to differences and variations in the instantaneous channel conditions to maintain the received E_b/N_0 at a desired level.

However, in many cases of mobile communication, especially in the case of packet-data traffic, there is not a strong need to provide a certain constant data rate over a radio link. Rather, from a user perspective, the data rate provided over the radio interface should simply be as "high as possible". Actually, even in case of typical "constant-rate" services such as voice and video, (short-term)

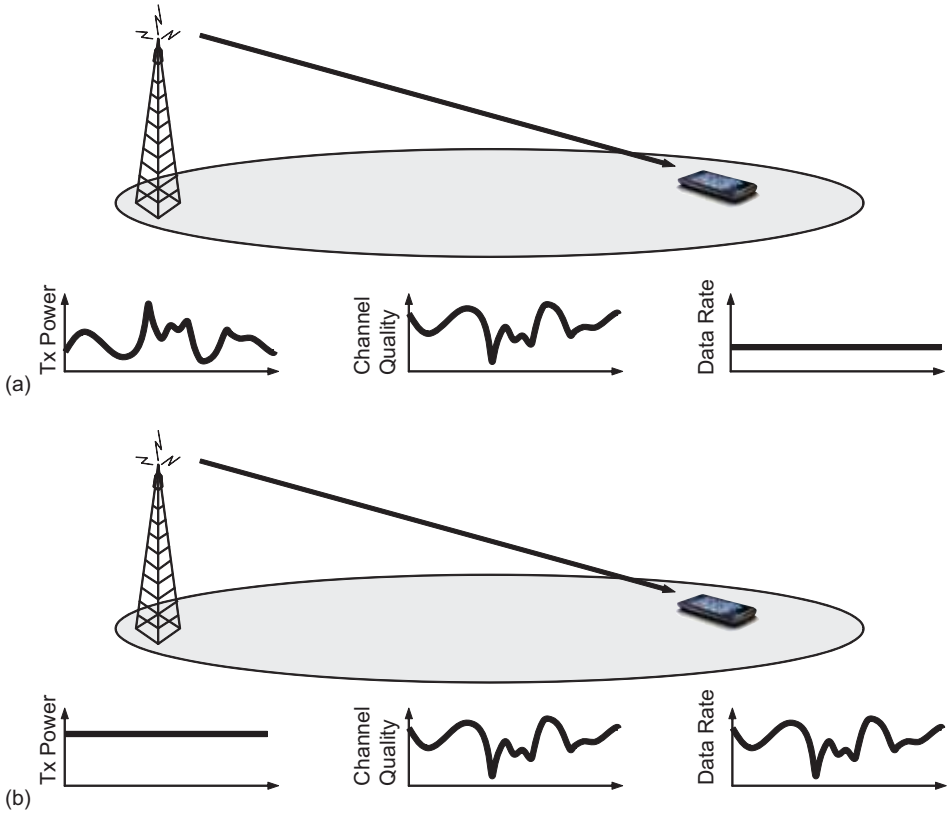


FIGURE 6.1

(a) Power control (top). (b) Rate control (bottom).

variations in the data rate are often not an issue, as long as the average data rate remains constant, assuming averaging over some relatively short time interval. In such cases – that is, when a constant data rate is not required – an alternative to transmit-power control is link adaptation by means of *dynamic rate control*. Rate control does not aim at keeping the instantaneous radio-link data rate constant, regardless of the instantaneous channel conditions. Instead, with rate control, the data rate is dynamically adjusted to compensate for the varying channel conditions. In situations with advantageous channel conditions, the data rate is increased, and vice versa. Thus, rate control maintains the $E_b/N_0 \sim P/R$ at the desired level, not by adjusting the transmission power P, but rather by adjusting the data rate R. This is illustrated in Figure 6.1b.

It can be shown that rate control is more efficient than power control [42,43]. Rate control in principle implies that the power amplifier is always transmitting at full power and therefore efficiently utilized. Power control, on the other hand, results in the power amplifier in most situations not being efficiently utilized as the transmission power is less than its maximum.

In practice, the radio-link data rate is controlled by adjusting the modulation scheme and/or the channel coding rate. In the case of advantageous radio-link conditions, the E_b/N_0 at the receiver is high and the main limitation of the data rate is the bandwidth of the radio link. Hence, in such situations higher-order modulation, for example 16QAM or 64QAM, together with a high code rate, is appropriate as discussed in Chapter 2. Similarly, in the case of poor radio-link conditions, QPSK and low-rate coding is used. For this reason, link adaptation by means of rate control is sometimes also referred to as *Adaptive Modulation and Coding* (AMC).

6.2 CHANNEL-DEPENDENT SCHEDULING

Scheduling controls the allocation of the shared resources among users at each time instant. It is closely related to link adaptation, and often scheduling and link adaptation is seen as one joint function. The scheduling principles, as well as which resources are shared between users, differ depending on the radio-interface characteristics – for example, whether uplink or downlink is considered and whether different users' transmissions are mutually orthogonal or not.

6.2.1 Downlink Scheduling

In the downlink, transmissions to different terminals within a cell are typically mutually orthogonal, implying that, at least in theory, there is no interference between the transmissions (no intra-cell interference). Downlink intra-cell orthogonality can be achieved in the time domain (*Time-Division Multiplexing*, TDM), in the frequency domain (*Frequency-Domain Multiplexing*, FDM), or in the code domain (*Code-Domain Multiplexing*, CDM). In addition, the spatial domain can also be used to separate users, at least in a quasi-orthogonal way, through different antenna arrangements. This is sometimes referred to as *Spatial-Division Multiplexing* (SDM), although in most cases it is used in combination with one or several of the above multiplexing strategies and is not discussed further in this chapter.

For packet data, where the traffic is often very bursty, it can be shown that TDM is preferable from a theoretical point of view [44,45] and is therefore typically the main component in the downlink [46,47]. However, as discussed in Chapter 3, the TDM component is often combined with

Petitioners' Exhibit 1003, p. 440
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

sharing of the radio resource also in the frequency domain (FDM) or in the code domain (CDM). For example, in the case of HSPA (see Chapter 19), downlink multiplexing is a combination of TDM and CDM. On the other hand, in the case of LTE, downlink multiplexing is a combination of TDM and FDM. The reasons for sharing the resources not only in the time domain will be elaborated upon later in this section.

When transmissions to multiple users occur in parallel, either by using FDM or CDM, there is also an instantaneous sharing of the total available cell transmit power. In other words, not only are the time/frequency/code resources shared resources, but also the power resource in the base station. In contrast, in the case of sharing only in the time domain there is, by definition, only a single transmission at a time and thus no instantaneous sharing of the total available cell transmit power.

For the purpose of discussion, assume initially a TDM-based downlink with a single user being scheduled at a time. In this case, the utilization of the radio resources is maximized if, at each time instant, all resources are assigned to the user with the best instantaneous channel condition:

- In the case of link adaptation based on power control, this implies that the lowest possible transmit power can be used for a given data rate and thus minimizes the interference to transmissions in other cells for a given link utilization.
- In the case of link adaptation based on rate control, this implies that the highest data rate is achieved for a given transmit power or, in other words, for a given interference to other cells, the highest link utilization is achieved.

However, if applied to the downlink, transmit-power control in combination with TDM scheduling implies that the total available cell transmit power will, in most cases, not be fully utilized. Thus, rate control is generally preferred [42,44,47,48].

The strategy outlined above is an example of channel-dependent scheduling, where the scheduler takes the instantaneous radio-link conditions into account. Scheduling the user with the instantaneously best radio-link conditions is often referred to as *max-C/I* (or *maximum rate*) scheduling. Since the radio conditions for the different radio links within a cell typically vary independently, at each point in time there is almost always a radio link whose channel quality is near its peak (see Figure 6.2). Thus, the channel eventually used for transmission will typically have a high quality and, with rate control, a correspondingly high data rate can be used. This translates into a high system capacity. The gain obtained by transmitting to users with favorable radio-link conditions is commonly known as multi-user diversity; the multi-user diversity gains are larger, the larger the channel variations and the larger the number of users in a cell. Hence, in contrast to the traditional view that fast fading – that is, rapid variations in the radio-link quality – is an undesirable effect that has to be combated, the possibility of channel-dependent scheduling implies that *fading is in fact potentially beneficial and should be exploited*.

Mathematically, the max-C/I (maximum rate) scheduler can be expressed as scheduling user k given by:

$$k = \arg\max_i R_i,$$

where R_i is the instantaneous data rate for user i. Although, from a system capacity perspective, max-C/I scheduling is beneficial, this scheduling principle will not be fair in all situations. If all terminals are, on average, experiencing similar channel conditions and large variations in the instantaneous channel conditions are only due to, for example, fast multi-path fading, all users will experience the

Petitioners' Exhibit 1003, p. 441
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

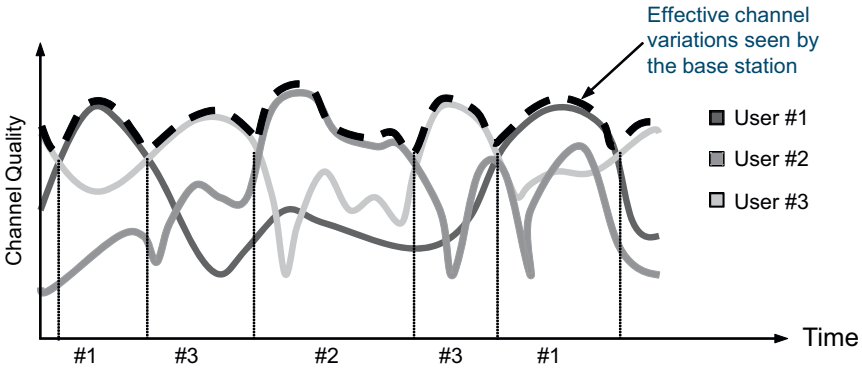


FIGURE 6.2

Channel-dependent scheduling.

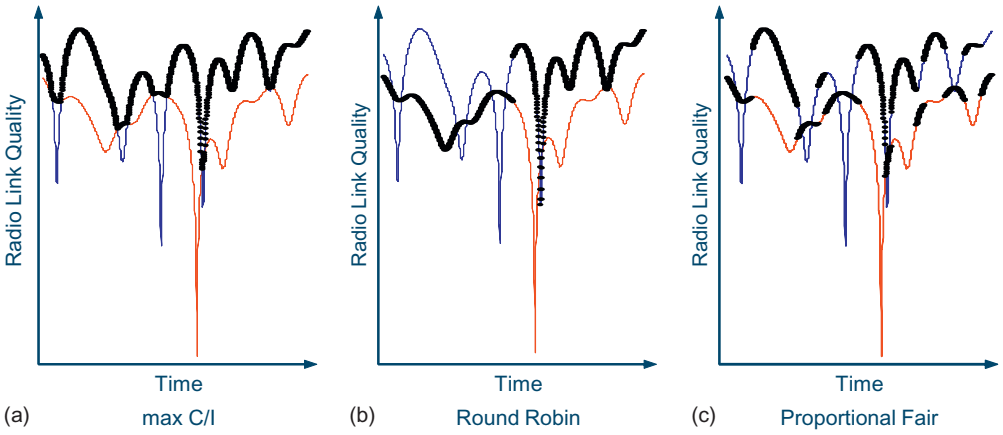


FIGURE 6.3

Examples of three different scheduling behaviors for two users with different average channel quality: (a) max-C/I; (b) round robin; (c) proportional fair. The selected user is shown with bold lines.

same average data rate. Any variations in the instantaneous data rate are rapid and often not even noticeable by the user. However, in practice different terminals will also experience differences in the (short-term) average channel conditions – for example, due to differences in the distance and shadow fading between the base station and the terminal. In this case, the channel conditions experienced by one terminal may, for a relatively long time, be worse than the channel conditions experienced by other terminals. A pure max-C/I-scheduling strategy may then, in essence, "starve" the terminal with the bad channel conditions, and the terminal with bad channel conditions will never be scheduled. This is illustrated in Figure 6.3a, where a max-C/I scheduler is used to schedule between two different users with different average channel quality. The same user is scheduled virtually all the

Petitioners' Exhibit 1003, p. 442
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

time. Although resulting in the highest system capacity, this situation is often not acceptable from a quality-of-service point of view.

An alternative to the max-C/I scheduling strategy is so-called *round-robin* scheduling, illustrated in Figure 6.3b. This scheduling strategy lets users take turns in using the shared resources, without taking the instantaneous channel conditions into account. Round-robin scheduling can be seen as fair scheduling in the sense that the same amount of radio resources (the same amount of time) is given to each communication link. However, round-robin scheduling is not fair in the sense of providing the same service quality to all communication links. In that case more radio resources (more time) must be given to communication links with bad channel conditions. Furthermore, as round-robin scheduling does not take the instantaneous channel conditions into account in the scheduling process, it will lead to lower overall system performance but more equal service quality between different communication links, compared to max-C/I scheduling.

Thus, what is needed is a scheduling strategy that is able to utilize the fast channel variations to improve the overall cell throughput while still ensuring the same average user throughput for all users or at least a certain minimum user throughput for all users. When discussing and comparing different scheduling algorithms it is important to distinguish between different types of variations in the service quality:

- Fast variations in the service quality corresponding to, for example, fast multi-path fading and fast variations in the interference level. For many packet-data applications, relatively large short-term variations in service quality are often acceptable or not even noticeable to the user.
- More long-term differences in the service quality between different communication links corresponding to, for example, differences in the distance to the cell site and shadow fading. In many cases there is a need to limit such long-term differences in service quality.

A practical scheduler should thus operate somewhere in between the max-C/I scheduler and the round-robin scheduler – that is, try to utilize fast variations in channel conditions as much as possible while still satisfying some degree of fairness between users.

One example of such a scheduler is the proportional-fair scheduler [49–51], illustrated in Figure 6.3c. In this strategy, the shared resources are assigned to the user with the *relatively* best radio-link conditions – that is, at each time instant, user k is selected for transmission according to:

$$k = \arg\max_i \frac{R_i}{\overline{R_i}},$$

where R_i is the instantaneous data rate for user i and $\overline{R_i}$ is the average data rate for user i. The average is calculated over a certain averaging period T_{PF}. To ensure efficient usage of the short-term channel variations and, at the same time, limit the long-term differences in service quality to an acceptable level, the time constant T_{PF} should be set longer than the time constant for the short-term variations. At the same time, T_{PF} should be sufficiently short so that quality variations within the interval T_{PF} are not strongly noticed by a user. Typically, T_{PF} can be set to be of the order of one second.

In the above discussion, it was assumed that all the radio resources in the downlink were assigned to a single user at a time – that is, scheduling was done purely in the time domain using TDM between users. However, in several situations, TDM is complemented by CDM or FDM. In principle, there are two reasons for not relying solely on TDM in the downlink:

Petitioners' Exhibit 1003, p. 443
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- In the case of insufficient payload – that is, the amount of data to transfer to a user is not sufficiently large to utilize the full channel capacity, and a fraction of resources could be assigned to another user, either through FDM or CDM.
- In the case where channel variations in the frequency domain are exploited through FDM, as discussed further below.

The scheduling strategies in these cases can be seen as generalizations of the schemes discussed for the TDM-only cases above. For example, to handle small payloads, a greedy filling approach can be used, where the scheduled user is selected according to max-C/I (or any other scheduling scheme). Once this user has been assigned resources matching the amount of data awaiting transmission, the second best user according to the scheduling strategy is selected and assigned (a fraction of) the residual resources and so on.

Finally, it should also be noted that the scheduling algorithm typically is a base-station-implementation issue and nothing that is normally specified in any standard. What need to be specified in a standard to support channel-dependent scheduling are channel-quality measurements/reports and the signaling needed for dynamic resource allocation.

6.2.2 Uplink Scheduling

The previous section discussed scheduling from a downlink perspective. However, scheduling is equally applicable to uplink transmissions and to a large extent the same principles can be considered, although there are some differences between the two.

Fundamentally, the uplink power resource is *distributed* among the users, while in the downlink the power resource is *centralized* within the base station. Furthermore, the maximum uplink transmission power of a single terminal is typically significantly lower than the output power of a base station. This has a significant impact on the scheduling strategy. Unlike the downlink, where pure TDMA can often be used, uplink scheduling typically has to rely on sharing in the frequency and/or code domain in addition to the time domain, as a single terminal may not have sufficient power for efficiently utilizing the link capacity.

Similar to the downlink case, channel-dependent scheduling is also beneficial in the uplink case. However, the characteristics of the underlying radio interface, most notably whether the uplink relies on orthogonal or non-orthogonal multiple access and the type of link adaptation scheme used, also have a significant impact on the uplink scheduling strategy.

In the case of a non-orthogonal multiple-access scheme such as CDMA, power control is typically essential for proper operation. As discussed earlier in this chapter, the purpose of power control is to control the received E_b/N_0 such that the received information can be recovered. However, in a non-orthogonal multiple-access setting, power control also serves the purpose of controlling the amount of interference affecting *other* users. This can be expressed as the *maximum tolerable interference level* at the base station in a shared resource. Even if, from a single user's perspective, it would be beneficial to transmit at full power to maximize the data rate, this may not be acceptable from an interference perspective as other terminals in this case may not be able to successfully transfer any data. Thus, with non-orthogonal multiple access, scheduling a terminal when the channel conditions are favorable may not directly translate into a higher data rate as the interference generated to other simultaneously transmitting terminals in the cell must be taken into account. Stated differently, the

Petitioners' Exhibit 1003, p. 444
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

received power (and thus the data rate) is, thanks to power control, in principle constant, regardless of the channel conditions at the time of transmission, while the *transmitted* power depends on the channel conditions at the time of transmission. Hence, even though channel-dependent scheduling in this example does not give a direct gain in terms of a higher data rate from the terminal, channel-dependent scheduling will still provide a gain for the system in terms of lower intra-cell interference.

The above discussion on non-orthogonal multiple access was simplified in the sense that no bounds on the terminals' transmission power were assumed. In practice, the transmission power of a terminal is upper bounded, due both to implementation and regulatory reasons, and scheduling a terminal for transmission in favorable channel conditions decreases the probability that the terminal has insufficient power to utilize the channel capacity.

In the case of an orthogonal multiple-access scheme, intra-cell power control is fundamentally not necessary and the benefits of channel-dependent scheduling become more similar to the downlink case. In principle, from an intra-cell perspective, a terminal can transmit at full power and the scheduler assigns a suitable part of the orthogonal resources (in practice a suitable part of the overall bandwidth) to the terminal for transmission. The remaining orthogonal resources can be assigned to other users. However, implementation constraints, for example leakage between the received signals or limited dynamic range in the receiver circuitry, may pose restrictions on the maximum tolerable power difference between the signals from simultaneously transmitting terminals. As a consequence, a certain degree of power control may be necessary, making the situation somewhat similar to the non-orthogonal case.

The discussion on non-orthogonal and orthogonal multiple access mainly considered intra-cell multiple access. However, in many practical systems universal frequency reuse between cells is applied. In this case, the inter-cell multiple access is non-orthogonal, regardless of the intra-cell multiple access, which sets limits on the allowable transmission power from a terminal.

Regardless of whether orthogonal or non-orthogonal multiple access is used, the same basic scheduling principles as for the downlink can be used. A max-C/I scheduler would assign all the uplink resources to the terminal with the best uplink channel conditions. Neglecting any power limitations in the terminal, this would result in the highest capacity (in an isolated cell) [44].

In the case of a non-orthogonal multiple-access scheme, *greedy filling* is one possible scheduling strategy [48]. With greedy filling, the terminal with the best radio conditions is assigned as high a data rate as possible. If the interference level at the receiver is smaller than the maximum tolerable level, the terminal with the second best channel conditions is allowed to transmit as well, continuing with more and more terminals until the maximum tolerable interference level at the receiver is reached. This strategy maximizes the air interface utilization but is achieved at the cost of potentially large differences in data rates between users. In the extreme case, a user at the cell border with poor channel conditions may not be allowed to transmit at all.

Strategies between greedy filling and max-C/I can also be envisioned – for example, different proportional-fair strategies. This can be achieved by including a weighting factor for each user, proportional to the ratio between the instantaneous and average data rates, into the greedy filling algorithm.

The schedulers above all assume knowledge of the instantaneous radio-link conditions, knowledge that can be hard to obtain in the uplink scenario, as discussed in Section 7.2.4. In situations when no information about the uplink radio-link quality is available at the scheduler, *round-robin* scheduling can be used. Similar to the downlink, round-robin implies terminals taking turns in transmitting, thus creating a TDMA-like operation with inter-user orthogonality in the time domain. Although the round-robin scheduler is simple, it is far from the optimal scheduling strategy.

Petitioners' Exhibit 1003, p. 445
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

However, as already discussed in Chapter 4, the transmission power in a terminal is limited and therefore additional sharing of the uplink resources in the frequency and/or code domain is required. This also impacts the scheduling decisions. For example, terminals far from the base station typically operate in the power-limited region, in contrast to terminals close to the base stations, which often are in the bandwidth-limited region (for a discussion on power-limited vs. bandwidth-limited operation, see Chapter 2). Thus, for a terminal far from the base station, increasing the bandwidth will not result in an increased data rate and it is better to only assign a small amount of the bandwidth to this terminal and assign the remaining bandwidth to other terminals. On the other hand, for terminals close to the base station, an increase in the assigned bandwidth will provide a higher data rate.

6.2.3 Link Adaptation and Channel-Dependent Scheduling in the Frequency Domain

In the previous section, TDM-based scheduling was assumed and it was explained how, in this case, channel variations in the time domain could be utilized to improve system performance by applying channel-dependent scheduling, especially in combination with dynamic rate control. However, if the scheduler has access to the frequency domain, for example through the use of OFDM transmission, scheduling and link adaptation can also take place in the frequency domain.

Link adaptation in the frequency domain implies that, based on knowledge about the instantaneous channel conditions also in the frequency domain – that is, knowledge about the attenuation as well as the noise/interference level of, in the extreme case, every OFDM subcarrier – the power and/or the data rate of each OFDM carrier can be individually adjusted for optimal utilization.

Similarly, channel-dependent scheduling in the frequency domain implies that, based on knowledge about the instantaneous channel conditions also in the frequency domain, different subcarriers are used for transmission to or from different terminals. The scheduling gains from exploiting variations in the frequency domain are similar to those obtained from time-domain variations. Obviously, in situations where the channel quality varies significantly with the frequency while the channel quality only varies slowly with time, channel-dependent scheduling in the frequency domain can enhance system capacity. An example of such a situation is a wideband indoor system with low mobility, where the quality only varies slowly with time.

6.2.4 Acquiring on Channel-State Information

To select a suitable data rate, in practice a suitable modulation scheme and channel-coding rate, the transmitter needs information about the radio-link channel conditions. Such information is also required for the purpose of channel-dependent scheduling. In the case of a system based on frequency-division duplex (FDD), only the receiver can accurately estimate the radio-link channel conditions.

For the downlink, most systems provide a downlink signal of a predetermined structure, known as the downlink pilot or the downlink reference signal. This reference signal is transmitted from the base station with constant power and can be used by the terminal to estimate the instantaneous downlink channel conditions. Information about the instantaneous downlink conditions can then be reported to the base station.

Basically, what is relevant for the transmitter is an estimate reflecting the channel conditions *at the time of transmission*. Hence, in principle, the terminal could apply a predictor, trying to predict the future channel conditions and report this predicted value to the base station. However, as this would

Petitioners' Exhibit 1003, p. 446
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

require specification of prediction algorithms and how they would operate when the terminal is moving at different speeds, most practical systems simply report the measured channel conditions to the base station. This can be seen as a very simple predictor, basically assuming the conditions in the near future will be similar to the current conditions. Thus, the more rapid the time-domain channel variations, the less efficient the link adaptation.

As there inevitably will be a delay between the point in time when the terminal measured the channel conditions and the application of the reported value in the transmitter, channel-dependent scheduling and link adaptation typically operates at its best at low terminal mobility. If the terminal starts to move at high speed, the measurement reports will be outdated once arriving at the base station. In such cases, it is often preferable to perform link adaptation on the long-term average channel quality and rely on hybrid ARQ with soft combining for the rapid adaptation.

For the uplink, estimation of the uplink channel conditions is not as straightforward, as there is typically no reference signal transmitted with constant power from each terminal. Means to estimate uplink channel conditions for LTE are discussed in Chapter 11.

In the case of a system with time-division duplex (TDD), where uplink and downlink communication are time multiplexed within the same frequency band, the instantaneous uplink signal quality attenuation could be estimated from downlink measurements of the terminal, due to the reciprocity of the multi-path fading in the case of TDD. However, it should then be noted that this may not provide full knowledge of the downlink channel conditions. As an example, the interference situations at the terminal and the base station are different also in the case of TDD.

6.2.5 Traffic Behavior and Scheduling

It should be noted that there is little difference between different scheduling algorithms at low system load – that is, when only one or, in some cases, a few users have data waiting for transmission at the base station at each scheduling instant. The differences between different scheduling algorithms are primarily visible at high load. However, not only the load, but also the traffic behavior affects the overall scheduling performance.

As discussed above, channel-dependent scheduling tries to exploit short-term variations in radio quality. Generally, a certain degree of long-term fairness in service quality is desirable, which should be accounted for in the scheduler design. However, since system throughput decreases the more fairness is enforced, a trade-off between fairness and system throughput is necessary. In this trade-off, it is important to take traffic characteristics into account as they have a significant influence on the trade-off between system throughput and service quality.

To illustrate this, consider three different downlink schedulers:

1. *Round-robin (RR) scheduler,* where channel conditions are not taken into account.
2. *Proportional-fair (PF) scheduler,* where short-term channel variations are exploited while maintaining the long-term average user data rate.
3. *Max-C/I scheduler,* where the user with the best instantaneous channel quality in absolute terms is scheduled.

For a full buffer scenario when there is always data available at the base station for all terminals in the cell, a max-C/I scheduler will result in no, or very low, user throughput for users at the cell edge with a low average channel quality. The reason is the fundamental strategy of the max-C/I

Petitioners' Exhibit 1003, p. 447
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

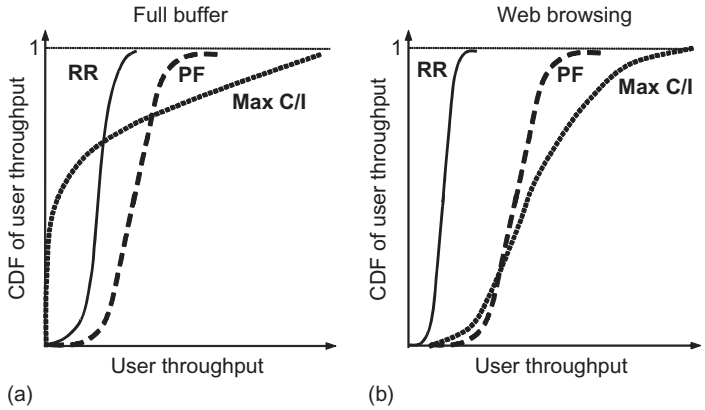


FIGURE 6.4

Illustration of the principle behavior of different scheduling strategies: (a) for full buffers; (b) for web-browsing traffic model.

scheduler – all resources are allocated for transmission to the terminal whose channel conditions support the highest data rate. Only in the rare, not to say unlikely, case of a cell-edge user having better conditions than a cell-center user, for example due to a deep fading dip for the cell-center user, will the cell-edge user be scheduled. A proportional-fair scheduler, on the other hand, will ensure some degree of fairness by selecting the user supporting the highest data rate relative to its average data rate. Hence, users tend to be scheduled on their fading peaks, regardless of the absolute quality. Thus, users on the cell edge will also be scheduled, thereby resulting in some degree of fairness between users.

For a scenario with bursty packet data, the situation is different. In this case, the users' buffers will be finite and in many cases also empty. For example, a web page has a certain size and, after transmitting the page, there is no more data to be transmitted to the terminal in question until the users requests a new page by clicking on a link. In this case, a max-C/I scheduler can still provide a certain degree of fairness. Once the buffer for the user with the highest C/I has been emptied, another user with non-empty buffers will have the highest C/I and be scheduled and so on. This is the reason for the difference between full buffer and web-browsing traffic illustrated in Figure 6.4. The proportional-fair scheduler has similar performance in both scenarios.

Clearly, the degree of fairness introduced by the traffic properties depends heavily on the actual traffic; a design made with certain assumptions may be less desirable in an actual network where the traffic pattern may be different from the assumptions made during the design. Therefore, relying solely on the traffic properties for fairness is not a good strategy, but the discussion above emphasizes the need to design the scheduler not only for the full buffer case.

6.3 ADVANCED RETRANSMISSION SCHEMES

Transmissions over wireless channels are subject to errors, for example due to variations in the received signal quality. To some degree, such variations can be counteracted through link adaptation,

as discussed above. However, receiver noise and unpredictable interference variations cannot be counteracted. Therefore, virtually all wireless communications systems employ some form of *Forward Error Correction* (FEC), tracing its roots to the pioneering work of Claude Shannon in 1948 [11]. There is a rich literature in the area of error-correction coding (see, for example, [52,53] and references therein), and a detailed description is beyond the scope of this book. In short, the basic principle beyond forward error-correction coding is to introduce redundancy in the transmitted signal. This is achieved by adding *parity bits* to the information bits prior to transmission (alternatively, the transmission could consists of parity bits alone, depending on the coding scheme used). The parity bits are computed from the information bits using a method given by the coding structure used. Thus, the number of bits transmitted over the channel is larger than the number of original information bits and a certain amount of *redundancy* has been introduced in the transmitted signal.

Another approach to handle transmissions errors is to use *Automatic Repeat Request* (ARQ). In an ARQ scheme, the receiver uses an error-detection code, typically a Cyclic Redundancy Check (CRC), to detect if the received packet is in error or not. If no error is detected in the received data packet, the received data is declared error-free and the transmitter is notified by sending a positive acknowledgement (ACK). On the other hand, if an error is detected, the receiver discards the received data and notifies the transmitter via a return channel by sending a negative acknowledgement (NAK). In response to an NAK, the transmitter retransmits the same information.

Virtually all modern communication systems, including LTE, employ a combination of forward error-correction coding and ARQ, known as *hybrid ARQ*. Hybrid ARQ uses forward error-correction codes to correct a subset of all errors and relies on error detection to detect uncorrectable errors. Erroneously received packets are discarded and the receiver requests retransmissions of corrupted packets. Thus, it is a combination of FEC and ARQ as described above. Hybrid ARQ was first proposed in [54] and numerous publications on hybrid ARQ have appeared since (see [52] and references therein). Most practical hybrid ARQ schemes are built around a CRC code for error detection and convolutional or Turbo codes for error correction, but in principle any error-detection and error-correction code can be used.

6.4 HYBRID ARQ WITH SOFT COMBINING

The hybrid-ARQ operation described above discards erroneously received packets and requests retransmission. However, despite it not being possible to decode the packet, the received signal still contains information, which is lost by discarding erroneously received packets. This shortcoming is addressed by *hybrid ARQ with soft combining*. In hybrid ARQ with soft combining, the erroneously received packet is stored in a buffer memory and later combined with the retransmission to obtain a single, combined packet that is more reliable than its constituents. Decoding of the error-correction code operates on the combined signal. If the decoding fails (typically a CRC code is used to detect this event), a retransmission is requested.

Retransmission in any hybrid-ARQ scheme must, by definition, represent the same set of information bits as the original transmission. However, the set of coded bits transmitted in each retransmission may be selected differently as long as they represent the same set of information bits. Hybrid ARQ with soft combining is therefore usually categorized into *Chase combining* and *incremental redundancy*, depending on whether the retransmitted bits are required to be identical to the original transmission or not.

Petitioners' Exhibit 1003, p. 449
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

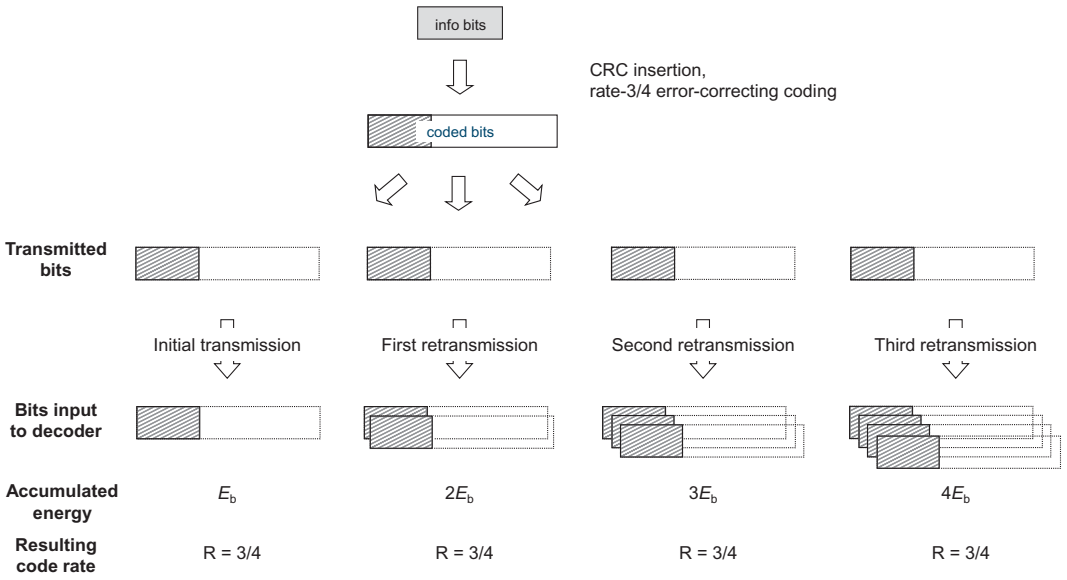


FIGURE 6.5

Example of Chase combining.

Chase combining, where the retransmissions consist of the same set of coded bits as the original transmission, was first proposed in [55]. After each retransmission, the receiver uses maximum-ratio combination to combine each received channel bit with any previous transmissions of the same bit, and the combined signal is fed to the decoder. As each retransmission is an identical copy of the original transmission, retransmissions with Chase combining can be seen as additional repetition coding. Therefore, as no new redundancy is transmitted, Chase combining does not give any additional coding gain but only increases the accumulated received E_b/N_0 for each retransmission (Figure 6.5).

Several variants of Chase combining exist. For example, only a subset of the bits transmitted in the original transmission might be retransmitted, so-called partial Chase combining. Furthermore, although combination is often done after demodulation but before channel decoding, combination can also be carried out at the modulation symbol level before demodulation, as long as the modulation scheme is unchanged between transmission and retransmission.

With *Incremental Redundancy* (IR), each retransmission does not have to be identical to the original transmission. Instead, *multiple sets* of coded bits are generated, each representing the same set of information bits [56,57]. Whenever a retransmission is required, the retransmission typically uses a different set of coded bits than the previous transmission. The receiver combines the retransmission with previous transmission attempts of the same packet. As the retransmission may contain additional parity bits not included in the previous transmission attempts, the resulting code rate is generally lowered by a retransmission. Furthermore, each retransmission does not necessarily have to consist of the same number of coded bits as the original and, in general, the modulation scheme can also be different for different

Petitioners' Exhibit 1003, p. 450
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

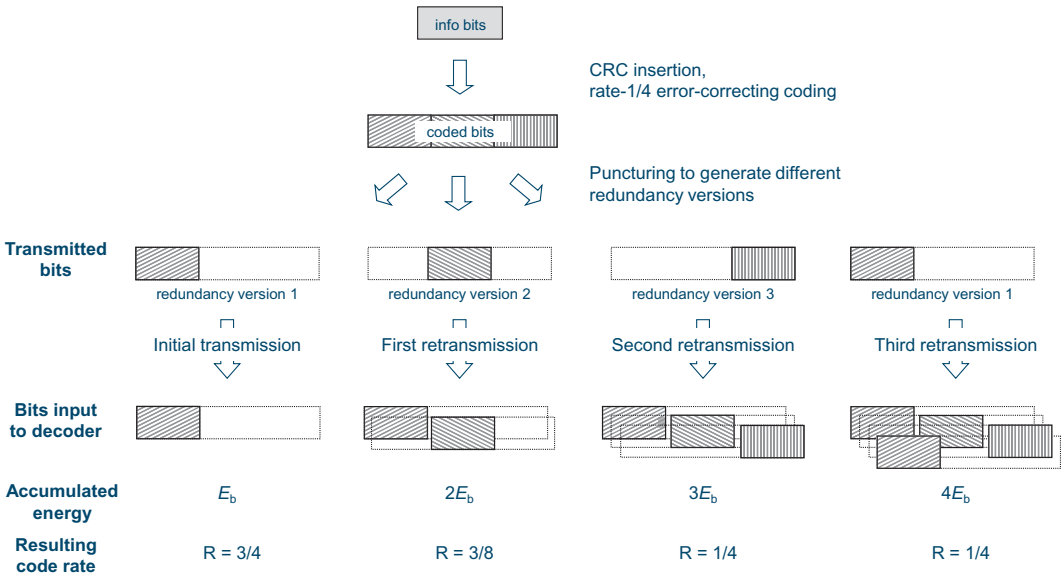


FIGURE 6.6

Example of incremental redundancy.

retransmissions. Hence, incremental redundancy can be seen as a generalization of Chase combining or, stated differently, Chase combining is a special case of incremental redundancy.

Typically, incremental redundancy is based on a low-rate code and the different redundancy versions are generated by puncturing the output of the encoder. In the first transmission only a limited number of coded bits are transmitted, effectively leading to a high-rate code. In the retransmissions, additional coded bits are transmitted. As an example, assume a basic rate-1/4 code. In the first transmission, only every third coded bit is transmitted, effectively giving a rate-3/4 code, as illustrated in Figure 6.6. In the case of a decoding error and a subsequent request for a retransmission, additional bits are transmitted, effectively leading to a rate-3/8 code. After a second retransmission the code rate is 1/4. In the case of more than two retransmissions, transmitted coded bits would already be repeated. In addition to a gain in accumulated received E_b/N_0, incremental redundancy also results in a coding gain for each retransmission. The gain with IR compared to Chase is larger for high initial code rates, while at lower initial coding rates Chase combining is almost as good as IR [58]. Furthermore, as shown in [59], the performance gain of incremental redundancy compared to Chase combining can also depend on the relative power difference between the transmission attempts.

With incremental redundancy, the code used for the first transmission should provide good performance not only when used alone, but also when used in combination with the code for the second transmission. The same holds for subsequent retransmissions. Thus, as the different redundancy versions typically are generated through puncturing of a low-rate mother code, the puncturing patterns should be defined such that all the code bits used by a high-rate code should also be part of any lower-rate codes. In other words, the resulting code rate R_i after transmission attempt i, consisting of

Petitioners' Exhibit 1003, p. 451
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

the coded bits from redundancy versions RV_k, $k = 1, \ldots, i$, should have similar performance as a good code designed directly for rate R_i. Examples of this for convolutional codes are the so-called rate-compatible convolutional codes [60].

In the discussion so far, it has been assumed that the receiver has received all the previously transmitted redundancy versions. If all redundancy versions provide the same amount of information about the data packet, the order of the redundancy versions is not critical. However, for some code structures, not all redundancy versions are of equal importance. One example here is Turbo codes, where the systematic bits are of higher importance than the parity bits. Hence, the initial transmission should at least include all the systematic bits and some parity bits. In the retransmission(s), parity bits not in the initial transmission can be included. However, if the initial transmission was received with poor quality or not at all, a retransmission with only parity bits is not appropriate as a retransmission of (some of) the systematic bits provides better performance. Incremental redundancy with Turbo codes can therefore benefit from multiple levels of feedback, for example by using two different negative acknowledgements – NAK to request additional parity bits and LOST to request a retransmission of the systematic bits. In general, the problem of determining the amount of systematic and parity bits in a retransmission based on the signal quality of previous transmission attempts is non-trivial.

Hybrid ARQ with soft combining, regardless of whether Chase or incremental redundancy is used, leads to an implicit reduction of the data rate by means of retransmissions and can thus be seen as *implicit* link adaptation. However, in contrast to link adaptation based on explicit estimates of the instantaneous channel conditions, hybrid ARQ with soft combining implicitly adjusts the coding rate based on the result of the decoding. In terms of overall throughput this kind of implicit link adaptation can be superior to explicit link adaptation, as additional redundancy is only added *when needed* – that is, when previous higher-rate transmissions were not possible to decode correctly. Furthermore, as it does not try to predict any channel variations, it works equally well, regardless of the speed at which the terminal is moving. Since implicit link adaptation can provide a gain in system throughput, a valid question is why explicit link adaptation is necessary at all. One major reason for having explicit link adaptation is the reduced delay. Although relying on implicit link adaptation alone is sufficient from a system throughput perspective, the end-user service quality may not be acceptable from a delay perspective.

Petitioners' Exhibit 1003, p. 452
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CHAPTER

LTE Radio Access: An Overview

7

The work on LTE was initiated in late 2004 with the overall aim of providing a new radio-access technology focusing on packet-switched data only. The first phase of the 3GPP work on LTE was to define a set of performance and capability targets for LTE [10]. This included targets on peak data rates, user/system throughput, spectral efficiency, and control/user-plane latency. In addition, requirements were also set on spectrum flexibility, as well as on interaction/compatibility with other 3GPP radio-access technologies (GSM, WCDMA/HSPA, and TD-SCDMA).

Once the targets were set, 3GPP studies on the feasibility of different technical solutions considered for LTE were followed by development of the detailed specifications. The first release of the LTE specifications, release 8, was completed in the spring of 2008 and commercial network operation began in late 2009. Release 8 has then been followed by additional LTE releases, introducing additional functionality and capabilities in different areas, as illustrated in Figure 7.1.

In parallel to the development of LTE, there has also been an evolution of the overall 3GPP network architecture, termed *System Architecture Evolution* (SAE), including both the radio-access network and the core network. Requirements were also set on the architecture evolution, leading to a new flat radio-access-network architecture with a single type of node, the *eNodeB*[1], as well as a new core-network architecture. An excellent description of the LTE-associated core-network architecture, the *Evolved Packet Core* (EPC), can be found in [9].

The remaining part of this chapter provides an overview of LTE up to and including release 10. The most important technologies used by LTE release 8 – including transmission schemes, scheduling, multi-antenna support, and spectrum flexibility – are covered, as well as the additional features introduced in LTE releases 9 and 10. The chapter can either be read on its own to get a high-level overview of LTE, or as an introduction to the subsequent chapters.

The following chapters, Chapters 8–18, then contain a detailed description of the LTE radio-access technology. Chapter 8 provides an overview of the LTE protocol structure, including RLC, MAC, and the physical layer, explaining the logical and physical channels, and the related data flow. The time–frequency structure on which LTE is based is covered in Chapter 9, followed by a detailed description of the physical layer for downlink and uplink transmission in Chapters 10 and 11 respectively. Chapter 12 contains a description of the retransmission mechanisms used in LTE, followed by a discussion on power control, scheduling, and interference management in Chapter 13. Access procedures, necessary for a terminal to connect to the network, are the topic of Chapter 14. Chapter 15 covers the multicast/broadcast functionality of LTE and Chapter 16 describes relaying operation. Chapter 17 addresses how radio-frequency (RF) requirements are defined in LTE, taking into account the spectrum flexibility. Finally, Chapter 18 contains an assessment of the system performance of LTE.

[1] eNodeB is a 3GPP term that can roughly be seen as being equivalent to a base station, see further in Chapter 8.

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 454
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

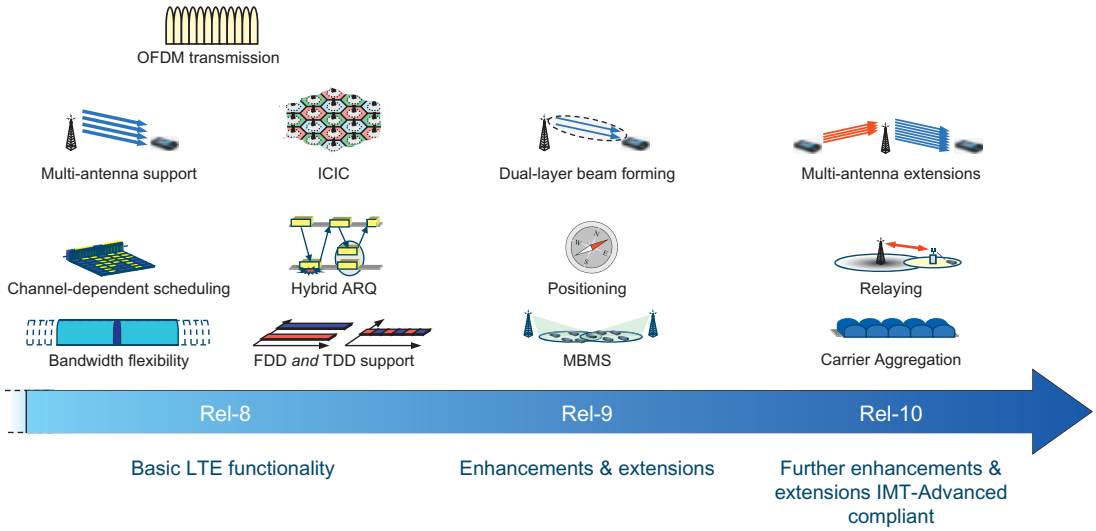


FIGURE 7.1

LTE and its evolution.

7.1 BASIC PRINCIPLES

Building upon the basic technologies described in the previous chapters, the main principles behind LTE will be described in the following.

7.1.1 Transmission Scheme

The LTE downlink transmission scheme is based on conventional OFDM. As discussed in Chapter 3, OFDM is an attractive transmission scheme for several reasons. Due to the relatively long OFDM symbol time in combination with a cyclic prefix, OFDM provides a high degree of robustness against channel frequency selectivity. Although signal corruption due to a frequency-selective channel can, in principle, be handled by equalization at the receiver side, the complexity of such equalization starts to become unattractively high for implementation in a terminal at larger bandwidths and especially in combination with advanced multi-antenna transmission schemes such as spatial multiplexing, thereby making OFDM an attractive choice for LTE for which a wide bandwidth and support for advanced multi-antenna transmission were key requirements.

OFDM also provides some additional benefits relevant for LTE:

- OFDM provides access to the frequency domain, thereby enabling an additional degree of freedom to the channel-dependent scheduler compared to time-domain-only scheduling used in major 3G systems.
- Flexible transmission bandwidth to support operation in spectrum allocations of different size is straightforward with OFDM, at least from a baseband perspective, by varying the number of OFDM subcarriers used for transmission. Note, however, that support of a flexible transmission

Petitioners' Exhibit 1003, p. 455
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

bandwidth also requires flexible RF filtering, etc., for which the exact transmission scheme is irrelevant. Nevertheless, maintaining the same baseband-processing structure, regardless of the bandwidth, eases terminal development and implementation.

- Broadcast/multicast transmission, where the same information is transmitted from multiple base stations, is straightforward with OFDM as already described in Chapter 3 and elaborated upon from an LTE perspective in Chapter 15.

Also, the LTE uplink is based on OFDM transmission. However, different means are taken to reduce the *cubic metric* of the uplink transmission, thereby enabling higher terminal power-amplifier efficiency. More specifically, for uplink data transmission, the OFDM modulator is preceded by a DFT precoder, leading to *DFT-spread OFDM* (DFTS-OFDM) as described in Chapter 4. Often, the term DFTS-OFDM is used to describe the LTE uplink transmission scheme in general. However, it should be understood that DFTS-OFDM is only applicable to uplink data transmission. Other means are used to achieve a low cubic metric for other types of uplink transmissions. Thus, the LTE uplink transmission scheme should be described as OFDM with different techniques, including DFT precoding for data transmission, being used to reduce the cubic metric of the transmitted signal.

The use of DFTS-OFDM on the LTE uplink allows for orthogonal separation of uplink transmissions also in the frequency domain. Orthogonal separation is in many cases beneficial as it avoids interference between uplink transmissions from different terminals within the cell (*intra-cell interference*). As discussed in Chapter 4, allocating a very large instantaneous bandwidth for transmission from a single terminal is not an efficient strategy in situations where the data rate is mainly limited by the available terminal transmit power rather than the bandwidth. In such situations, a terminal can instead be allocated only a part of the total available bandwidth and other terminals within the cell can be scheduled to transmit in parallel on the remaining part of the spectrum. In other words, the LTE uplink transmission scheme allows for both *time division* (TDMA) and *frequency division* (FDMA) between users.

7.1.2 Channel-Dependent Scheduling and Rate Adaptation

At the core of the LTE transmission scheme is the use of *shared-channel transmission* with the overall time–frequency resource dynamically shared between users. The use of shared-channel transmission is well matched to the rapidly varying resource requirements posed by packet-data communication and also enables several of the other key technologies on which LTE is based.

The scheduler controls, for each time instant, to which users the different parts of the shared resource should be assigned. The scheduler also determines the data rate to be used for each transmission. Thus, *rate adaptation* can be seen as a part of the scheduling functionality. The scheduler is thus a key element and to a large extent determines the overall system performance, especially in a highly loaded network. Both downlink and uplink transmissions are subject to tight scheduling in LTE. From Chapter 6 it is well known that a substantial gain in system capacity can be achieved if the channel conditions are taken into account in the scheduling decision, so-called *channel-dependent scheduling*. Due to the use of OFDM in both the downlink and uplink transmission directions, the scheduler has access to both the time and frequency domains. In other words, the scheduler can, for each time instant and frequency region, select the user with the best channel conditions, as illustrated in Figure 7.2.

Petitioners' Exhibit 1003, p. 456
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

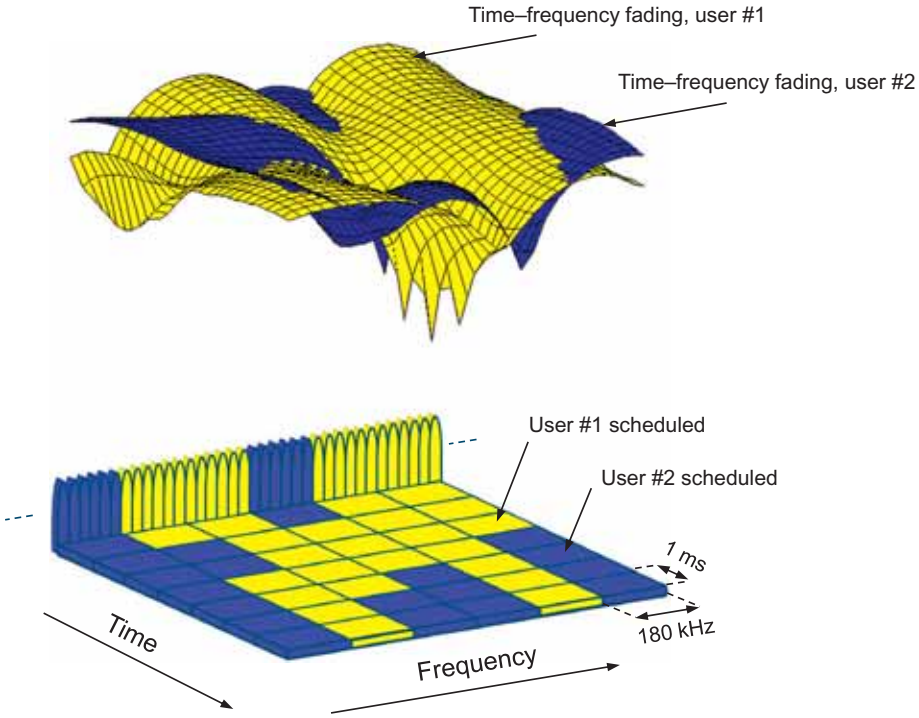


FIGURE 7.2

Downlink channel-dependent scheduling in the time and frequency domains.

The possibility of channel-dependent scheduling in the frequency domain is particularly useful at low terminal speeds – in other words, when the channel is varying slowly in time. As discussed in Chapter 6, channel-dependent scheduling relies on channel-quality variations between users to obtain a gain in system capacity. For delay-sensitive services, a time-domain-only scheduler may, due to the delay constraints, be forced to schedule a particular user, despite the channel quality not being at its peak. In such situations, exploiting channel-quality variations also in the frequency domain will help to improve the overall performance of the system. For LTE, scheduling decisions can be taken as often as once every 1 ms and the granularity in the frequency domain is 180 kHz. This allows for relatively rapid channel variations in both the time and frequency domains to be tracked and utilized by the scheduler.

To support downlink scheduling, a terminal may provide the network with *channel-state* reports indicating the instantaneous downlink channel quality in both the time and frequency domains. The channel state is typically obtained by measuring on *reference signals* transmitted in the downlink. Based on the channel-state reports, also referred to as *channel-state information* (CSI), the downlink scheduler can assign resources for downlink transmission to different terminals, taking the channel quality into account in the scheduling decision. In principle, a scheduled terminal can be assigned an arbitrary combination of 180 kHz wide *resource blocks* in each 1 ms scheduling interval.

Petitioners' Exhibit 1003, p. 457
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

As already mentioned, the LTE uplink is based on orthogonal separation of different uplink transmissions and it is the task of the uplink scheduler to assign resources in both the time and frequency domains to different terminals. Scheduling decisions, taken once per 1 ms, control what set of terminals are allowed to transmit within a cell during a given time interval and, for each terminal, on what frequency resources the transmission is to take place and what transmission parameters, including the data rate, to use.

Channel conditions can also be taken into account in the uplink scheduling process, similar to the downlink scheduling. However, as will be discussed in more detail in subsequent chapters, obtaining information about the uplink channel conditions may not be feasible or desirable in all situations. Therefore, different means to obtain *uplink diversity* are important as a complement in situations where uplink channel-dependent scheduling is not suitable.

7.1.3 Inter-Cell Interference Coordination

LTE is designed to operate with a one-cell frequency reuse, implying that the same time–frequency resources can be used in neighboring cells. In particular, the basic control channels are designed to operate properly also with the relatively low signal-to-interference ratio that may be experienced in a reuse-one deployment.

From an overall system-efficiency point-of-view, having access to the entire available spectrum in each cell and operating with one-cell reuse is always beneficial. However, it may also lead to relatively large variations in the signal-to-interference ratio, and thus also in the achievable data rates, over the cell area with potentially only relatively low data rates being available at the cell border. Thus, system performance, and especially the cell-edge user quality, can be further enhanced by allowing for some coordination in the scheduling between cells. The basic aim of such *inter-cell interference coordination* (ICIC) is to, if possible, avoid scheduling transmissions to/from terminals at the cell border simultaneously in neighboring cells, thereby avoiding the worst-case interference situations.

To support such interference coordination, the LTE specification includes several messages that can be communicated between eNodeBs using the so-called *X2 interface*, see Chapter 8. These messages provide information about the interference situation and/or scheduling strategies of the eNodeB issuing the message and can be used by an eNodeB receiving the message as input to its scheduling process. LTE interference coordination is discussed in more detail in Chapter 13.

An even more complicated interference situation may occur in so-called heterogeneous network deployments consisting of overlapping cell layers with large differences in the cell output power. This will be briefly discussed in Section 7.3.4 as part of the discussion on LTE release-10 features. The interference handling in heterogeneous network deployments will then be discussed in more detail in Chapter 13.

7.1.4 Hybrid ARQ with Soft Combining

Fast hybrid ARQ with soft combining is used in LTE to allow the terminal to rapidly request retransmissions of erroneously received transport blocks and to provide a tool for implicit rate adaptation. Retransmissions can be rapidly requested after each packet transmission, thereby minimizing the impact on end-user performance from erroneously received packets. Incremental redundancy is used as the soft combining strategy and the receiver buffers the soft bits to be able to perform soft combining between transmission attempts.

Petitioners' Exhibit 1003, p. 458
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.1.5 Multi-Antenna Transmission

Already from its first release, LTE included support for different multi-antenna transmission techniques as an integral part of the radio-interface specifications. In many respects, the use of multiple antennas is the key technology to reach many of the aggressive LTE performance targets. As discussed in Chapter 5, multiple antennas can be used in different ways for different purposes:

- Multiple receive antennas can be used for receive diversity. For uplink transmissions, this has been used in many cellular systems for several years. However, as dual receive antennas are the baseline for all LTE terminals, the downlink performance is also improved. The simplest way of using multiple receive antennas is classical receive diversity to collect additional energy and suppress fading, but additional gains can be achieved in interference-limited scenarios if the antennas are used not only to provide diversity, but also to suppress interference, as discussed in Chapter 5.
- Multiple transmit antennas at the base station can be used for transmit diversity and different types of beam-forming. The main goal of beam-forming is to improve the received SINR and, eventually, improve system capacity and coverage.
- *Spatial multiplexing*, sometimes referred to as MIMO, using multiple antennas at both the transmitter and receiver is supported by LTE. Spatial multiplexing results in an increased data rate, channel conditions permitting, in bandwidth-limited scenarios by creating several parallel "channels", as described in Chapter 5. Alternatively, by combining the spatial properties with the appropriate interference-suppressing receiver processing, multiple terminals can transmit on the same time–frequency resource in order to improve the overall cell capacity. This is sometimes referred to as *multi-user MIMO*.

In general, the different multi-antenna techniques are beneficial in different scenarios. As an example, at relatively low SINR, such as at high load or at the cell edge, spatial multiplexing provides relatively limited benefits. Instead, in such scenarios multiple antennas at the transmitter side should be used to raise the SINR by means of beam-forming. On the other hand, in scenarios where there already is a relatively high SINR, for example in small cells, raising the signal quality further provides relatively minor gains as the achievable data rates are then mainly bandwidth limited rather than SINR limited. In such scenarios, spatial multiplexing should instead be used to fully exploit the good channel conditions. The multi-antenna scheme used is under control of the base station, which therefore can select a suitable scheme for each transmission.

Up to four layers can be spatially multiplexed in release 8. Later releases further enhance the multi-antenna support, as described later.

7.1.6 Spectrum Flexibility

A high degree of spectrum flexibility is one of the main characteristics of the LTE radio-access technology. The aim of this spectrum flexibility is to allow for the deployment of LTE radio access in difference frequency bands with different characteristics, including different duplex arrangements and different sizes of the available spectrum. Chapter 17 outlines further details of how spectrum flexibility is achieved in LTE.

7.1.6.1 *Flexibility in Duplex Arrangement*

One important part of the LTE requirements in terms of spectrum flexibility is the possibility to deploy LTE-based radio access in both paired *and* unpaired spectrum. Therefore, LTE supports both

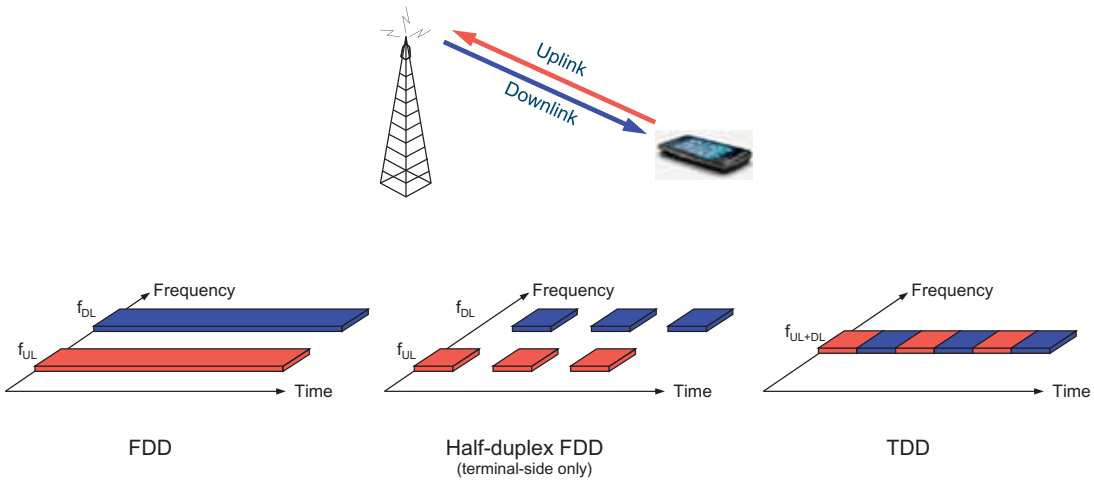


FIGURE 7.3

Frequency- and time-division duplex.

frequency- and time-division-based duplex arrangements. *Frequency-Division Duplex* (FDD), as illustrated on the left in Figure 7.3, implies that downlink and uplink transmission take place in different, sufficiently separated, frequency bands. *Time-Division Duplex* (TDD), as illustrated on the right in Figure 7.3, implies that downlink and uplink transmission take place in different, non-overlapping time slots. Thus, TDD can operate in unpaired spectrum, whereas FDD requires paired spectrum. The required flexibility and resulting requirements to support LTE operation in different paired and unpaired frequency arrangements are further discussed in Chapter 17.

Operation in both paired and unpaired spectrum has been supported by 3GPP radio-access technologies even before the introduction of LTE by means of FDD-based WCDMA/HSPA in combination with TDD-based TD-SCDMA radio. However, this was then achieved by means of, at least in the details, relatively different radio-access technologies leading to additional effort and complexity when developing and implementing dual-mode terminals capable of both FDD and TDD operation. LTE, on the other hand, supports both FDD and TDD *within a single radio-access technology*, leading to a minimum of deviation between FDD and TDD for LTE-based radio access. As a consequence of this, the overview of the LTE radio access provided in the following chapters is, to a large extent, valid for both FDD and TDD. In the case of differences between FDD and TDD, these differences will be explicitly indicated. Furthermore, the TDD mode, also known as TD-LTE, is designed with coexistence between TD-LTE and TD-SCDMA in mind to simplify a gradual migration from TD-SCDMA to TD-LTE.

LTE also supports *half-duplex* FDD at the terminal (illustrated in the middle of Figure 7.3). In half-duplex FDD, transmission and reception *at a specific terminal* are separated in both frequency and time. The base station still uses full-duplex FDD as it simultaneously may schedule *different* terminals in uplink and downlink; this is similar to, for example, GSM operation. The main benefit with half-duplex FDD is the reduced terminal complexity as no duplex filter is needed in the terminal. This is especially beneficial in the case of multi-band terminals which otherwise would need multiple sets of duplex filters.

Petitioners' Exhibit 1003, p. 460
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.1.6.2 *Bandwidth Flexibility*

An important characteristic of LTE is the possibility for different transmission bandwidths on both downlink and uplink. The main reason for this is that the amount of spectrum available for LTE deployment may vary significantly between different frequency bands and also depending on the exact situation of the operator. Furthermore, the possibility of operating in different spectrum allocations gives the possibility for gradual migration of spectrum from other radio-access technologies to LTE.

LTE supports operation in a wide range of spectrum allocations, achieved by a flexible transmission bandwidth being part of the LTE specifications. To efficiently support very high data rates when spectrum is available, a wide transmission bandwidth is necessary, as discussed in Chapter 2. However, a sufficiently large amount of spectrum may not always be available, either due to the band of operation or due to a gradual migration from another radio-access technology, in which case LTE can be operated with a more narrow transmission bandwidth. Obviously, in such cases, the maximum achievable data rates will be reduced accordingly. As discussed below, the spectrum flexibility is further improved in later releases of LTE.

The LTE physical-layer specifications [61–64] are bandwidth agnostic and do not make any particular assumption on the supported transmission bandwidths beyond a minimum value. As will be seen in the following, the basic radio-access specification, including the physical-layer and protocol specifications, allows for any transmission bandwidth ranging from roughly 1 MHz up to around 20 MHz. At the same time, at an initial stage, radio-frequency requirements are only specified for a limited subset of transmission bandwidths, corresponding to what is predicted to be relevant spectrum-allocation sizes and relevant migration scenarios. Thus, in practice the LTE radio-access technology supports a limited set of transmission bandwidths, but additional transmission bandwidths can easily be introduced by updating only the RF specifications.

7.2 LTE RELEASE 9

After completing the first release of LTE, work continued in 3GPP with introducing additional functionality in the second release of the LTE specifications, release 9. The main enhancements seen in release 9, completed in late 2009, were support for multicast transmission, support for network-assisted positioning services, and enhancements to beam-forming in the downlink.

7.2.1 Multicast and Broadcast Support

Multi-cell broadcast implies transmission of the same information from multiple cells, as described in Chapter 3. By exploiting this at the terminal, effectively using signal power from multiple cell sites at the detection, a substantial improvement in coverage (or higher broadcast data rates) can be achieved. By transmitting not only identical signals from multiple cell sites (with identical coding and modulation), but also synchronizing the transmission timing between the cells, the signal at the terminal will appear exactly as a signal transmitted from a single cell site and subject to multi-path propagation. Due to the OFDM robustness to multi-path propagation, such multi-cell transmission, in 3GPP also referred to as *Multicast/Broadcast Single-Frequency Network* (MBSFN) transmission, will then not only improve the received signal strength, but also eliminate the inter-cell interference as described in

Petitioners' Exhibit 1003, p. 461
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Chapter 3. Thus, with OFDM, multi-cell broadcast/multicast throughput may eventually be limited by noise only and can then, in the case of small cells, reach extremely high values.

It should be noted that the use of MBSFN transmission for multi-cell broadcast/multicast assumes the use of tight synchronization and time alignment of the signals transmitted from different cell sites.

7.2.2 Positioning

Positioning, as the name implies, refers to functionality in the radio-access network to determine the location of individual terminals. Determining the position of a terminal can, in principle, be done by including a GPS receiver in the terminal. Although this is a quite common feature, not all terminals include the necessary GSP receiver and there may also be cases when the GPS service is not available. LTE release 9 therefore introduces positioning support inherent in the radio-access network. By measuring on special reference signals transmitted regularly from different cell sites, the location of the terminal can be determined.

7.2.3 Dual-Layer Beam-Forming

Release 9 enhances the support for combining spatial multiplexing with beam-forming. Although the combination of beam-forming and spatial multiplexing was already possible in release 8, this was then restricted to so-called *codebook-based precoding* (see Chapter 10). In release 9, spatial multiplexing can be combined with so-called *non-codebook-based precoding*, thereby improving the flexibility in deploying various multi-antenna schemes. The enhancements can also be seen as the basis for a further improvement in the area in LTE release10.

7.3 LTE RELEASE 10 AND IMT-ADVANCED

As described in Chapter 1, *IMT-Advanced* is the term used by the ITU for radio-access technologies beyond IMT-2000. As a first step in defining IMT-Advanced, the ITU defined a set of requirements that any IMT-Advanced compliant technology should fulfill [65]. Examples of these requirements are support for at least 40 MHz bandwidth, peak spectral efficiencies of 15 bit/s/Hz in downlink and 6.75 bit/s/Hz in uplink (corresponding to peak rates of at least 600 and 270 Mbit/s respectively), and control and user plane latency of less than 100 and 10 ms respectively.

One of the main targets of LTE release 10 was to ensure that the LTE radio-access technology would be fully compliant with the IMT-Advanced requirements, thus the name *LTE-Advanced* is often used for LTE release 10. However, in addition to the ITU requirements, 3GPP also defined its own targets and requirements [66] for LTE release 10 (LTE-Advanced). These targets/requirements extended the ITU requirements both in terms of being more aggressive as well as including additional requirements. One important requirement was *backwards compatibility*. Essentially this means that an earlier-release LTE terminal should always be able to access a carrier supporting LTE release-10 functionality, although obviously not being able to utilize all the release-10 features of that carrier.

LTE release 10 was completed in late 2010 and enhances LTE spectrum flexibility through *carrier aggregation*, further extends multi-antenna transmission, introduces support for *relaying*, and provides improvements in the area of inter-cell interference coordination in *heterogeneous network deployments*.

Petitioners' Exhibit 1003, p. 462
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

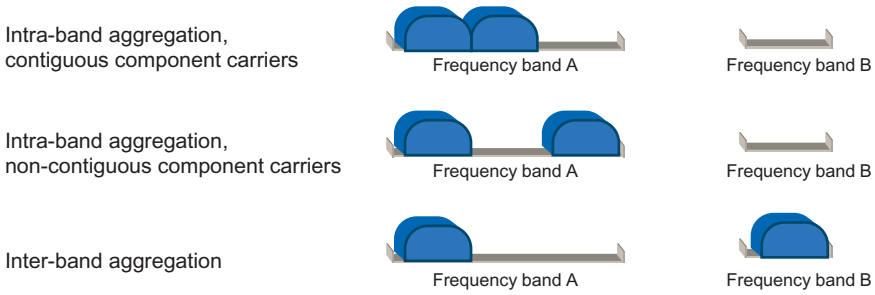


FIGURE 7.4

Carrier aggregation.

7.3.1 Carrier Aggregation

As mentioned earlier, the first release of LTE already provided extensive support for deployment in spectrum allocations of various characteristics, with bandwidths ranging from roughly 1 MHz up to 20 MHz in both paired and unpaired bands. In LTE release 10 the transmission bandwidth can be further extended by means of so-called *carrier aggregation* (CA), where multiple *component carriers* are aggregated and jointly used for transmission to/from a single terminal. Up to five component carriers, possibly each of different bandwidth, can be aggregated, allowing for transmission bandwidths up to 100 MHz. Backwards compatibility is catered for as each component carrier uses the release-8 structure. Hence, to a release-8/9 terminal each component carrier will appear as an LTE release-8 carrier, while a carrier-aggregation-capable terminal can exploit the total aggregated bandwidth, enabling higher data rates. In the general case, a different number of component carriers can be aggregated for the downlink and uplink.

Component carriers do not have to be contiguous in frequency, which enables exploitation of *fragmented spectrum*; operators with a fragmented spectrum can provide high-data-rate services based on the availability of a wide overall bandwidth even though they do not posses a single wideband spectrum allocation. From a baseband perspective, there is no difference between the cases in Figure 7.4 and they are all supported by LTE release 10. However, the RF-implementation complexity is vastly different with the first case being the least complex. Thus, although spectrum aggregation is supported by the basic specifications, the actual release-10 RF requirements will be strongly constrained, including specification of only a limited number of aggregation scenarios and including support of inter-band aggregation only for the most advanced terminals, but excluding non-contiguous intra-band aggregation.

7.3.2 Extended Multi-Antenna Transmission

In release 10, downlink spatial multiplexing is expanded to support up to eight transmission layers. Along with this, and as discussed in more detail in Chapter 10 an enhanced *reference-signal structure* is introduced to improve the support of various beam-forming solutions. This can be seen as an extension of the release-9 dual-layer beam-forming to support up to eight antenna ports and eight corresponding layers. Together with the support for carrier aggregation, this enables downlink data rates up to 3 Gbit/s or 30 bit/s/Hz.

Petitioners' Exhibit 1003, p. 463
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

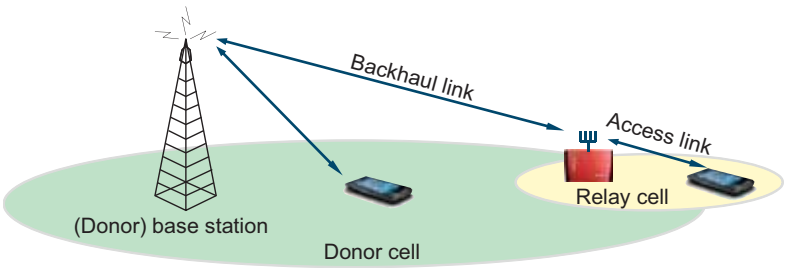


FIGURE 7.5

Example of relaying.

Uplink spatial multiplexing of up to four layers is also part of release 10. It consists of a codebook-based scheme under control of the base station, which means that the structure can also be used for uplink transmit-side beam-forming. Together with the possibility for uplink carrier aggregations, this allows for uplink data rates up to 1.5 Gbit/s or 15 bit/s/Hz.

7.3.3 Relaying

Relaying implies that the terminal communicates with the network via a *relay node* that is *wirelessly connected* to a *donor cell* using the LTE radio-interface technology (Figure 7.5). From a terminal point of view, the relay node will appear as an ordinary cell. This has the important advantage of simplifying the terminal implementation and making the relay node backwards compatible – that is, also accessible to LTE release-8/9 terminals. In essence, the relay is a low-power base station wirelessly connected to the remaining part of the network. One of the attractive features of a relay is the LTE-based wireless backhaul, as this could provide a simple way of improving coverage, for example in indoor environments, by simply placing relays at the problematic locations. At a later stage, if motivated by the traffic situation, the wireless donor-relay link could be replaced by an optical fiber in order to use the precious radio resources in the donor cell for terminal communication instead of serving the relay.

7.3.4 Heterogeneous Deployments

Heterogeneous deployments refer to deployments with a mixture of cells with different downlink transmission power, operating on (partially) the same set of frequencies and with overlapping geographical coverage (Figure 7.6). A typical example is a pico cell placed within the coverage area of a macro cell. Although such deployments were already supported in release 8, release 10 introduced improved inter-cell interference handling focusing on scenarios with large power differences between overlapping cells.

7.4 TERMINAL CAPABILITIES

To support different scenarios, which may call for different terminal capabilities in terms of data rates, as well as to allow for market differentiation in terms of low- and high-end terminals with a

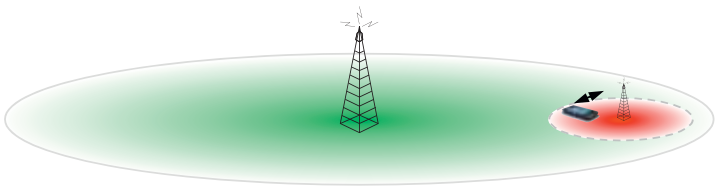


FIGURE 7.6

Example of heterogeneous deployment with a pico cell inside a macro cell.

Table 7.1 UE Categories

	Category							
	Release 8/9/10					Release 10 only		
	1	2	3	4	5	6	7	8
Downlink peak rate (Mbit/s)	10	50	100	150	300	300	300	3000
Uplink peak rate (Mbit/s)	5	25	50	50	75	50	150	1500
Maximum downlink modulation	64QAM							
Maximum uplink modulation	16QAM				64QAM	16QAM	64QAM	
Max. number of layers for downlink spatial multiplexing	1	2			4	Signaled separately		

corresponding difference in price, not all terminals support all capabilities. Furthermore, terminals from an earlier release of the standard will not support features introduced in later versions of LTE. For example, a release-8 terminal will obviously not support carrier aggregation as this feature was introduced in release 10. Therefore, as part of the connection setup, the terminal indicates not only which release of LTE it supports, but also its capabilities within the release.

In principle, the different parameters could be specified separately, but to limit the number of combinations and avoid a parameter combination that does not make sense, a set of physical-layer capabilities are lumped together to form a UE category (UE, *User Equipment*, is the term used in 3GPP to denote a terminal). In total five different UE categories have been specified for LTE release 8/9, ranging from the low-end category 1 not supporting spatial multiplexing to the high-end category 5 supporting the full set of features in the release-8/9 physical layer specifications. The categories are summarized in Table 7.1 (in simplified form; for the full set of details, see [67]). Note that, regardless

Petitioners' Exhibit 1003, p. 465
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

of the category, a terminal is always capable of receiving transmissions from up to four antenna ports. This is necessary as the system information can be transmitted on up to four antenna ports.

In LTE release 10, features such as carrier aggregation and uplink spatial multiplexing are introduced, which calls for additional capability signaling compared to release 8/9, either in the form of additional UE categories or as separate capabilities. Defining new categories for each foreseen combination of the maximum number of component carriers and maximum degree of spatial multiplexing could be done in principle, although the number of categories might become very large and which categories a terminal support may be frequency-band dependent. Therefore, in release 10, three additional UE categories were defined as seen in Table 7.1, and the maximum number of component carriers and degree of spatial multiplexing supported, both in uplink and downlink, are signaled separately from the category number. A release-10 terminal may therefore declare itself as, for example, category 4 but capable of uplink spatial multiplexing. Hence, categories 1–5 may have a slightly different meaning for a release-8/9 and a release-10 terminal, depending on the value of the separately declared capabilities. Furthermore, in order to be able to operate in release-8/9 networks, a release-10 UE has to be able to declare both release-8/9 and release-10 categories.

In addition to the capabilities mentioned in the different UE categories, there are some capabilities specified outside the categories. The duplexing schemes supported is one such example, the support of UE-specific reference signals for FDD in release 8 is another. Whether the terminal supports other radio-access technologies, for example GSM and WCDMA, is also declared separately.

Petitioners' Exhibit 1003, p. 466
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CHAPTER

Radio-Interface Architecture

8

This chapter contains a brief overview of the overall architecture of an LTE radio-access network and the associated core network, followed by descriptions of the radio-access network user-plane and control-plane protocols.

8.1 OVERALL SYSTEM ARCHITECTURE

In parallel to the work on the LTE radio-access technology in 3GPP, the overall system architecture of both the *Radio-Access Network* (RAN) and the *Core Network* (CN) was revisited, including the split of functionality between the two network parts. This work was known as the *System Architecture Evolution* (SAE) and resulted in a flat RAN architecture, as well as a new core network architecture referred to as the *Evolved Packet Core* (EPC). Together, the LTE RAN and the EPC can be referred to as the *Evolved Packet System* (EPS).[1]

The RAN is responsible for all radio-related functionality of the overall network including, for example, scheduling, radio-resource handling, retransmission protocols, coding and various multi-antenna schemes. These functions will be discussed in detail in the subsequent chapters.

The EPC is responsible for functions not related to the radio interface but needed for providing a complete mobile-broadband network. This includes, for example, authentication, charging functionality, and setup of end-to-end connections. Handling these functions separately, instead of integrating them into the RAN, is beneficial as it allows for several radio-access technologies to be served by the same core network.

Although this book focuses on the LTE RAN, a brief overview of the EPC, as well as how it connects to the RAN, is useful. For an excellent in-depth discussion of EPC, the reader is referred to [9].

8.1.1 Core Network

The EPC is a radical evolution from the GSM/GPRS core network used for GSM and WCDMA/HSPA. EPC supports access to the *packet-switched domain* only, with no access to *the circuit-switched domain*. It consists of several different types of nodes, some of which are briefly described below and illustrated in Figure 8.1.

[1] UTRAN, the WCDMA/HSPA radio-access network, is also part of the EPS.

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 468
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

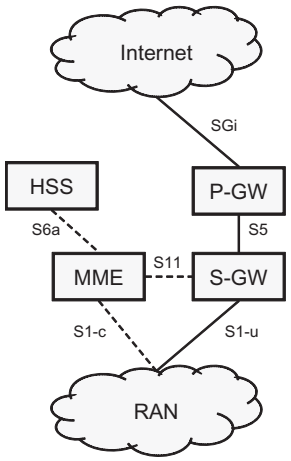


FIGURE 8.1

Core-network (EPC) architecture.

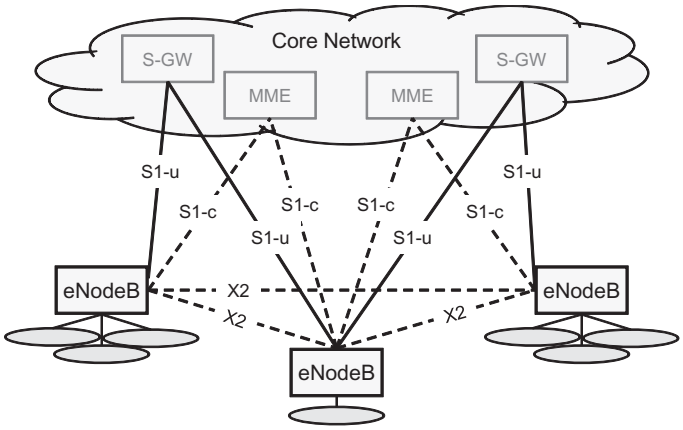


FIGURE 8.2

Radio-access-network interfaces.

The *Mobility Management Entity* (MME) is the control-plane node of the EPC. Its responsibilities include connection/release of bearers to a terminal, handling of IDLE to ACTIVE transitions, and handling of security keys. The functionality operating between the EPC and the terminal is sometimes referred to as the *Non-Access Stratum* (NAS), to separate it from the *Access Stratum* (AS) which handles functionality operating between the terminal and the radio-access network.

The *Serving Gateway* (S-GW) is the user-plane node connecting the EPC to the LTE RAN. The S-GW acts as a mobility anchor when terminals move between eNodeBs (see next section), as well as a mobility anchor for other 3GPP technologies (GSM/GPRS and HSPA). Collection of information and statistics necessary for charging is also handled by the S-GW.

The *Packet Data Network Gateway* (PDN Gateway, P-GW) connects the EPC to the internet. Allocation of the IP address for a specific terminal is handled by the P-GW, as well as quality-of-service enforcement according to the policy controlled by the PCRF (see below). The P-GW is also the mobility anchor for non-3GPP radio-access technologies, such as CDMA2000, connected to the EPC.

In addition, the EPC also contains other types of nodes such as *Policy and Charging Rules Function* (PCRF) responsible for quality-of-service (QoS) handling and charging, and the *Home Subscriber Service* (HSS) node, a database containing subscriber information. There are also some additional nodes present as regards network support of *Multimedia Broadcast Multicast Services* (MBMS) (see Chapter 15 for a more detailed description of MBMS, including the related architecture aspects).

It should be noted that the nodes discussed above are *logical* nodes. In an actual physical implementation, several of them may very well be combined. For example, the MME, P-GW, and S-GW could very well be combined into a single physical node.

Petitioners' Exhibit 1003, p. 469
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

8.1.2 Radio-Access Network

The LTE radio-access network uses a flat architecture with a single type of node[2] – the *eNodeB*. The eNodeB is responsible for all radio-related functions in one or several cells. It is important to note that an eNodeB is a *logical* node and not a physical implementation. One common implementation of an eNodeB is a three-sector site, where a base station is handling transmissions in three cells, although other implementations can be found as well, such as one baseband processing unit to which a number of remote radio heads are connected. One example of the latter is a large number of indoor cells, or several cells along a highway, belonging to the same eNodeB. Thus, a base station is a *possible* implementation of, but not *the same* as, an eNodeB.

As can be seen in Figure 8.2, the eNodeB is connected to the EPC by means of the *S1 interface*, more specifically to the S-GW by means of the *S1 user-plane part*, S1-u, and to the MME by means of the *S1 control-plane part*, S1-c. One eNodeB can be connected to multiple MMEs/S-GWs for the purpose of load sharing and redundancy.

The *X2 interface*, connecting eNodeBs to each other, is mainly used to support active-mode mobility. This interface may also be used for multi-cell *Radio Resource Management* (RRM) functions such as *Inter-Cell Interference Coordination* (ICIC) discussed in Chapter 13. The X2 interface is also used to support lossless mobility between neighboring cells by means of packet forwarding.

8.2 RADIO PROTOCOL ARCHITECTURE

With the overall network architecture in mind, the RAN protocol architecture for the user as well as the control planes can be discussed. Figure 8.3 illustrates the RAN protocol architecture (the MME is, as discussed in the previous section, not part of the RAN but is included in the figure for completeness). As seen in the figure, many of the protocol entities are common to the user and control planes. Therefore, although this section mainly describes the protocol architecture from a user-plane perspective, the description is in many respects also applicable to the control plane. Control-plane-specific aspects are discussed in Section 8.3.

The LTE radio-access network provides one or more *Radio Bearers* to which IP packets are mapped according to their Quality-of-Service requirements. A general overview of the LTE (user-plane) protocol architecture for the downlink is illustrated in Figure 8.4. As will become clear in the subsequent discussion, not all the entities illustrated in Figure 8.4 are applicable in all situations. For example, neither MAC scheduling nor hybrid ARQ with soft combining is used for broadcast of the basic system information. The LTE protocol structure related to uplink transmissions is similar to the downlink structure in Figure 8.4, although there are some differences with respect to, for example, transport-format selection.

The different protocol entities of the radio-access network are summarized below and described in more detail in the following sections.

- *Packet Data Convergence Protocol* (PDCP) performs IP header compression to reduce the number of bits to transmit over the radio interface. The header-compression mechanism is based

[2]The introduction of MBMS (see Chapter 15) in release 9 and relaying (see Chapter 16) in release 10 brings additional node types to the RAN.

Petitioners' Exhibit 1003, p. 470
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

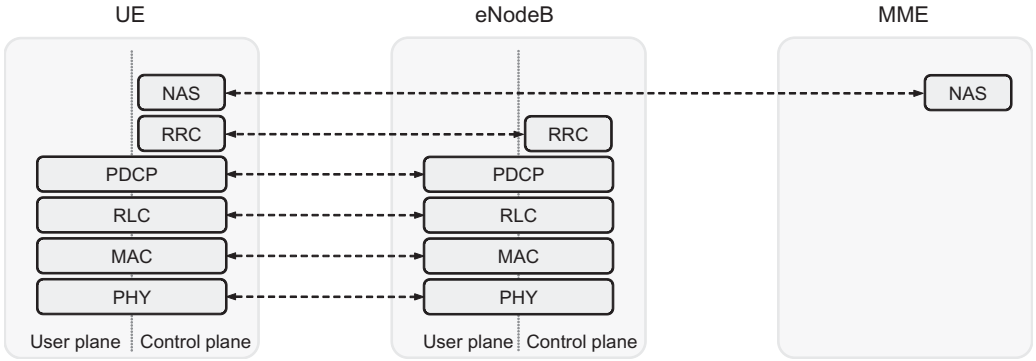


FIGURE 8.3

Overall RAN protocol architecture.

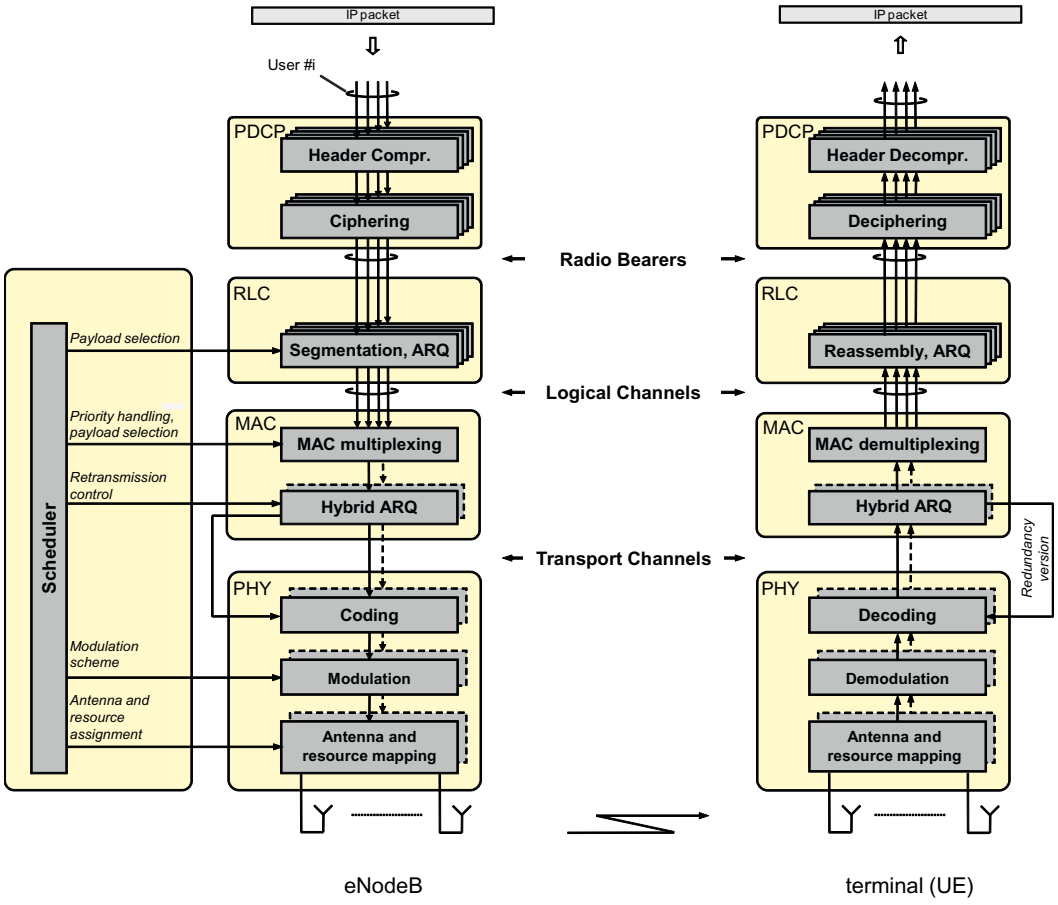


FIGURE 8.4

LTE protocol architecture (downlink).

Petitioners' Exhibit 1003, p. 471
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

on Robust Header Compression (ROHC) [68], a standardized header-compression algorithm also used for several mobile-communication technologies. PDCP is also responsible for ciphering and, for the control plane, integrity protection of the transmitted data, as well as in-sequence delivery and duplicate removal for handover. At the receiver side, the PDCP protocol performs the corresponding deciphering and decompression operations. There is one PDCP entity per radio bearer configured for a terminal.

- *Radio-Link Control* (RLC) is responsible for segmentation/concatenation, retransmission handling, duplicate detection, and in-sequence delivery to higher layers. The RLC provides services to the PDCP in the form of *radio bearers*. There is one RLC entity per radio bearer configured for a terminal.
- *Medium-Access Control* (MAC) handles multiplexing of logical channels, hybrid-ARQ retransmissions, and uplink and downlink scheduling. The scheduling functionality is located in the eNodeB for both uplink and downlink. The hybrid-ARQ protocol part is present in both the transmitting and receiving ends of the MAC protocol. The MAC provides services to the RLC in the form of *logical channels*.
- *Physical Layer* (PHY) handles coding/decoding, modulation/demodulation, multi-antenna mapping, and other typical physical-layer functions. The physical layer offers services to the MAC layer in the form of *transport channels*.

To summarize the flow of downlink data through all the protocol layers, an example illustration for a case with three IP packets, two on one radio bearer and one on another radio bearer, is given in Figure 8.5. The data flow in the case of uplink transmission is similar. The PDCP performs (optional) IP-header compression, followed by ciphering. A PDCP header is added, carrying information required for deciphering in the terminal. The output from the PDCP is forwarded to the RLC.

The RLC protocol performs concatenation and/or segmentation of the PDCP SDUs[3] and adds an RLC header. The header is used for in-sequence delivery (per logical channel) in the terminal and for identification of RLC PDUs in the case of retransmissions. The RLC PDUs are forwarded to the MAC layer, which multiplexes a number of RLC PDUs and attaches a MAC header to form a transport block. The transport-block size depends on the instantaneous data rate selected by the link-adaptation mechanism. Thus, the link adaptation affects both the MAC and RLC processing. Finally, the physical layer attaches a CRC to the transport block for error-detection purposes, performs coding and modulation, and transmits the resulting signal, possibly using multiple transmit antennas.

The remainder of the chapter contains an overview of the RLC, MAC, and physical layers. A more detailed description of the LTE physical-layer processing is given in Chapters 10 (downlink) and 11 (uplink), followed by descriptions of some specific uplink and downlink radio-interface functions and procedures in the subsequent chapters.

8.2.1 Radio-Link Control

The RLC protocol is responsible for segmentation/concatenation of (header-compressed) IP packets, also known as RLC SDUs, from the PDCP into suitably sized RLC PDUs. It also handles

[3] In general, the data entity from/to a higher protocol layer is known as a Service Data Unit (SDU) and the corresponding entity to/from a lower protocol layer entity is called a Protocol Data Unit (PDU).

Petitioners' Exhibit 1003, p. 472
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

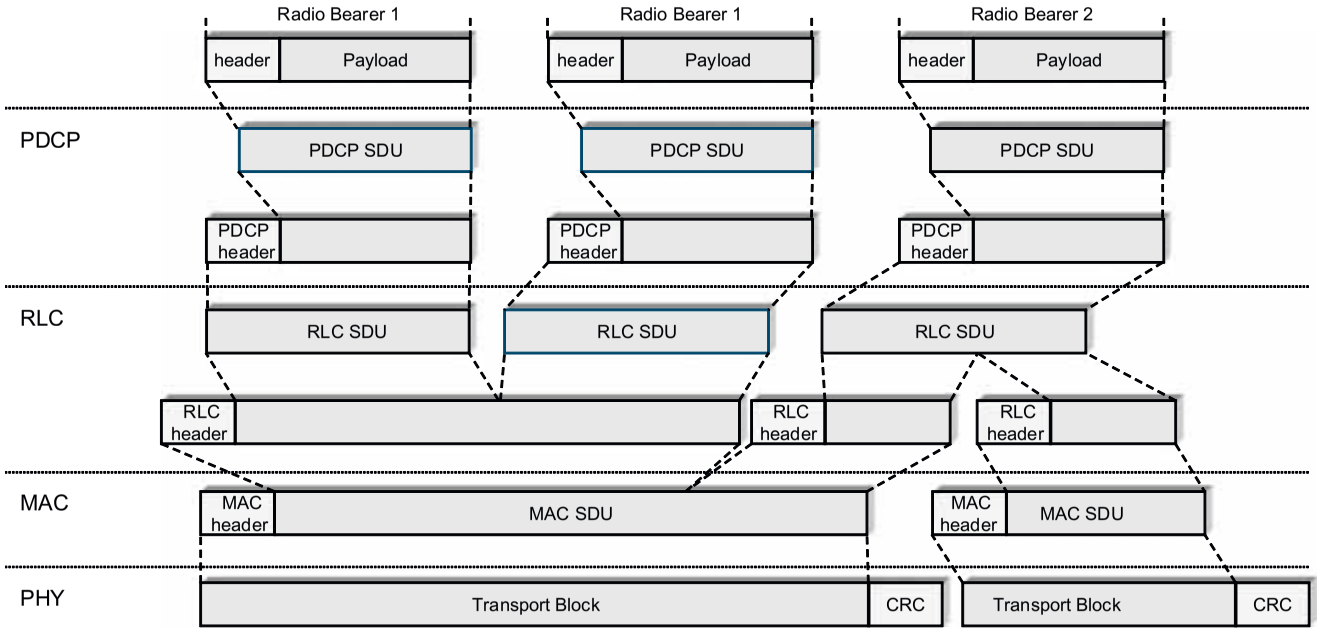


FIGURE 8.5

Example of LTE data flow.

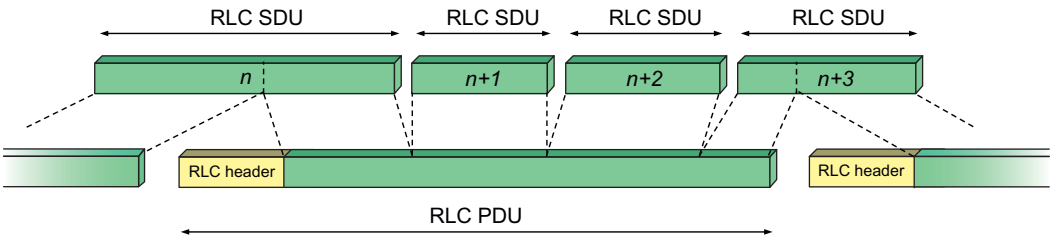


FIGURE 8.6

RLC segmentation and concatenation.

retransmission of erroneously received PDUs, as well as removal of duplicated PDUs. Finally, the RLC ensures in-sequence delivery of SDUs to upper layers. Depending on the type of service, the RLC can be configured in different modes to perform some or all of these functions.

Segmentation and concatenation, one of the main RLC functions, is illustrated in Figure 8.6. Depending on the scheduler decision, a certain amount of data is selected for transmission from the RLC SDU buffer and the SDUs are segmented/concatenated to create the RLC PDU. Thus, for LTE the RLC PDU size varies *dynamically*. For high data rates, a large PDU size results in a smaller relative overhead, while for low data rates, a small PDU size is required as the payload would otherwise be too large. Hence, as the LTE data rates may range from a few kbit/s up to 3 Gbit/s, dynamic PDU sizes are motivated for LTE in contrast to earlier mobile-communication technologies, which typically use a fixed PDU size. Since the RLC, scheduler, and rate adaptation mechanisms are all located in the eNodeB, dynamic PDU sizes are easily supported for LTE. In each RLC PDU, a header is included, containing, among other things, a sequence number used for in-sequence delivery and by the retransmission mechanism.

The RLC retransmission mechanism is also responsible for providing error-free delivery of data to higher layers. To accomplish this, a retransmission protocol operates between the RLC entities in the receiver and transmitter. By monitoring the sequence numbers of the incoming PDUs, the receiving RLC can identify missing PDUs. Status reports are then fed back to the transmitting RLC entity, requesting retransmission of missing PDUs. Based on the received status report, the RLC entity at the transmitter can take the appropriate action and retransmit the missing PDUs if needed.

Although the RLC is capable of handling transmission errors due to noise, unpredictable channel variations, etc., error-free delivery is in most cases handled by the MAC-based hybrid-ARQ protocol. The use of a retransmission mechanism in the RLC may therefore seem superfluous at first. However, as will be discussed in Section 8.2.2.3, this is not the case and the use of both RLC- and MAC-based retransmission mechanisms is in fact well motivated by the differences in the feedback signaling.

The details of RLC are further described in Chapter 12.

8.2.2 Medium-Access Control

The MAC layer handles logical-channel multiplexing, hybrid-ARQ retransmissions, and uplink and downlink scheduling. It is also responsible for multiplexing/demultiplexing data across multiple component carriers when carrier aggregation is used.

8.2.2.1 Logical Channels and Transport Channels

The MAC provides services to the RLC in the form of *logical channels*. A logical channel is defined by the *type* of information it carries and is generally classified as a *control channel*, used for transmission of control and configuration information necessary for operating an LTE system, or as a *traffic channel*, used for the user data. The set of logical-channel types specified for LTE includes:

- *The Broadcast Control Channel* (BCCH), used for transmission of *system information* from the network to all terminals in a cell. Prior to accessing the system, a terminal needs to acquire the system information to find out how the system is configured and, in general, how to behave properly within a cell.
- The *Paging Control Channel* (PCCH), used for paging of terminals whose location on a cell level is not known to the network. The paging message therefore needs to be transmitted in multiple cells.
- The *Common Control Channel* (CCCH), used for transmission of control information in conjunction with random access.
- The *Dedicated Control Channel* (DCCH), used for transmission of control information to/from a terminal. This channel is used for individual configuration of terminals such as different handover messages.
- The *Multicast Control Channel* (MCCH), used for transmission of control information required for reception of the MTCH (see below).
- The *Dedicated Traffic Channel* (DTCH), used for transmission of user data to/from a terminal. This is the logical channel type used for transmission of all uplink and non-MBSFN downlink user data.
- The *Multicast Traffic Channel* (MTCH), used for downlink transmission of MBMS services.

From the physical layer, the MAC layer uses services in the form of *transport channels*. A transport channel is defined by *how* and *with what characteristics* the information is transmitted over the radio interface. Data on a transport channel is organized into *transport blocks*. In each *Transmission Time Interval* (TTI), at most one transport block of dynamic size is transmitted over the radio interface to/from a terminal in the absence of spatial multiplexing. In the case of spatial multiplexing (MIMO), there can be up to two transport blocks per TTI.

Associated with each transport block is a *Transport Format* (TF), specifying *how* the transport block is to be transmitted over the radio interface. The transport format includes information about the transport-block size, the modulation-and-coding scheme, and the antenna mapping. By varying the transport format, the MAC layer can thus realize different data rates. Rate control is therefore also known as *transport-format selection*.

The following transport-channel types are defined for LTE:

- The *Broadcast Channel* (BCH) has a fixed transport format, provided by the specifications. It is used for transmission of parts of the BCCH system information, more specifically the so-called *Master Information Block* (MIB), as described in Chapter 14.
- The *Paging Channel* (PCH) is used for transmission of paging information from the PCCH logical channel. The PCH supports *discontinuous reception* (DRX) to allow the terminal to save battery power by waking up to receive the PCH only at predefined time instants. The LTE paging mechanism is also described in Chapter 14.

Petitioners' Exhibit 1003, p. 475
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

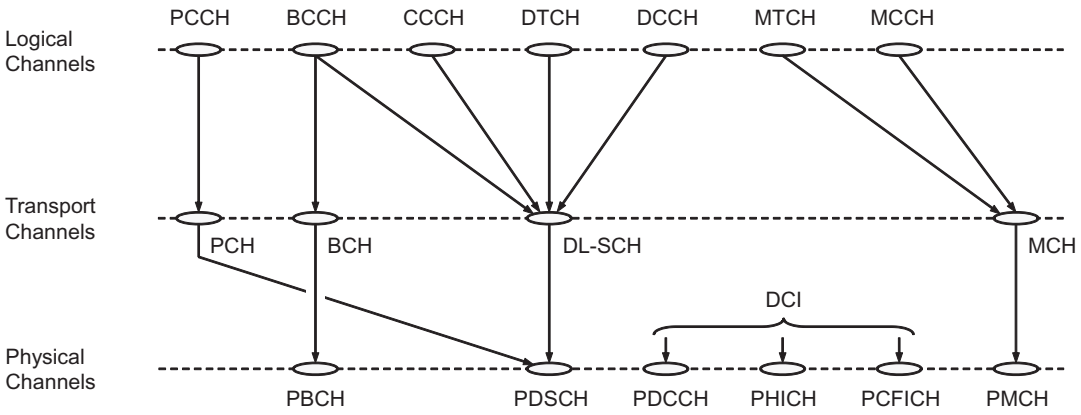


FIGURE 8.7

Downlink channel mapping.

- The *Downlink Shared Channel* (DL-SCH) is the main transport channel used for transmission of downlink data in LTE. It supports key LTE features such as dynamic rate adaptation and channel-dependent scheduling in the time and frequency domains, hybrid ARQ with soft combining, and spatial multiplexing. It also supports DRX to reduce terminal power consumption while still providing an always-on experience. The DL-SCH is also used for transmission of the parts of the BCCH system information not mapped to the BCH. There can be multiple DL-SCHs in a cell, one per terminal[4] scheduled in this TTI, and, in some subframes, one DL-SCH carrying system information.
- The *Multicast Channel* (MCH) is used to support MBMS. It is characterized by a semi-static transport format and semi-static scheduling. In the case of multi-cell transmission using MBSFN, the scheduling and transport format configuration is coordinated among the transmission points involved in the MBSFN transmission. MBSFN transmission is described in Chapter 15.
- The Uplink Shared Channel (UL-SCH) is the uplink counterpart to the DL-SCH – that is, the uplink transport channel used for transmission of uplink data.

In addition, the *Random-Access Channel* (RACH) is also defined as a transport channel, although it does not carry transport blocks.

Part of the MAC functionality is multiplexing of different logical channels and mapping of the logical channels to the appropriate transport channels. The supported mappings between logical-channel types and transport-channel types are given in Figure 8.7 for the downlink and Figure 8.8 for the uplink. The figures clearly indicate how DL-SCH and UL-SCH are the main downlink and uplink transport channels respectively. In the figures, the corresponding physical channels, described further below, are also included and the mapping between transport channels and physical channels is illustrated.

To support priority handling, multiple logical channels, where each logical channel has its own RLC entity, can be multiplexed into one transport channel by the MAC layer. At the receiver, the

[4]For carrier aggregation, a UE may receive multiple DL-SCHs, one per component carrier.

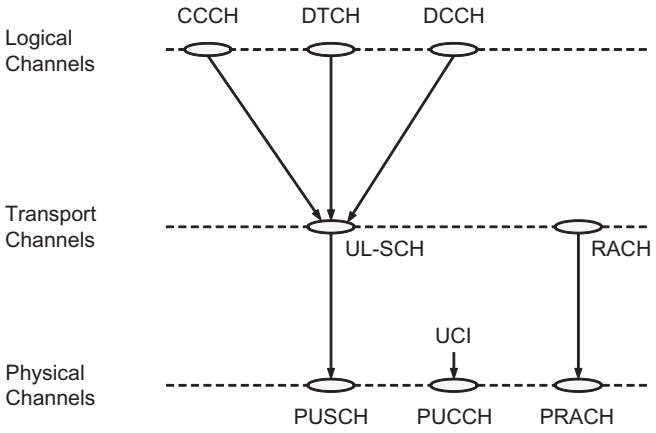


FIGURE 8.8

Uplink channel mapping.

MAC layer handles the corresponding demultiplexing and forwards the RLC PDUs to their respective RLC entity for in-sequence delivery and the other functions handled by the RLC. To support the demultiplexing at the receiver, a MAC header, shown in Figure 8.9, is used. To each RLC PDU, there is an associated sub-header in the MAC header. The sub-header contains the identity of the logical channel (LCID) from which the RLC PDU originated and the length of the PDU in bytes. There is also a flag indicating whether this is the last sub-header or not. One or several RLC PDUs, together with the MAC header and, if necessary, padding to meet the scheduled transport-block size, form one transport block which is forwarded to the physical layer.

In addition to multiplexing of different logical channels, the MAC layer can also insert the so-called *MAC control elements* into the transport blocks to be transmitted over the transport channels. A MAC control element is used for inband control signaling – for example, timing-advance commands and random-access response, as described in Sections 11.5 and 14.3 respectively. Control elements are identified with reserved values in the LCID field, where the LCID value indicates the type of control information. Furthermore, the length field in the sub-header is removed for control elements with a fixed length.

The MAC multiplexing functionality is also responsible for handling of multiple component carriers in the case of carrier aggregation. The basic principle for carrier aggregation is independent processing of the component carriers in the physical layer, including control signaling, scheduling and hybrid-ARQ retransmissions, while carrier aggregation is invisible to RLC and PDCP. Carrier aggregation is therefore mainly seen in the MAC layer, as illustrated in Figure 8.10, where logical channels, including any MAC control elements, are multiplexed to form one (two in the case of spatial multiplexing) transport block(s) per component carrier with each component carrier having its own hybrid-ARQ entity.

8.2.2.2 Scheduling

One of the basic principles of LTE radio access is shared-channel transmission – that is, time–frequency resources are dynamically shared between users. The *scheduler* is part of the MAC layer

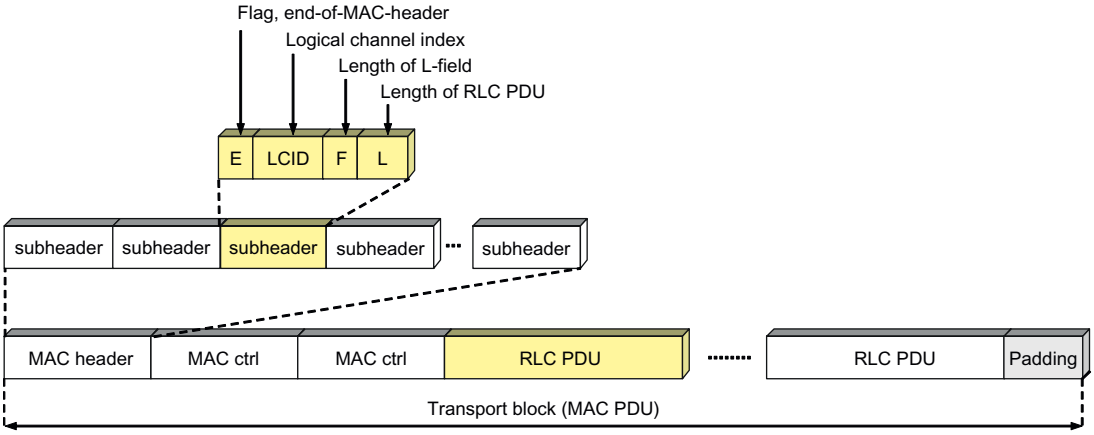


FIGURE 8.9

MAC header and SDU multiplexing.

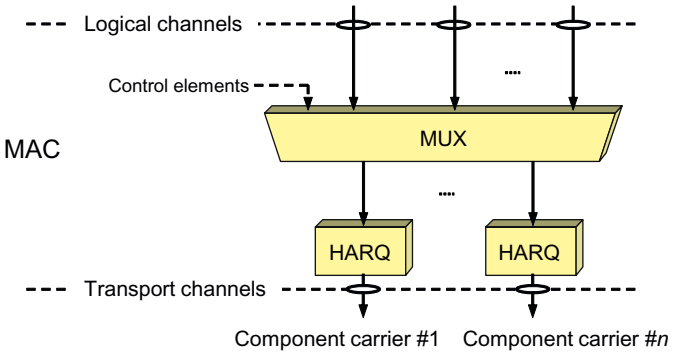


FIGURE 8.10

MAC operation in the case of multiple component carriers.

(although often better viewed as a separate entity as illustrated in Figure 8.4) and controls the assignment of uplink and downlink resources in terms of so-called *resource-block pairs.* Resource blocks correspond to a time–frequency unit of 1 ms times 180 kHz, as described in more detail in Chapter 9.

The basic operation of the scheduler is so-called *dynamic* scheduling, where the eNodeB in each 1 ms interval takes a scheduling decision and sends scheduling information to the selected set of terminals. However, there is also a possibility for semi-persistent scheduling where a semi-static scheduling pattern is signaled in advance to reduce the control-signaling overhead. Coordination of scheduling decisions across multiple cells residing in different eNodeBs is supported using signaling over the X2 interface.

Petitioners' Exhibit 1003, p. 478
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Uplink and downlink scheduling are separated in LTE, and uplink and downlink scheduling decisions can be taken independently of each other (within the limits set by the uplink/downlink split in the case of half-duplex FDD operation).

The downlink scheduler is responsible for (dynamically) controlling which terminal(s) to transmit to and, for each of these terminals, the set of resource blocks upon which the terminal's DL-SCH should be transmitted. Transport-format selection (selection of transport-block size, modulation scheme, and antenna mapping) and logical-channel multiplexing for downlink transmissions are controlled by the eNodeB, as illustrated in the left part of Figure 8.11. As a consequence of the scheduler controlling the data rate, the RLC segmentation and MAC multiplexing will also be affected by the scheduling decision. The outputs from the downlink scheduler can be seen in Figure 8.4.

The uplink scheduler serves a similar purpose, namely to (dynamically) control which terminals are to transmit on their respective UL-SCH and on which uplink time–frequency resources (including component carrier). Despite the fact that the eNodeB scheduler determines the transport format for the terminal, it is important to point out that the uplink scheduling decision is taken *per terminal* and not per radio bearer. Thus, although the eNodeB scheduler controls the payload of a scheduled terminal, the terminal is still responsible for selecting *from which radio bearer(s)* the data is taken. The terminal autonomously handles logical-channel multiplexing according to rules, the parameters of which can be configured by the eNodeB. This is illustrated in the right part of Figure 8.11, where the eNodeB scheduler controls the transport format and the terminal controls the logical-channel multiplexing.

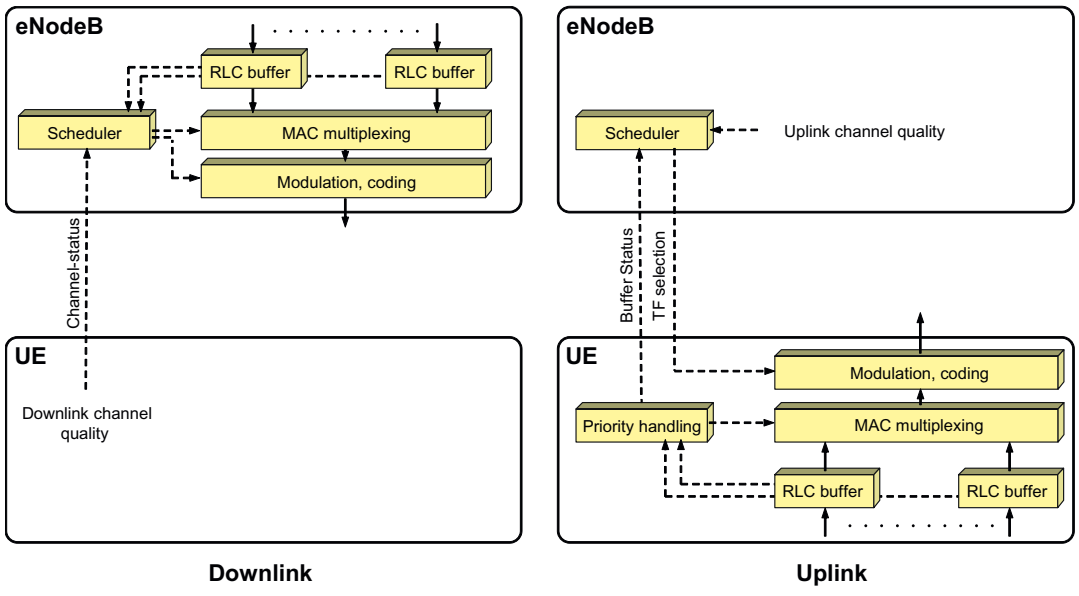


FIGURE 8.11

Transport-format selection in downlink and uplink.

Although the scheduling strategy is implementation specific and not specified by 3GPP, the overall goal of most schedulers is to take advantage of the channel variations between terminals and preferably schedule transmissions to a terminal on resources with advantageous channel conditions. A benefit of the use of OFDM in LTE is the possibility to exploit channel variations in both time and frequency domains through channel-dependent scheduling. This was mentioned earlier in Chapter 7 and illustrated in Figure 7.2. For the larger bandwidths supported by LTE, where a significant amount of frequency-selective fading will often be experienced, the possibility for the scheduler to also exploit frequency-domain channel variations becomes increasingly important compared to exploiting time-domain variations only. The possibility to also exploit frequency-domain variations is beneficial especially at low speeds, where the variations in the time domain are relatively slow compared to the delay requirements set by many services.

Downlink channel-dependent scheduling is supported through *channel-state reports*, transmitted by the UE and reflecting the instantaneous channel quality in the time and frequency domains, as well as information necessary to determine the appropriate antenna processing in the case of spatial multiplexing. In the uplink, the channel-state information necessary for uplink channel-dependent scheduling can be based on a *sounding reference signal* transmitted from each terminal for which the eNodeB wants to estimate the uplink channel quality. To aid the uplink scheduler in its decisions, the terminal can transmit buffer-status information to the eNodeB using a MAC message. Obviously, this information can only be transmitted if the terminal has been given a valid scheduling grant. For situations when this is not the case, an indicator that the terminal needs uplink resources is provided as part of the uplink L1/L2 control-signaling structure (see Chapter 11).

Interference coordination, which tries to control the inter-cell interference on a slow basis, as mentioned in Chapter 7, is also part of the scheduler. As the scheduling strategy is not mandated by the specifications, the interference-coordination scheme (if used) is vendor specific and may range from simple higher-order reuse deployments to more advanced schemes. The mechanisms supporting inter-cell interference coordination are discussed in Chapter 13.

8.2.2.3 Hybrid ARQ with Soft Combining

Hybrid ARQ with soft combining provides robustness against transmission errors. As hybrid-ARQ retransmissions are fast, many services allow for one or multiple retransmissions, thereby forming an implicit (closed loop) rate-control mechanism. The hybrid-ARQ protocol is part of the MAC layer, while the actual soft combining is handled by the physical layer.[5]

Obviously, hybrid ARQ is not applicable for all types of traffic. For example, broadcast transmissions, where the same information is intended for multiple terminals, typically do not rely on hybrid ARQ. Hence, hybrid ARQ is only supported for the DL-SCH and the UL-SCH, although its usage is optional.

The LTE hybrid-ARQ protocol uses multiple parallel stop-and-wait processes. Upon reception of a transport block, the receiver makes an attempt to decode the transport block and informs the transmitter about the outcome of the decoding operation through a single acknowledgement bit indicating whether the decoding was successful or if a retransmission of the transport block is required. Further details on transmission of hybrid-ARQ acknowledgements are found in Chapters 10–12. Clearly, the receiver must know to which hybrid-ARQ process a received acknowledgement is associated. This is

[5]The soft combining is done before or as part of the channel decoding, which clearly is a physical-layer functionality.

Petitioners' Exhibit 1003, p. 480
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

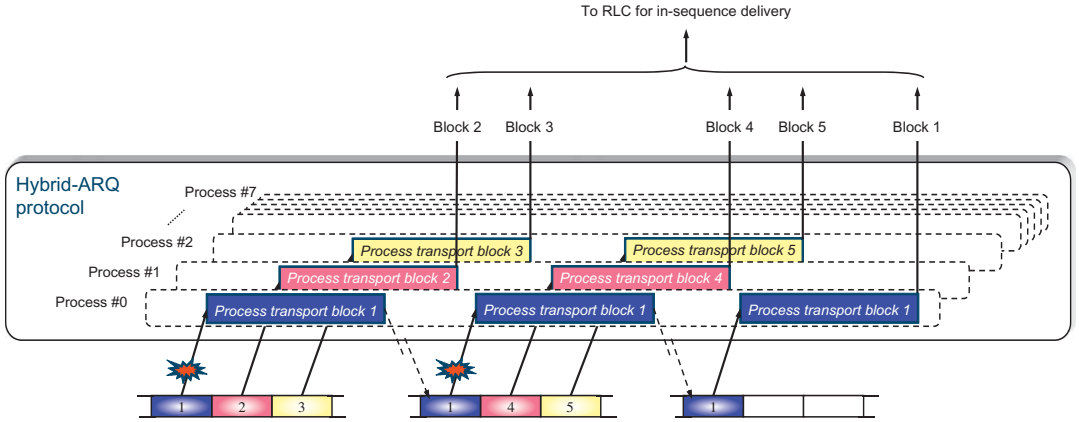


FIGURE 8.12

Multiple parallel hybrid-ARQ processes.

solved by using the timing of the acknowledgement for association with a certain hybrid-ARQ process. Note that, in the case of TDD operation, the time relation between the reception of data in a certain hybrid-ARQ process and the transmission of the acknowledgement is also affected by the uplink/downlink allocation.

The use of multiple parallel hybrid-ARQ processes, illustrated in Figure 8.12, for each user can result in data being delivered from the hybrid-ARQ mechanism out of sequence. For example, transport block 5 in the figure was successfully decoded before transport block 1 which required retransmissions. In-sequence delivery of data is therefore ensured by the RLC layer. The same reordering mechanism in the RLC is also used to handle in-sequence delivery across multiple component carriers in the case of carrier aggregation. As mentioned above, the hybrid-ARQ retransmissions are handled independently per component carrier, which may result in out-of-sequence delivery in a similar way as within a component carrier.

Downlink retransmissions may occur at any time after the initial transmission – that is, the protocol is asynchronous – and an explicit hybrid-ARQ process number is used to indicate which process is being addressed. In an asynchronous hybrid-ARQ protocol, the retransmissions are in principle scheduled similarly to the initial transmissions. Uplink retransmissions, on the other hand, are based on a synchronous protocol, the retransmission occurs at a predefined time after the initial transmission and the process number can be implicitly derived. In a synchronous protocol the time instant for the retransmissions is fixed once the initial transmission has been scheduled, which must be accounted for in the scheduling operation. However, note that the scheduler knows from the hybrid-ARQ entity in the eNodeB whether a terminal will perform a retransmission or not.

The hybrid-ARQ mechanism will rapidly correct transmission errors due to noise or unpredictable channel variations. As discussed above, the RLC is also capable of requesting retransmissions, which at first sight may seem unnecessary. However, the reason for having two retransmission mechanisms on top of each other can be seen in the feedback signaling – hybrid ARQ provides fast retransmissions but due to errors in the feedback the residual error rate is typically too high for, for example,

good TCP performance, while RLC ensures (almost) error-free data delivery but slower retransmissions than the hybrid-ARQ protocol. Hence, the combination of hybrid ARQ and RLC provides an attractive combination of small round-trip time and reliable data delivery. Furthermore, as the RLC and hybrid ARQ are located in the same node, tight interaction between the two is possible, as discussed in Chapter 12.

8.2.3 Physical Layer

The physical layer is responsible for coding, physical-layer hybrid-ARQ processing, modulation, multi-antenna processing, and mapping of the signal to the appropriate physical time–frequency resources. It also handles mapping of transport channels to physical channels, as shown in Figures 8.7 and 8.8.

As mentioned in the introduction, the physical layer provides services to the MAC layer in the form of transport channels. Data transmission in downlink and uplink use the DL-SCH and UL-SCH transport-channel types respectively. There is at most one or, in the case of spatial multiplexing, two transport blocks per TTI on a DL-SCH or UL-SCH. In the case of carrier aggregation, there is one DL-SCH (or UL-SCH) per component carrier.

A *physical channel* corresponds to the set of time–frequency resources used for transmission of a particular transport channel and each transport channel is mapped to a corresponding physical channel, as shown in Figures 8.7 and 8.8. In addition to the physical channels with a corresponding transport channel, there are also physical channels without a corresponding transport channel. These channels, known as L1/L2 control channels, are used for *downlink control information* (DCI), providing the terminal with the necessary information for proper reception and decoding of the downlink data transmission, and *uplink control information* (UCI) used for providing the scheduler and the hybrid-ARQ protocol with information about the situation at the terminal.

The physical-channel types defined in LTE include the following:

- The *Physical Downlink Shared Channel* (PDSCH) is the main physical channel used for unicast data transmission, but also for transmission of paging information.
- The *Physical Broadcast Channel* (PBCH) carries part of the system information, required by the terminal in order to access the network.
- The *Physical Multicast Channel* (PMCH) is used for MBSFN operation.
- The *Physical Downlink Control Channel* (PDCCH) is used for downlink control information, mainly scheduling decisions, required for reception of PDSCH, and for scheduling grants enabling transmission on the PUSCH.
- The *Physical Hybrid-ARQ Indicator Channel* (PHICH) carries the hybrid-ARQ acknowledgement to indicate to the terminal whether a transport block should be retransmitted or not.
- The *Physical Control Format Indicator Channel* (PCFICH) is a channel providing the terminals with information necessary to decode the set of PDCCHs. There is only one PCFICH per component carrier.
- The *Physical Uplink Shared Channel* (PUSCH) is the uplink counterpart to the PDSCH. There is at most one PUSCH per uplink component carrier per terminal.
- The *Physical Uplink Control Channel* (PUCCH) is used by the terminal to send hybrid-ARQ acknowledgements, indicating to the eNodeB whether the downlink transport block(s) was successfully received or not, to send channel-state reports aiding downlink channel-dependent scheduling, and for requesting resources to transmit uplink data upon. There is at most one PUCCH per terminal.

Petitioners' Exhibit 1003, p. 482
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- The *Physical Random-Access Channel* (PRACH) is used for random access, as described in Chapter 14.

Note that some of the physical channels, more specifically the channels used for downlink control information (PCFICH, PDCCH, PHICH) and uplink control information (PUCCH), do not have a corresponding transport channel.

The remaining downlink transport channels are based on the same general physical-layer processing as the DL-SCH, although with some restrictions in the set of features used. This is especially true for PCH and MCH transport channels. For the broadcast of system information on the BCH, a terminal must be able to receive this information channel as one of the first steps prior to accessing the system. Consequently, the transmission format must be known to the terminals a priori and there is no dynamic control of any of the transmission parameters from the MAC layer in this case. The BCH is also mapped to the physical resource (the OFDM time–frequency grid) in a different way, as described in more detail in Chapter 14.

For transmission of paging messages on the PCH, dynamic adaptation of the transmission parameters can, to some extent, be used. In general, the processing in this case is similar to the generic DL-SCH processing. The MAC can control modulation, the amount of resources, and the antenna mapping. However, as an uplink has not yet been established when a terminal is paged, hybrid ARQ cannot be used as there is no possibility for the terminal to transmit a hybrid-ARQ acknowledgement.

The MCH is used for MBMS transmissions, typically with single-frequency network operation, as described in Chapter 3, by transmitting from multiple cells on the same resources with the same format at the same time. Hence, the scheduling of MCH transmissions must be coordinated between the cells involved and dynamic selection of transmission parameters by the MAC is not possible.

8.3 CONTROL-PLANE PROTOCOLS

The control-plane protocols are, among other things, responsible for connection setup, mobility, and security. Control messages transmitted from the network to the terminals can originate either from the MME, located in the core network, or from the *Radio Resource Control* (RRC), located in the eNodeB.

NAS control-plane functionality, handled by the MME, includes EPS bearer management, authentication, security, and different idle-mode procedures such as paging. It is also responsible for assigning an IP address to a terminal. For a detailed discussion about the NAS control-plane functionality, see [9].

The RRC is located in the eNodeB and is responsible for handling the RAN-related procedures, including:

- Broadcast of system information necessary for the terminal to be able to communicate with a cell. Acquisition of system information is described in Chapter 14.
- Transmission of paging messages originating from the MME to notify the terminal about incoming connection requests. Paging, discussed further in Chapter 14, is used in the RRC_IDLE state (described further below) when the terminal is not connected to a particular cell. Indication of system-information update is another use of the paging mechanism, as is public warning systems.

Petitioners' Exhibit 1003, p. 483
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Connection management, including setting up bearers and mobility within LTE. This includes establishing an RRC context – that is, configuring the parameters necessary for communication between the terminal and the radio-access network.
- Mobility functions such as cell (re)selection.
- Measurement configuration and reporting.
- Handling of UE capabilities; when connection is established the terminal will announce its capabilities as all terminals are not capable of supporting all the functionality described in the LTE specifications, as briefly discussed in Chapter 7.

RRC messages are transmitted to the terminal using *signaling radio bearers* (SRBs), using the same set of protocol layers (PDCP, RLC, MAC and PHY) as described in Section 8.2. The SRB is mapped to the common control channel (CCCH) during establishment of connection and, once a connection is established, to the dedicated control channel (DCCH). Control-plane and user-plane data can be multiplexed in the MAC layer and transmitted to the terminal in the same TTI. The aforementioned MAC control elements can also be used for control of radio resources in some specific cases where low latency is more important than ciphering, integrity protection, and reliable transfer.

8.3.1 State Machine

In LTE, a terminal can be in two different states, as illustrated in Figure 8.13, RRC_CONNECTED and RRC_IDLE.

In RRC_CONNECTED, there is an RRC context established – that is, the parameters necessary for communication between the terminal and the radio-access network are known to both entities. The cell to which the terminal is belongs is known and an identity of the terminal, the *Cell Radio-Network Temporary Identifier* (C-RNTI), used for signaling purposes between the terminal and the network, has been configured. RRC_CONNECTED is intended for data transfer to/from the terminal, but *discontinuous reception* (DRX) can be configured in order to reduce terminal power consumption (DRX is described in further detail in Chapter 13). Since there is an RRC context established in the eNodeB in RRC_CONNECTED, leaving DRX and starting to receive/transmit data is relatively fast as no connection with its associated signaling is needed.

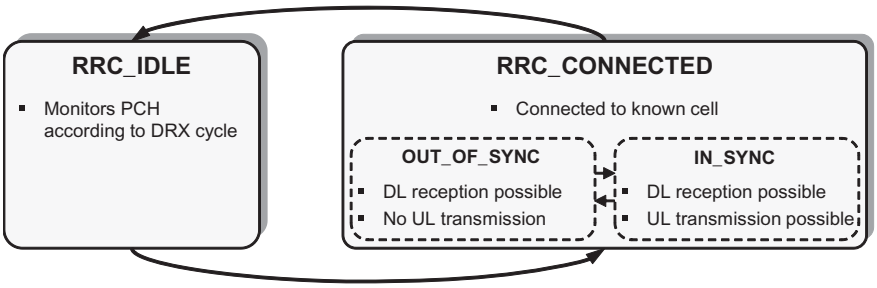


FIGURE 8.13

LTE states.

Although expressed differently in the specifications, RRC_CONNECTED can be thought of as having two substates, IN_SYNC and OUT_OF_SYNC, depending on whether the uplink is synchronized to the network or not. Since LTE uses an orthogonal FDMA/TDMA-based uplink, it is necessary to synchronize the uplink transmission from different terminals such that they arrive at the receiver at (approximately) the same time. The procedure for obtaining and maintaining uplink synchronization is described in Chapter 11, but in short the receiver measures the arrival time of the transmissions from each actively transmitting terminal and sends timing-correction commands in the downlink. As long as the uplink is synchronized, uplink transmission of user data and L1/L2 control signaling is possible. If no uplink transmission has taken place within a configurable time window, timing alignment is obviously not possible and the uplink is declared to be non-synchronized. In this case, the terminal needs to perform a random-access procedure to restore uplink synchronization prior to transmission of uplink data or control information.

In RRC_IDLE, there is no RRC context in the radio-access network and the terminal does not belong to a specific cell. No data transfer may take place as the terminal sleeps most of the time in order to reduce battery consumption. Uplink synchronization is not maintained and hence the only uplink transmission activity that may take place is random access, discussed in Chapter 14, to move to RRC_CONNECTED. When moving to RRC_CONNECTED the RRC context needs to be established in both the radio-access network and the terminal. Compared to leaving DRX this takes a somewhat longer time. In the downlink, terminals in RRC_IDLE periodically wake up in order to receive paging messages, if any, from the network, as described in Chapter 14.

Petitioners' Exhibit 1003, p. 485
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CHAPTER

Physical Transmission Resources

9

In Chapter 8, the overall LTE architecture was discussed, including an overview of the different protocol layers. Prior to discussing the detailed LTE downlink and uplink transmission schemes, a description of the basic time- and frequency-domain structure of LTE will be provided in this chapter.

9.1 OVERALL TIME–FREQUENCY STRUCTURE

OFDM is the basic transmission scheme for both the downlink and uplink transmission directions in LTE although, for the uplink, specific means are taken to reduce the cubic metric of the transmitted signal, thereby allowing for improved efficiency for the terminal transmitter power amplifier. Thus, for data transmission, DFT precoding is applied before OFDM modulation, leading to *DFT-spread OFDM* or *DFTS-OFDM*, as described in Chapter 4. It should be noted though that DFTS-OFDM is only applied to uplink *data* transmission – that is, for the transmission of the UL-SCH transport channel. As will be seen in Chapter 11, for other uplink transmissions, such as the transmission of *L1/L2 control signaling* and different types of *reference-signal transmissions*, other means are taken to limit the cubic metric of the transmitted signal.

The LTE OFDM subcarrier spacing equals 15 kHz for both downlink and uplink. As discussed in Chapter 3, the selection of the subcarrier spacing in an OFDM-based system needs to carefully balance overhead from the cyclic prefix against sensitivity to Doppler spread/shift and other types of frequency errors and inaccuracies. The choice of 15 kHz for the LTE subcarrier spacing was found to offer a good balance between these two constraints.

Assuming an FFT-based transmitter/receiver implementation, 15 kHz subcarrier spacing corresponds to a sampling rate $f_s = 15\,000 \cdot N_{\text{FFT}}$, where N_{FFT} is the FFT size. It is important to understand though that the LTE specifications do not in any way mandate the use of FFT-based transmitter/receiver implementations and even less so a particular FFT size or sampling rate. Nevertheless, FFT-based implementations of OFDM are common practice and an FFT size of 2048, with a corresponding sampling rate of 30.72 MHz, is suitable for the wider LTE carrier bandwidths, such as bandwidths of the order of 15 MHz and above. However, for smaller carrier bandwidths, a smaller FFT size and a correspondingly lower sampling rate can very well be used. The sampling rate above illustrates another factor influencing the choice of the LTE subcarrier spacing, namely a desire to simplify implementation of dual-mode LTE/HSPA terminals. Assuming a power-of-two FFT size and a subcarrier spacing of 15 kHz, the sampling rate $\Delta f \cdot N_{\text{FFT}}$ will be a multiple or sub-multiple of the HSPA chip rate of 3.84 Mchip/s.

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 486
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

In addition to the 15 kHz subcarrier spacing, a *reduced subcarrier spacing* of 7.5 kHz, with a corresponding OFDM symbol time that is twice as long, is also defined for LTE. The introduction of the reduced subcarrier spacing specifically targeted MBSFN-based multicast/broadcast transmissions (see Chapter 15). However, currently the 7.5 kHz subcarrier numerology is only partly implemented in the LTE specifications. Thus, at least for LTE up to and including release 10, only the 15 kHz subcarrier spacing is fully supported. The remaining discussions within this and the following chapters will assume the 15 kHz subcarrier spacing unless explicitly stated otherwise.

In the time domain, LTE transmissions are organized into (*radio*) *frames* of length 10 ms, each of which is divided into ten equally sized *subframes* of length 1 ms, as illustrated in Figure 9.1. Each subframe consists of two equally sized *slots* of length $T_{slot} = 0.5$ ms, with each slot consisting of a number of OFDM symbols including cyclic prefix.[1]

To provide consistent and exact timing definitions, different time intervals within the LTE specifications are defined as multiples of a basic time unit $T_s = 1/(15\,000 \cdot 2048)$. The basic time unit T_s can thus be seen as the sampling time of an FFT-based transmitter/receiver implementation with an FFT size equal to 2048. The time intervals outlined in Figure 9.1 can thus also be expressed as $T_{frame} = 307\,200 \cdot T_s$, $T_{subframe} = 30\,720 \cdot T_s$, and $T_{slot} = 15\,360 \cdot T_s$ for the frame, subframe, and slot durations respectively.

On a higher level, each frame is identified by a *System Frame Number* (SFN). The SFN is used to control different transmission cycles that may have a period longer than one frame, such as paging sleep-mode cycles and periods for channel-status reporting. The SFN period equals 1024, thus the SFN repeats itself after 1024 frames or roughly 10 seconds.

The 15 kHz LTE subcarrier spacing corresponds to a useful symbol time $T_u = 2048 \cdot T_s$ or approximately 66.7 μs. The overall OFDM symbol time is then the sum of the useful symbol time and the cyclic-prefix length T_{CP}. As illustrated in Figure 9.1, LTE defines two cyclic-prefix lengths, the *normal* cyclic prefix and an *extended* cyclic prefix, corresponding to seven and six OFDM symbols per slot respectively. The exact cyclic-prefix lengths, expressed in the basic time unit T_s, are given in Figure 9.1. It can be noted that, in the case of the normal cyclic prefix, the cyclic-prefix length for the first OFDM symbol of a slot is somewhat larger compared to the remaining OFDM symbols. The reason for this is simply to fill the entire 0.5 ms slot, as the number of basic time units T_s per slot (15 360) is not divisible by seven.

The reasons for defining two cyclic-prefix lengths for LTE are twofold:

- A longer cyclic prefix, although less efficient from a cyclic-prefix-overhead point of view, may be beneficial in specific environments with extensive delay spread, for example in very large cells. It is important to have in mind, though, that a longer cyclic prefix is not necessarily beneficial in the case of large cells, even if the delay spread is very extensive in such cases. If, in large cells, link performance is limited by noise rather than by signal corruption due to residual time dispersion not covered by the cyclic prefix, the additional robustness to radio-channel time dispersion, due to the use of a longer cyclic prefix, may not justify the corresponding additional energy overhead of a longer cyclic prefix.

[1] This is valid for the "normal" downlink subframes. As described in Section 9.5.2, the *special subframe* present in the case of TDD operation is not divided into two slots but rather into three fields. However, the number of OFDM symbols in the special subframe is the same as for the normal subframes illustrated in Figure 9.1.

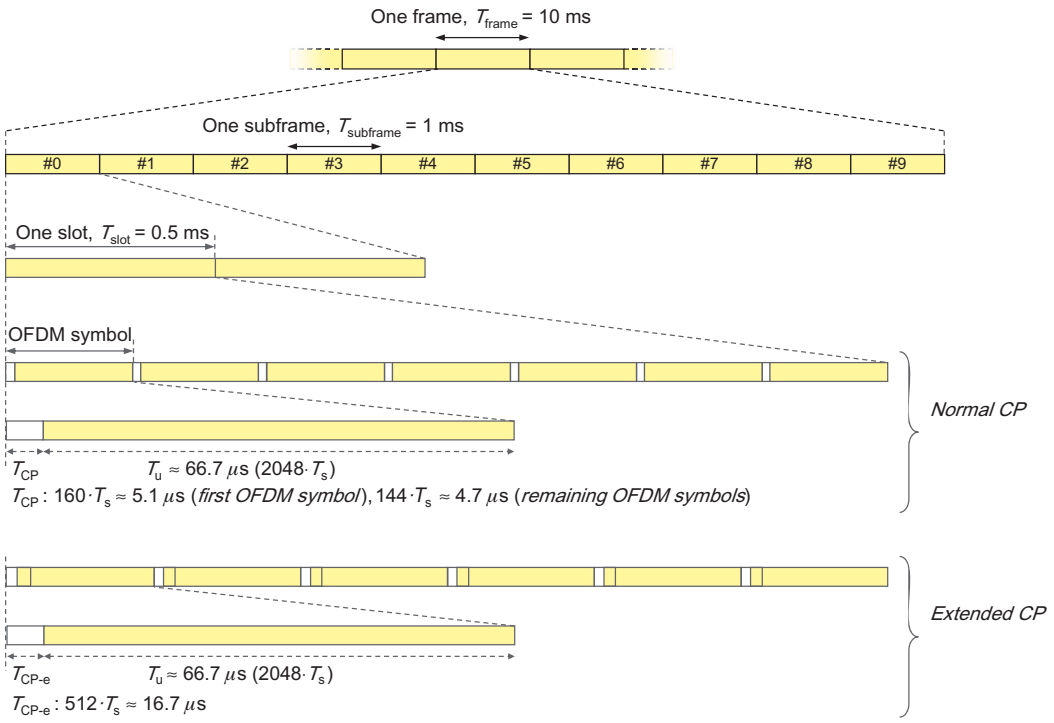


FIGURE 9.1

LTE time-domain structure.

- As already discussed in Chapter 3, in the case of MBSFN-based multicast/broadcast transmission, the cyclic prefix should not only cover the main part of the actual channel time dispersion, but also the timing difference between the transmissions received from the cells involved in the MBSFN transmission. In the case of MBSFN operation, the extended cyclic prefix is therefore used.

It should be noted that different cyclic-prefix lengths may be used for different subframes within a frame. As an example, to be discussed further in Chapter 15, MBSFN-based multicast/broadcast transmission is always confined to a limited set of subframes, in which case the use of the extended cyclic prefix, with its associated additional cyclic-prefix overhead, may only be applied to these subframes.[2]

A *resource element*, consisting of one subcarrier during one OFDM symbol, is the smallest physical resource in LTE. Furthermore, as illustrated in Figure 9.2, resource elements are grouped into *resource blocks*, where each resource block consists of 12 consecutive subcarriers in the frequency domain and one 0.5 ms slot in the time domain. Each resource block thus consists of $7 \cdot 12 = 84$

[2]The extended cyclic prefix is then actually applied only to the so-called MBSFN part of the MBSFN subframes (see Section 9.2).

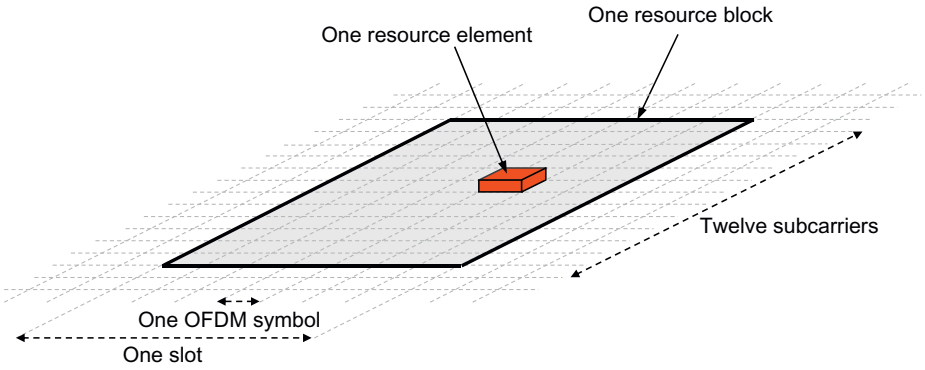


FIGURE 9.2

The LTE physical time–frequency resource.

resource elements in the case of a normal cyclic prefix and $6 \bullet 12 = 72$ resource elements in the case of an extended cyclic prefix.

Although resource blocks are defined over one slot, the basic time-domain unit for dynamic scheduling in LTE is one subframe, consisting of two consecutive slots. The reason for defining the resource blocks over one slot is that *distributed downlink transmission*, as described in Chapter 10 and *uplink frequency hopping* (described in Chapter 11) are defined on a slot or resource-block basis. The minimum scheduling unit, consisting of two time-consecutive resource blocks within one subframe (one resource block per slot), can be referred to as a *resource-block pair*.

The LTE physical-layer specification allows for a carrier to consist of any number of resource blocks in the frequency domain, ranging from a minimum of six resource blocks up to a maximum of 110 resource blocks. This corresponds to an overall transmission bandwidth ranging from roughly 1 MHz up to in the order of 20 MHz with very fine granularity and thus allows for a very high degree of LTE bandwidth flexibility, at least from a physical-layer-specification point of view. However, as mentioned in Chapter 7, LTE radio-frequency requirements are, at least initially, only specified for a limited set of transmission bandwidths, corresponding to a limited set of possible values for the number of resource blocks within a carrier. Also note that, in LTE release 10, the total bandwidth of the transmitted signal can be as large as 100 MHz by aggregating multiple carriers, as mentioned in Chapter 7 and further described in Section 9.3.

The resource-block definition above applies to both the downlink and uplink transmission directions. However, there is a minor difference between the downlink and uplink in terms of where the carrier center frequency is located in relation to the subcarriers.

In the downlink (upper part of Figure 9.3), there is an unused *DC-subcarrier* that coincides with the carrier center frequency. The reason why the DC-subcarrier is not used for downlink transmission is that it may be subject to disproportionately high interference due, for example, to local-oscillator leakage.

On the other hand, in the uplink (lower part of Figure 9.3), no unused DC-subcarrier is defined and the center frequency of an uplink carrier is located *between* two uplink subcarriers. The presence of an unused DC-carrier in the center of the spectrum would have prevented the assignment of the entire cell bandwidth to a single terminal and still retain the assumption of mapping to consecutive

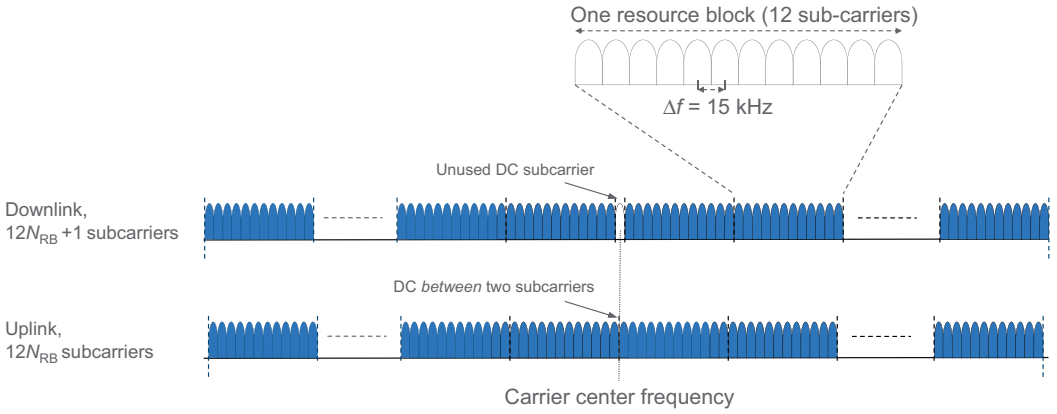


FIGURE 9.3

Frequency-domain structure for LTE.

inputs of the OFDM modulator, something that is needed to retain the low-cubic-metric property of the DFTS-OFDM modulation used for uplink data transmission.

9.2 NORMAL SUBFRAMES AND MBSFN SUBFRAMES

In LTE, each downlink subframe (and the DwPTS in the case of TDD; see Section 9.5.2 for a discussion of the TDD frame structure) is normally divided into a *control region*, consisting of the first few OFDM symbols, and a *data region*, consisting of the remaining part of the subframe. The detailed usage of the resource elements in the two regions will be discussed in detail in Chapter 10; at this stage all we need to know is that the control region carries L1/L2 signaling necessary to control uplink and downlink data transmissions.

Additionally, already from the first release of LTE, so-called *MBSFN subframes* have also been defined. The original intention with MBSFN subframes was, as indicated by the name, to support MBSFN transmission, as described in Chapter 15. However, MBSFN subframes have also been found to be useful in other contexts, for example as part of relaying functionality, as discussed in Chapter 16. Hence, MBSFN subframes are therefore better seen as a generic tool and not related only to MBSFN transmission.

An MBSFN subframe, illustrated in Figure 9.4, consists of a control region of length one or two OFDM symbols, which is in essence identical to its counterpart in a normal subframe, followed by an *MBSFN region* whose contents depend on the usage of the MBSFN subframe. The reason for keeping the control region also in MBSFN subframes is, for example, to transmit control signaling necessary for uplink transmissions. All terminals, from LTE release 8 and onwards, are capable of receiving the control region of an MBSFN subframe. This is the reason why MBSFN subframes have been found useful as a generic tool to introduce, in a backwards-compatible way, new types of signaling and transmission not part of an earlier release of the LTE radio-access specification. Terminals not capable of receiving transmissions in the MBSFN region will simply ignore those transmissions.

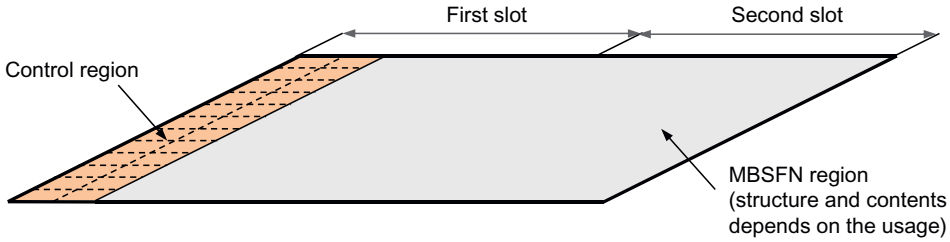


FIGURE 9.4

Resource-block structure for MBSFN subframes, assuming normal cyclic prefix for the control region and extended cyclic prefix for the MBSFN region.

Information about the set of subframes that are configured as MBSFN subframes in a cell is provided as part of the system information. In principle, an arbitrary pattern of MBSFN subframes can be configured with the pattern repeating after 40 ms.[3] However, as information necessary to operate the system (to be more specific, synchronization signals, system information and paging, all of which will be discussed in detail in later chapters) needs to be transmitted in order for terminals to find and connect to a cell, subframes where such information is provided cannot be configured as MBSFN subframes. Therefore, subframes 0, 4, 5, and 9 for FDD and subframes 0, 1, 5, and 6 for TDD cannot be configured as MBSFN subframes, leaving the remaining six subframes as candidates for MBSFN subframes.

9.3 CARRIER AGGREGATION

The possibility for *carrier aggregation* was introduced in LTE release 10. In the case of carrier aggregation, multiple LTE carriers, each with a bandwidth up to 20 MHz, can be transmitted in parallel to/from the same terminal, thereby allowing for an overall wider bandwidth and correspondingly higher per-link data rates. In the context of carrier aggregation, each carrier is referred to as a *component carrier*[4] as, from an RF point-of-view, the entire set of aggregated carriers can be seen as a single (RF) carrier.

Up to five component carriers, possibly of different bandwidths up to 20 MHz, can be aggregated allowing for overall transmission bandwidths up to 100 MHz. A terminal capable of carrier aggregation may receive or transmit simultaneously on multiple component carriers. Each component carrier can also be accessed by an LTE terminal from earlier releases – that is, component carriers are *backwards compatible*. Thus, in most respects and unless otherwise mentioned, the physical-layer description in the following chapters applies to each component carrier separately in the case of carrier aggregation.

[3]The reason for this value is that both the 10 ms frame length and the 8 ms hybrid-ARQ round-trip time are factors in the 40 ms, which is important for relaying operation (see also Chapter 16).
[4]In the specifications, the term *cell* is used instead of component carrier, but as the term cell is something of a misnomer in the uplink case, the term component carrier is used herein.

Petitioners' Exhibit 1003, p. 491
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

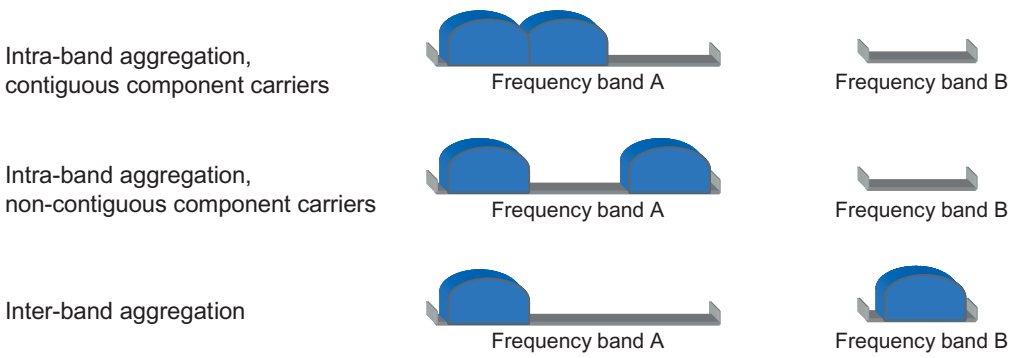


FIGURE 9.5

Different types of carrier aggregation.

It should be noted that aggregated component carriers do not need to be contiguous in the frequency domain. Rather, with respect to the frequency location of the different component carriers, three different cases can be identified (see also Figure 9.5):

- Intra-band aggregation with frequency-contiguous component carriers
- Intra-band aggregation with non-contiguous component carriers
- Inter-band aggregation with non-contiguous component carriers.

The possibility to aggregate non-adjacent component carriers allows for exploitation of a fragmented spectrum; operators with a fragmented spectrum can provide high-data-rate services based on the availability of a wide overall bandwidth even though they do not posses a single wideband spectrum allocation. Except from an RF point of view there is no difference between the three different cases outlined in Figure 9.5 and they are all supported by the basic LTE release-10 specification. However, the complexity of RF implementation is vastly different, with the first case being the least complex. Thus, although spectrum aggregation is supported by the physical-layer and protocol specifications, the actual implementation will be strongly constrained, including specification of only a limited number of aggregation scenarios and aggregation over a dispersed spectrum only being supported by the most advanced terminals.

A terminal capable of carrier aggregation has one downlink *primary* component carrier and an associated uplink primary component carrier. In addition, it may have one or several *secondary* component carriers in each direction. Different terminals may have different carriers as their primary component carrier – that is, the configuration of the primary component carrier is terminal specific. The association between the downlink primary carrier and the corresponding uplink primary carrier is cell specific and signaled as part of the system information. This is similar to the case without carrier aggregation, although in the latter case the association is trivial. The reason for such an association is, for example, to determine to which uplink component carrier a certain scheduling grant transmitted on the downlink relates without having to explicitly signal the component-carrier number.

All idle mode procedures apply to the primary component carrier only or, expressed differently, carrier aggregation with additional secondary carriers configured only applies to terminals in the RRC_CONNECTED state. Upon connection to the network, the terminal performs the related procedures such

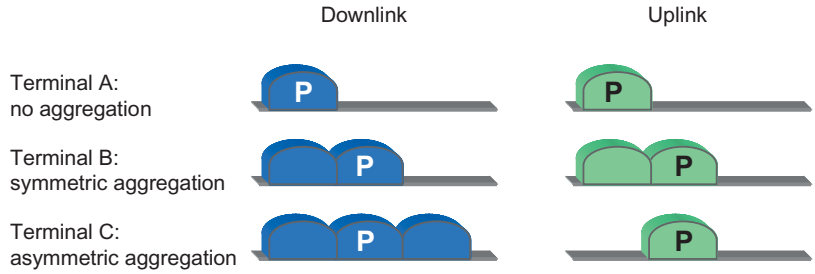


FIGURE 9.6

Examples of carrier aggregation ("P" denotes the primary component carrier).

as cell search and random access (see Chapter 14 for a detailed description of these procedures) following the same steps as in the absence of carrier aggregation. Once the communication between the network and the terminal is established, additional secondary component carriers can be configured.

The fact that carrier aggregation is terminal specific – that is, different terminals may be configured to use different sets of component carriers – is useful not only from a network perspective to balance the load across component carriers, but also to handle different capabilities between terminals. Some terminals may be able to transmit/receive on multiple component carriers, while other terminals may do so on only a single carrier. This is an obvious consequence of being able to serve terminals from earlier releases at the same time as a carrier-aggregation-capable release-10 terminal, but it also allows for different capabilities in terms of carrier aggregation for different terminals as well as a differentiation between downlink and uplink carrier-aggregation capability. For example, a terminal may be capable of two component carriers in the downlink but of only a single component carrier – that is, no carrier aggregation – in the uplink, as is the case for terminal C in Figure 9.6. Note also that the primary component-carrier configuration can differ between terminals. Asymmetric carrier aggregation can also be useful to handle different spectrum allocations, for example if an operator has more spectrum available for downlink transmissions than uplink transmissions.

In release 10, only downlink-heavy asymmetries are supported – that is, the number of uplink component carriers configured for a terminal is always equal to or smaller than the number of configured downlink component carriers. Uplink-heavy asymmetries are less likely to be of practical interest and would also complicate the overall control signaling structure, as in such a case multiple uplink component carriers would need to be associated with the same downlink component carrier.

Carrier aggregation is supported for both FDD and TDD, although all component carriers need to have the same duplex scheme. Furthermore, in the case of TDD, the uplink–downlink configuration should be the same across component carriers. The special subframe configuration can be different for the different components carriers though, as long as the resulting downlink–uplink switch time is sufficiently large.

9.4 FREQUENCY-DOMAIN LOCATION OF LTE CARRIERS

In principle, an LTE carrier could be positioned anywhere within the spectrum and, actually, the basic LTE physical-layer specification does not say anything about the exact frequency location of an LTE

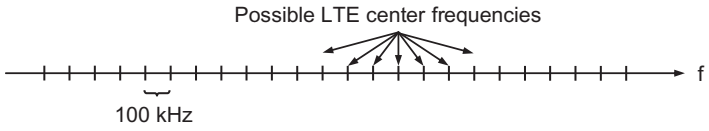


FIGURE 9.7

LTE carrier raster.

carrier, including the frequency band. However, in practice, there is obviously a need for restrictions on where an LTE carrier can be positioned in the frequency domain.

- In the end, an LTE terminal must be implemented and RF-wise such a terminal can obviously only support certain frequency bands. The frequency bands for which LTE is specified to operate are discussed in Chapter 17.
- After being activated, an LTE terminal has to search for a network-transmitted carrier within the frequency bands supported by the terminal. In order for that carrier search not to take an unreasonably long time, there is a need to limit the set of frequencies to be searched.

For this reason it is assumed that, within each supported frequency band, LTE carriers may exist on a 100 kHz *carrier raster* or *carrier grid* – that is, the carrier center frequency can be expressed as $m \cdot 100\,\text{kHz}$, where m is an integer (see Figure 9.7).

In the case of carrier aggregation, multiple carriers can be transmitted to/from the same terminal. In order for the different component carriers to be accessible also by earlier-release terminals, each component carrier should fall on the 100 kHz carrier grid. However, in the case of carrier aggregation, there is an additional constraint that the carrier spacing between adjacent component carriers should be a multiple of the 15 kHz subcarrier spacing to allow transmission/reception with a single FFT.[5] Thus, in the case of carrier aggregation, the carrier spacing between the different component carriers should be a multiple of 300 kHz, the smallest carrier spacing being a multiple of both 100 kHz (the raster grid) and 15 kHz (the subcarrier spacing). A consequence of this is that there will always be a small number of unused subcarriers between two component carriers, even when they are located as close as possible to each other, as illustrated in Figure 9.8.

9.5 DUPLEX SCHEMES

Spectrum flexibility is one of the key features of LTE. In addition to the flexibility in transmission bandwidth, LTE also supports operation in both paired and unpaired spectrum by supporting both FDD- and TDD-based duplex operation with the time–frequency structures illustrated in Figure 9.9. Although the time-domain structure is, in most respects, the same for FDD and TDD, there are some differences, most notably the presence of a *special subframe* in the case of TDD. The special subframe is used to provide the necessary guard time for downlink–uplink switching, as discussed below.

[5]This is obviously only relevant for component carriers that are contiguous in the frequency domain. Furthermore, in the case of independent frequency errors between component carriers, separate FFTs may be needed at the receiver.

Petitioners' Exhibit 1003, p. 494
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

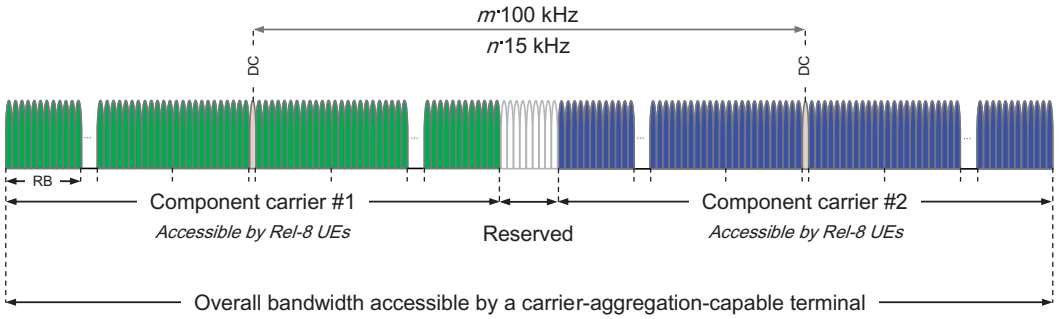


FIGURE 9.8

LTE carrier raster and carrier aggregation.

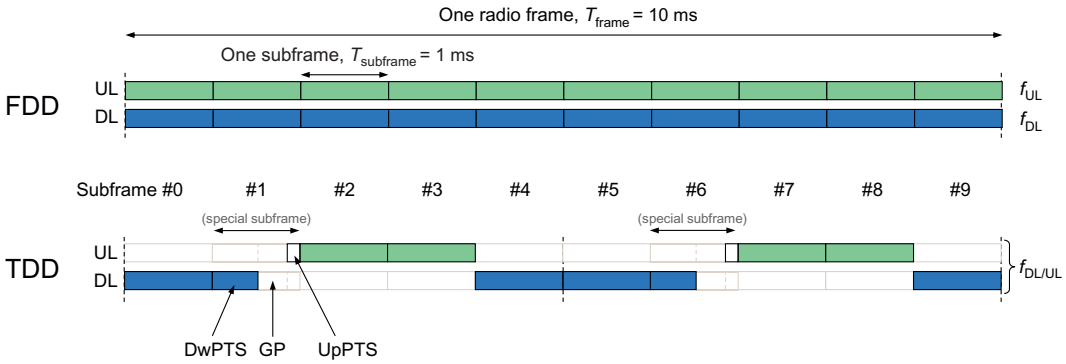


FIGURE 9.9

Uplink/downlink time–frequency structure for FDD and TDD.

9.5.1 Frequency-Division Duplex (FDD)

In the case of FDD operation (upper part of Figure 9.9), there are two carrier frequencies, one for uplink transmission (f_{UL}) and one for downlink transmission (f_{DL}). During each frame, there are thus ten uplink subframes and ten downlink subframes, and uplink and downlink transmission can occur simultaneously within a cell. Isolation between downlink and uplink transmissions is achieved by transmission/reception filters, known as duplex filters, and a sufficiently large *duplex separation* in the frequency domain.

Even if uplink and downlink transmission can occur simultaneously within a cell in the case of FDD operation, a terminal may be capable of *full-duplex* operation or only *half-duplex* operation for a certain frequency band, depending on whether or not it is capable of simultaneous transmission/reception. In the case of full-duplex capability, transmission and reception may also occur simultaneously at a terminal, whereas a terminal capable of only half-duplex operation cannot transmit and receive simultaneously. As mentioned in Chapter 7, supporting only half-duplex operation allows for simplified terminal implementation due to relaxed duplex-filter requirements. This applies especially

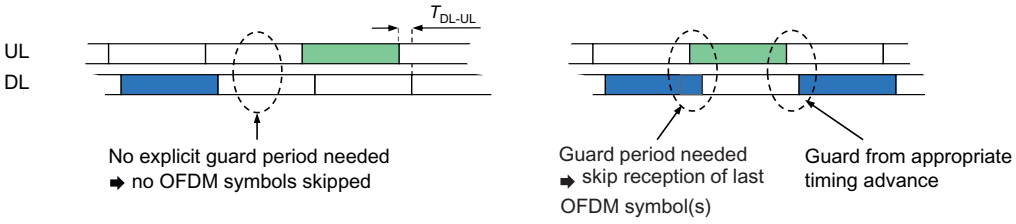


FIGURE 9.10

Guard time at the terminal for half-duplex FDD.

for certain frequency bands with a narrow duplex gap. Hence, full duplex support is *frequency-band dependent* such that a terminal may support only half-duplex operation in certain frequency bands while being capable of full-duplex operation in the remaining supported bands. It should be noted that full/half-duplex capability is a property of the *terminal*; the base station is operating in full duplex irrespective of the terminal capabilities. Hence, as the relevant transmission structures and timing relations are identical between full-duplex and half-duplex FDD, a single cell may simultaneously support a mixture of full-duplex and half-duplex FDD terminals. Half-duplex operation has an impact on the sustained data rates that can be provided to/from a single mobile terminal as it cannot transmit in all uplink subframes, but the cell capacity is hardly affected as typically it is possible to schedule different terminals in uplink and downlink in a given subframe.

Since a half-duplex terminal is not capable of simultaneous transmission and reception, the scheduling decisions must take this into account and half-duplex operation can be seen as a scheduling restriction, as will be discussed in more detail in Chapter 13. If a terminal is scheduled such that downlink reception in one subframe immediately precedes a subframe of uplink transmission, a guard time is necessary for the terminal to switch from reception to transmission. This is created in such cases by allowing the terminal to skip receiving[6] the last OFDM symbol(s) in the downlink subframe, as illustrated in Figure 9.10.

9.5.2 Time-Division Duplex (TDD)

In the case of TDD operation (lower part of Figure 9.9), there is a single carrier frequency only and uplink and downlink transmissions are separated in the time domain on a cell basis. As seen in the figure, some subframes are allocated for uplink transmissions and some subframes for downlink transmission, with the switch between downlink and uplink occurring in the *special subframe* (subframe 1 and, in some cases, subframe 6). Different asymmetries in terms of the amount of resources – that is, subframes – allocated for uplink and downlink transmission respectively are provided through the seven different downlink/uplink configurations illustrated in Figure 9.11. As seen in the figure, subframes 0 and 5 are always allocated for downlink transmission while subframe 2 is always allocated for uplink transmissions. The remaining subframes (except the special subframe; see below)

[6]The impact on the decoding performance can be accounted for by the rate adaptation mechanism. For very high data rates, the performance impact may be somewhat larger due to the downlink interleaving structure, in which case it may be preferable not to schedule an uplink transmission immediately after a downlink reception.

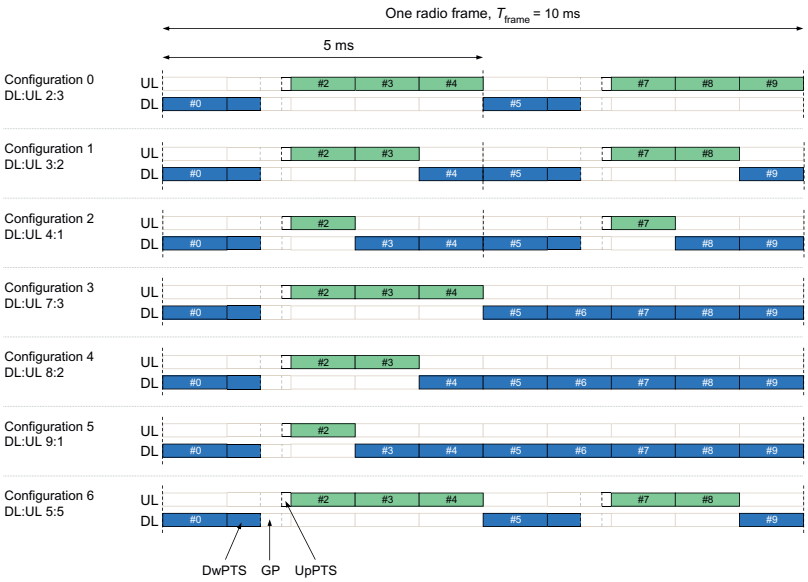


FIGURE 9.11

Different downlink/uplink configurations in the case of TDD.

can then be flexibly allocated for downlink or uplink transmission depending on the configured downlink/uplink configuration. To avoid severe interference between downlink and uplink transmissions in different cells, neighboring cells typically have the same downlink/uplink configuration. This makes it difficult to change the downlink/uplink configuration dynamically, for example on a frame-by-frame basis. Therefore, the current LTE specification assumes that the downlink/uplink configuration is relatively static. It can be changed on a very slow basis though, in order to adapt to changing traffic patterns. It could also, in principle, be different in different areas, for example to match different traffic patterns, although inter-cell interference needs to be carefully addressed in this case.

As the same carrier frequency is used for uplink and downlink transmission, both the base station and the terminal need to switch from transmission to reception and vice versa. The switch between downlink and uplink occurs in the special subframe, which is split into three parts: a downlink part (DwPTS), a guard period (GP), and an uplink part (UpPTS).

The DwPTS is in essence treated as a normal downlink subframe,[7] although the amount of data that can be transmitted is smaller due to the reduced length of the DwPTS compared to a normal subframe. The UpPTS, however, is not used for data transmission due to the very short duration. Instead, it can be used for channel sounding or random access. It can also be left empty, in which case it serves as extra guard period.

An essential aspect of any TDD system is the possibility to provide a sufficiently large *guard period* (or guard time), where neither downlink nor uplink transmissions occur. This guard period is necessary for switching from downlink to uplink transmission and vice versa and, as already mentioned, is

[7]For the shortest DwPTS duration of three OFDM symbols, DwPTS cannot be used for PDSCH transmission.

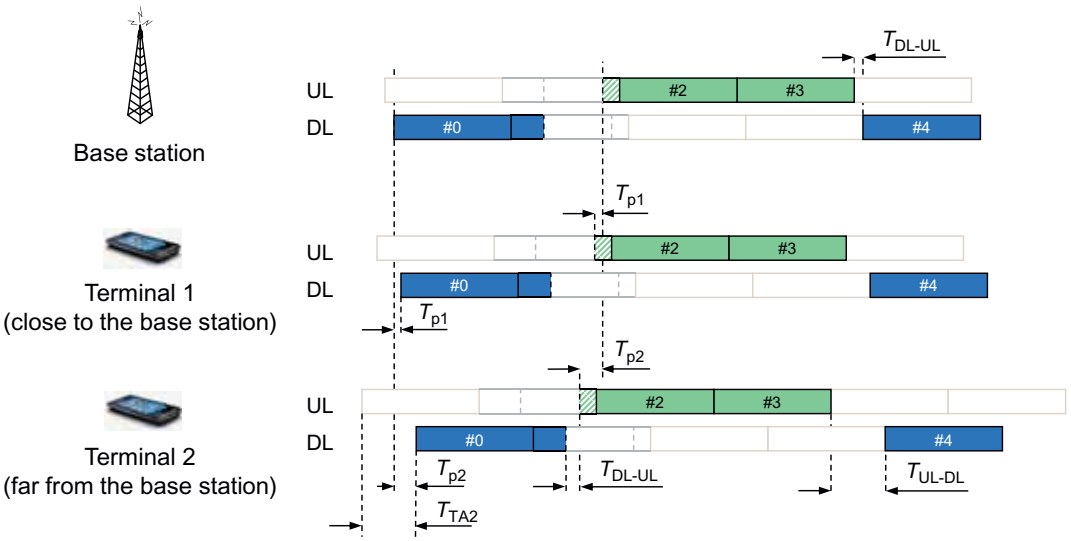


FIGURE 9.12

Timing relation for TDD operation.

obtained from the special subframe. The required length of the guard period depends on several factors. First, it should be sufficiently large to provide the necessary time for the circuitry in base stations and the terminals to switch from downlink to uplink. Switching is typically relatively fast, of the order of 20 microseconds, and in most deployments does not significantly contribute to the required guard time.

Secondly, the guard time should also ensure that uplink and downlink transmissions do not interfere at the base station. This is handled by advancing the uplink timing at the terminals such that, at the base station, the last uplink subframe before the uplink-to-downlink switch ends before the start of the first downlink subframe. The uplink timing of each terminal can be controlled by the base station by using the timing advance mechanism, as will be elaborated upon in Chapter 11. Obviously, the guard period must be large enough to allow the terminal to receive the downlink transmission and switch to transmission before it starts the (timing-advanced) uplink transmission. In essence, some of the guard period of the special subframe is "moved" from the downlink-to-uplink switch to the uplink-to-downlink switch by the timing-advance mechanism. This is illustrated in Figure 9.12. As the timing advance is proportional to the distance to the base station, a larger guard period is required when operating in large cells compared to small cells.

Finally, the selection of the guard period also needs to take interference between base stations into account. In a multi-cell network, inter-cell interference from downlink transmissions in neighboring cells must decay to a sufficiently low level before the base station can start to receive uplink transmissions. Hence, a larger guard period than is motivated by the cell size itself may be required as the last part of the downlink transmissions from distant base stations otherwise may interfere with uplink reception. The amount of guard period depends on the propagation environments, but in some cases the inter-base-station interference is a non-negligible factor when determining the guard period.

Petitioners' Exhibit 1003, p. 498
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 9.1 Resulting Guard Period in OFDM Symbols for Different DwPTS and UpPTS Lengths (Normal Cyclic Prefix)

	DwPTS								
	12	11		10		9		3	
GP	1	1	2	2	3	3	4	9	10
UpPTS	1	2	1	2	1	2	1	2	1

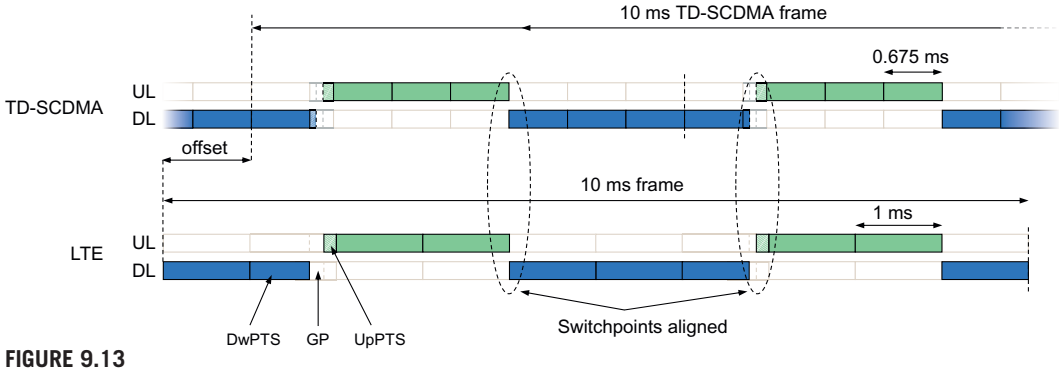


FIGURE 9.13

Coexistence between TD-SCDMA and LTE.

From the above discussion, it is clear that a sufficient amount of configurability of the guard period is needed to meet different deployment scenarios. Therefore, a set of DwPTS/GP/UpPTS configurations is supported as shown in Table 9.1, where each configuration corresponds to a given length of the three fields in the special subframes. The DwPTS/GP/UpPTS configuration used in the cell is signaled as part of the system information.

9.5.3 LTE and TD-SCDMA Coexistence

In addition to supporting a wide range of different guard periods, an important aspect in the design of TDD in LTE was to simplify coexistence with and migration from systems based on the 3GPP TD-SCDMA standard (see Chapter 19 for details on TD-SCDMA). Basically, to handle inter-system interference from two different but co-sited TDD systems operating close in frequency, it is necessary to align the switch-points between the two systems. Since LTE supports configurable lengths of the DwPTS field, the switch-points of LTE and TD-SCDMA (or any other TDD system) can be aligned, despite the different subframe lengths used in the two systems. Aligning the switch-points between TD-SCDMA and LTE is the technical reason for splitting the special subframe into the three fields DwPTS/GP/UpPTS instead of locating the switch-point at the subframe boundary. An example of LTE/TD-SCDMA coexistence is given in Figure 9.13.

The set of possible lengths of DwPTS/GP/UpPTS is selected to support common coexistence deployments, as well as to provide a high degree of guard-period flexibility for the reasons discussed earlier. The UpPTS length is one or two OFDM symbols and the DwPTS length can vary from three[8] to twelve OFDM symbols, resulting in guard periods ranging from one to ten OFDM symbols. The resulting guard period for the different DwPTS and UpPTS configurations supported is summarized in Table 9.1 for the case of normal cyclic prefix. As discussed earlier, the DwPTS can be used for downlink data transmission, while the UpPTS can be used for sounding or random access only, due to its short duration.

[8]The smallest DwPTS length is motivated by the location of the primary synchronization signal in the DwPTS (see Chapter 14).

Petitioners' Exhibit 1003, p. 500
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CHAPTER

Downlink Physical-Layer Processing

10

In Chapter 8, the LTE radio-interface architecture was discussed with an overview of the functions and characteristics of the different protocol layers. Chapter 9 then gave an overview of the basic time–frequency structure of LTE transmissions, including the structure of the OFDM time–frequency grid being the fundamental physical resource on both uplink and downlink.

This chapter will provide a more detailed description of the downlink physical-layer functionality, including the transport-channel processing (Section 10.1), downlink reference signals (Section 10.2), details on downlink multi-antenna transmission (Section 10.3), and downlink L1/L2 control signaling (Section 10.4). Chapter 11 will provide a corresponding description for the *uplink* transmission direction. The later chapters will then go further into the details of some specific uplink and downlink functions and procedures.

10.1 TRANSPORT-CHANNEL PROCESSING

As described in Chapter 8, transport channels provide the interface between the MAC layer and the physical layer. As also described, for the LTE downlink there are four different types of transport channels defined, the Downlink Shared Channel (DL-SCH), the Multicast Channel (MCH), the Paging Channel (PCH), and the Broadcast Channel (BCH). This section provides a description of the physical-layer processing applied to DL-SCH transport channels, including the mapping to the physical resource – that is, to the resource elements of the OFDM time–frequency grid. DL-SCH is the main downlink transport-channel type in LTE and is used for transmission of user-specific higher-layer information, both user data and dedicated control information, as well as part of the downlink system information. The DL-SCH physical-layer processing is to a large extent applicable also to MCH and PCH transport channels, although with some additional constraints. On the other hand, the physical-layer processing, and the transmission structure in general, for the BCH is quite different. BCH transmission is described in Chapter 14 as part of the discussion on LTE system information.

10.1.1 Processing Steps

The different steps of the DL-SCH physical layer processing are outlined in Figure 10.1. In the case of carrier aggregation – that is, transmission on multiple component carriers in parallel to the same terminal – the transmissions on the different carriers correspond to separate transport channels with separate and more or less independent physical-layer processing. The transport-channel processing outlined in Figure 10.1 and the discussion below is thus valid also in the case of carrier aggregation.

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 502
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

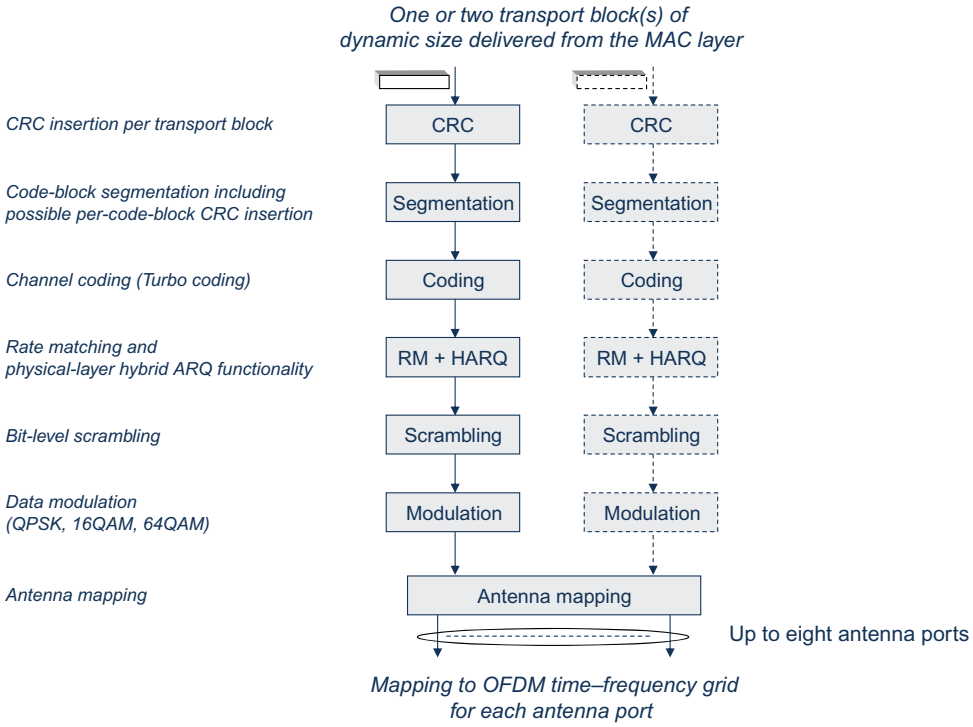


FIGURE 10.1

Physical-layer processing for DL-SCH.

Within each *Transmission Time Interval* (TTI), corresponding to one subframe of length 1 ms, up to two transport blocks of dynamic size are delivered to the physical layer and transmitted over the radio interface for each component carrier. The number of transport blocks transmitted within a TTI depends on the configuration of the multi-antenna transmission scheme, as described in Section 10.3.

- In the case of no *spatial multiplexing* there is at most a single transport block in a TTI.
- In the case of spatial multiplexing, with transmission on multiple *layers* in parallel to the same terminal, there are two transport blocks within a TTI.[1]

10.1.1.1 CRC Insertion Per Transport Block

In the first step of the physical-layer processing, a 24-bit CRC is calculated for and appended to each transport block. The CRC allows for receiver-side detection of errors in the decoded transport block. The corresponding error indication can, for example, be used by the downlink hybrid-ARQ protocol as a trigger for requesting retransmissions.

[1]This is true for initial transmissions. In the case of hybrid-ARQ retransmissions there may also be cases when a single transport block is transmitted over multiple layers, as discussed, for example, in Section 10.3.2.

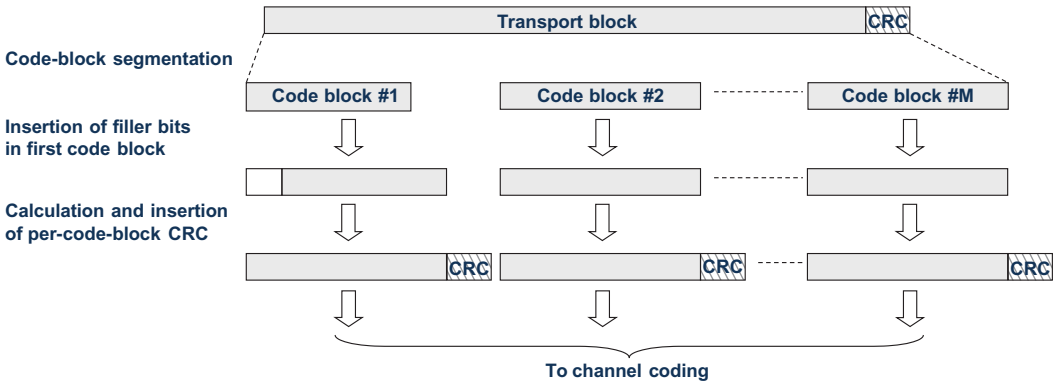


FIGURE 10.2

Code-block segmentation and per-code-block CRC insertion.

10.1.1.2 Code-Block Segmentation and Per-Code-Block CRC Insertion

The LTE Turbo-coder internal interleaver is only defined for a limited number of code-block sizes, with a maximum block size of 6144 bits. If the transport block, including the transport-block CRC, exceeds this maximum code-block size, *code-block segmentation*, illustrated in Figure 10.2, is applied before the Turbo coding. Code-block segmentation implies that the transport block is segmented into smaller *code blocks*, the sizes of which should match the set of code-block sizes supported by the Turbo coder.

In order to ensure that a transport block of arbitrary size can be segmented into code blocks that match the set of available code-block sizes, the specification includes the possibility to insert "dummy" *filler bits* at the head of the first code block. However, the set of transport-block sizes currently defined for LTE has been selected so that filler bits are not needed.

As can be seen in Figure 10.2, code-block segmentation also implies that an additional CRC (also of length 24 bits, but different compared to the transport-block CRC described above) is calculated for and appended to each code block. Having a CRC per code block allows for early detection of correctly decoded code blocks and correspondingly early termination of the iterative decoding of that code block. This can be used to reduce the terminal processing effort and corresponding energy consumption. In the case of a single code block no additional code-block CRC is applied.

One could argue that, in case of code-block segmentation, the transport-block CRC is redundant and implies unnecessary overhead as the set of code-block CRCs should indirectly provide information about the correctness of the complete transport block. However, code-block segmentation is only applied to large transport blocks for which the relative extra overhead due to the additional transport-block CRC is small. The transport-block CRC also adds additional error-detection capabilities and thus further reduces the risk for undetected errors in the decoded transport block.

Information about the transport-block size is provided to the terminal as part of the scheduling assignment transmitted on the PDCCH control channel, as described in Section 10.4.4. Based on this information, the terminal can determine the code-block size and number of code blocks. The terminal receiver can thus, based on the information provided in the scheduling assignment, straightforwardly undo the code-block segmentation and recover the decoded transport blocks.

Petitioners' Exhibit 1003, p. 504
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

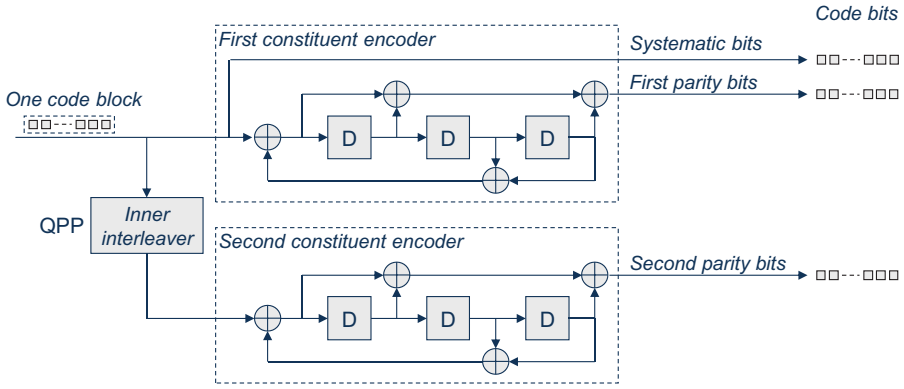


FIGURE 10.3

LTE Turbo encoder.

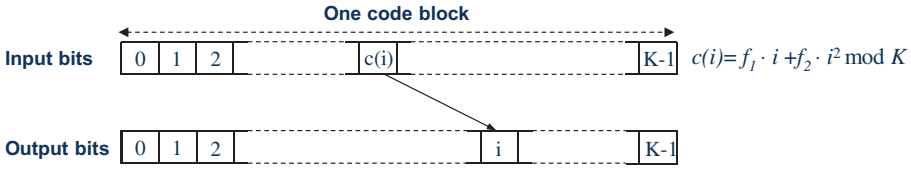


FIGURE 10.4

Principles of QPP-based interleaving.

10.1.1.3 Channel Coding

Channel coding for DL-SCH (as well as for PCH and MCH) is based on Turbo coding [53], with encoding according to Figure 10.3. The encoding consists of two rate-1/2, eight-state constituent encoders, implying an overall code rate of 1/3, in combination with QPP-based[2] interleaving [69]. As illustrated in Figure 10.4, the QPP interleaver provides a mapping from the input (non-interleaved) bits to the output (interleaved) bits according to the function:

$$c(i) = f_1 \cdot i + f_2 \cdot i^2 \bmod K,$$

where i is the index of the bit at the output of the interleaver, $c(i)$ is the index of the same bit at the input of the interleaver, and K is the code-block/interleaver size. The values of the parameters f_1 and f_2 depend on the code-block size K. The LTE specification lists all supported code-block sizes, ranging from a minimum of 40 bits to a maximum of 6144 bits, together with the associated values for the parameters f_1 and f_2. Thus, once the code-block size is known, the Turbo-coder inner interleaving, as well as the corresponding de-interleaving at the receiver side, can straightforwardly be carried out.

A QPP-based interleaver is *maximum contention free* [70], implying that the decoding can be parallelized without the risk for contention when the different parallel processes are accessing the

[2]QPP = Quadrature Permutation Polynomial.

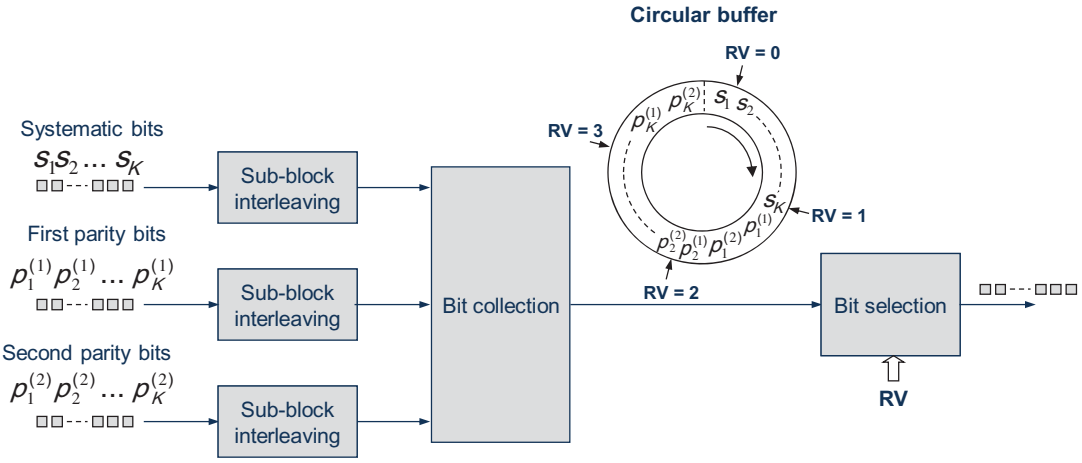


FIGURE 10.5

Rate matching and hybrid-ARQ functionality.

interleaver memory. For the very high data rates supported by LTE, the improved possibilities for parallel processing offered by QPP-based interleaving can substantially simplify the Turbo-encoder/decoder implementation.

10.1.1.4 Rate Matching and Physical-Layer Hybrid-ARQ Functionality

The task of the rate-matching and physical-layer hybrid-ARQ functionality is to extract, from the blocks of code bits delivered by the channel encoder, the exact set of code bits to be transmitted within a given TTI/subframe.

As illustrated in Figure 10.5, the outputs of the Turbo encoder (systematic bits, first parity bits, and second parity bits) are first separately interleaved. The interleaved bits are then inserted into what can be described as a circular buffer with the systematic bits inserted first, followed by alternating insertion of the first and second parity bits.

The bit selection then extracts consecutive bits from the circular buffer to an extent that matches the number of available resource elements in the resource blocks assigned for the transmission. The exact set of bits to extract depends on the *redundancy version* (RV) corresponding to different starting points for the extraction of coded bits from the circular buffer. As can be seen, there are four different alternatives for the redundancy version. The transmitter/scheduler selects the redundancy version and provides information about the selection as part of the scheduling assignment (see Section 10.4.4).

Note that the rate-matching and hybrid-ARQ functionality operates on the full set of code bits corresponding to one transport block and not separately on the code bits corresponding to a single code block.

10.1.1.5 Bit-Level Scrambling

LTE downlink scrambling implies that the block of code bits delivered by the hybrid-ARQ functionality is multiplied (*exclusive-or* operation) by a bit-level *scrambling sequence*. Without downlink scrambling,

the channel decoder at the terminal could, at least in principle, be equally matched to an interfering signal as to the target signal, thus being unable to properly suppress the interference. By applying different scrambling sequences for neighboring cells, the interfering signal(s) after descrambling is (are) randomized, ensuring full utilization of the processing gain provided by the channel code. Thus, the bit scrambling essentially serves the same purpose as the scrambling applied at chip level after the direct-sequence spreading in DS-CDMA-based systems such as WCDMA/HSPA. Fundamentally, channel coding can be seen as "advanced" spreading providing processing gain similar to direct-sequence spreading but also additional coding gain.

In LTE, downlink scrambling is applied to all transport channels as well as to the downlink L1/L2 control signaling. For all downlink transport-channel types except MCH, as well as for the L1/L2 control signaling, the scrambling sequences differ between neighboring cells (*cell-specific scrambling*) to ensure interference randomization between the cells. This is achieved by having the scrambling sequences depend on the physical-layer cell identity (Chapter 14). In contrast, in the case of MBSFN-based transmission using MCH, the same scrambling should be applied to all cells taking part in the MBSFN transmission – that is, all cells within the so-called *MBSFN area* (see Chapter 15).

10.1.1.6 Data Modulation

The downlink data modulation transforms the block of scrambled bits to a corresponding block of complex modulation symbols. The set of modulation schemes supported for the LTE downlink includes QPSK, 16QAM, and 64QAM, corresponding to two, four, and six bits per modulation symbol respectively.

10.1.1.7 Antenna Mapping

The antenna mapping jointly processes the modulation symbols corresponding to the one or two transport blocks and maps the result to different *antenna ports*. The antenna mapping can be configured in different ways corresponding to different multi-antenna transmission schemes, including transmit diversity, beam-forming, and spatial multiplexing. As indicated in Figure 10.1, LTE supports transmission using up to eight antenna ports depending on the exact multi-antenna transmission scheme. More details about LTE downlink multi-antenna transmission are provided in Section 10.3.

Note that the antenna ports referred to above do not necessarily correspond to specific physical antennas. Rather, an antenna port is a more general concept introduced, for example, to allow for beam-forming using multiple physical antennas without the terminal being aware of the beam-forming carried out at the transmitter side.

At least for the downlink, an antenna port can be seen as corresponding to the transmission of a *reference signal* (Section 10.2). Any data transmission from the antenna port can then rely on that reference signal for channel estimation for coherent demodulation. Thus, if the same reference signal is transmitted from multiple physical antennas, these physical antennas correspond to a *single* antenna port. Similarly, if two different reference signals are transmitted from the same set of physical antennas, this corresponds to *two separate antenna ports*.

It should be noted that the LTE specification actually has a somewhat more general definition of an antenna port, essentially just saying that two received signals can be assumed to have experienced the same overall channel, including any joint processing at the transmitter side, if and only if they have been transmitted on the same antenna port.

Petitioners' Exhibit 1003, p. 507
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10.1.1.8 Resource-Block Mapping

The resource-block mapping takes the symbols to be transmitted on each antenna port and maps them to the resource elements of the set of resource blocks assigned by the MAC scheduler for the transmission. As described in Chapter 9, each resource block consists of 84 resource elements (twelve subcarriers during seven OFDM symbols).[3] However, some of the resource elements within a resource block will not be available for the transport-channel transmission as they are occupied by:

- different types of downlink reference signals, as described in Section 10.2;
- downlink L1/L2 control signaling (one, two, or three OFDM symbols at the head of each subframe), as described in Section 10.4[4].

Furthermore, as will be described in Chapter 14, within some resource blocks, additional resource elements are reserved for the transmission of *synchronization signals* as well as for the transmission of the BCH transport channel.

In the TDD special subframe (Section 9.5.2), mapping is limited to the DwPTS.

10.1.2 Localized and Distributed Resource Mapping

As already discussed in Chapter 7, when deciding what set of resource blocks to use for transmission to a specific terminal, the network may take the downlink channel conditions in both the time and frequency domains into account. Such time/frequency-domain channel-dependent scheduling, taking channel variations – for example, due to frequency-selective fading – into account, may significantly improve system performance in terms of achievable data rates and overall cell throughput.

However, in some cases downlink channel-dependent scheduling is not suitable to use or is not practically possible:

- For low-rate services such as voice, the feedback signaling associated with channel-dependent scheduling may lead to extensive relative overhead.
- At high mobility (high terminal speed), it may be difficult or even practically impossible to track the instantaneous channel conditions to the accuracy required for channel-dependent scheduling to be efficient.

In such situations, an alternative means to handle radio-channel frequency selectivity is to achieve frequency diversity by distributing a downlink transmission in the frequency domain.

One way to distribute a downlink transmission in the frequency domain, and thereby achieve frequency diversity, is to assign multiple non-frequency-contiguous resource blocks for the transmission to a terminal. LTE allows for such *distributed resource-block allocation* by means of *resource allocation types 0 and 1* (see Section 10.4.4). However, although sufficient in many cases, distributed resource-block allocation by means of these resource-allocation types has certain drawbacks:

- For both types of resource allocations, the minimum size of the allocated resource can be as large as four resource-block pairs and may thus not be suitable when resource allocations of smaller sizes are needed.
- In general, both these resource-allocation methods are associated with a relatively large PDCCH payload.

[3] 72 resource elements in the case of extended cyclic prefix.
[4] In MBSFN subframes, the control region is limited to a maximum of two OFDM symbols.

Petitioners' Exhibit 1003, p. 508
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

In contrast, *resource-allocation type 2* (Section 10.4.4) always allows for the allocation of a single resource-block pair and is also associated with a relatively small PDCCH payload size. However, resource allocation type 2 only allows for the allocation of resource blocks that are contiguous in the frequency domain. In addition, regardless of the type of resource allocation, frequency diversity by means of distributed resource-block allocation will only be achieved in the case of resource allocations larger than one resource-block pair.

In order to provide the possibility for distributed resource-block allocation in the case of resource-allocation type 2, as well as to allow for distributing the transmission of a single resource-block pair in the frequency domain, the notion of a *Virtual Resource Block* (VRB) has been introduced for LTE.

What is being provided in the resource allocation is the resource allocation in terms of VRB pairs. The key to distributed transmission then lies in the mapping from VRB pairs to *Physical Resource Block* (PRB) pairs – that is, to the actual physical resource used for transmission.

The LTE specification defines two types of VRBs: *localized* VRBs and *distributed* VRBs. In the case of localized VRBs, there is a direct mapping from VRB pairs to PRB pairs, as illustrated in Figure 10.6. However, in the case of distributed VRBs, the mapping from VRB pairs to PRB pairs is more elaborate in the sense that:

- consecutive VRBs are not mapped to PRBs that are consecutive in the frequency domain; and
- even a single VRB pair is distributed in the frequency domain.

The basic principle of distributed transmission is outlined in Figure 10.7 and consists of two steps:

- A mapping from VRB pairs to PRB pairs such that consecutive VRB pairs are not mapped to frequency-consecutive PRB pairs (first step of Figure 10.7). This provides frequency diversity between consecutive VRB pairs. The spreading in the frequency domain is done by means of a block-based "interleaver" operating on resource-block pairs.

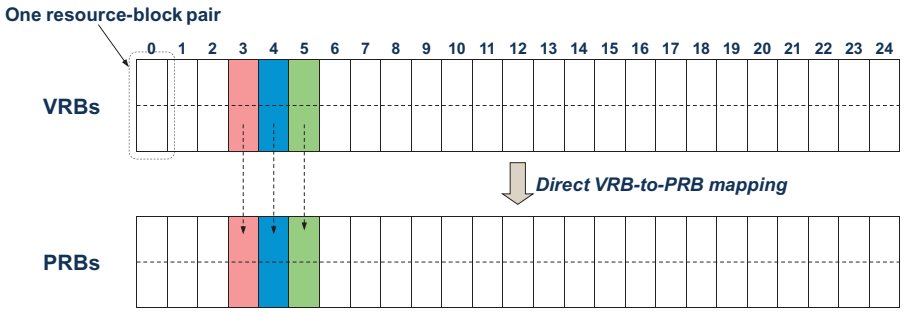


FIGURE 10.6

VRB-to-PRB mapping in the case of localized VRBs. A cell bandwidth corresponding to 25 resource blocks is assumed.

- A split of each resource-block pair such that the two resource blocks of the resource-block pair are transmitted with a certain frequency gap in between (second step of Figure 10.7). This also provides frequency diversity for a single VRB pair. This step can be seen as the introduction of frequency hopping on a slot basis.

Whether the VRBs are localized (and thus mapped according to Figure 10.6) or distributed (mapped according to Figure 10.7) is indicated on the associated PDCCH in the case of type 2 resource allocation. Thus, it is possible to dynamically switch between distributed and localized transmission and also mix distributed and localized transmission for different terminals within the same subframe.

The exact size of the frequency gap in Figure 10.7 depends on the overall downlink cell bandwidth according to Table 10.1. These gaps have been chosen based on two criteria:

1. The gap should be of the order of half the downlink cell bandwidth in order to provide good frequency diversity also in the case of a single VRB pair.
2. The gap should be a multiple of P^2, where P is the size of a *resource-block group* as defined in Section 10.4.4 and used for resource allocation types 0 and 1. The reason for this constraint is to ensure a smooth coexistence in the same subframe between distributed transmission as described above and transmissions based on downlink allocation types 0 and 1.

Due to the constraint that the gap size should be a multiple of P^2, the gap size will in most cases deviate from exactly half the cell bandwidth. In these cases, not all resource blocks within the cell bandwidth can be used for distributed transmission. As an example, for a cell bandwidth corresponding to 25 resource blocks (the example in Figure 10.7) and a corresponding gap size equal to 12 according to Table 10.1, the 25th resource-block pair cannot be used for distributed transmission.

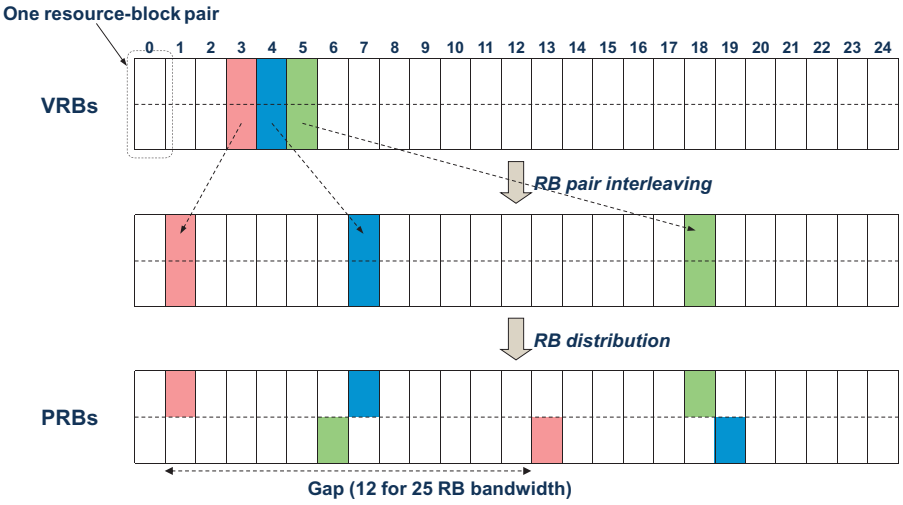


FIGURE 10.7

VRB-to-PRB mapping in the case of distributed VRBs. A cell bandwidth corresponding to 25 resource blocks is assumed.

Table 10.1 Gap Size for Different Cell Bandwidths (Number of Resource Blocks)

	Bandwidth									
	6	**7–8**	**9–10**	**11**	**12–19**	**20–26**	**27–44**	**45–63**	**64–79**	**80–110**
P	1	1	1	2	2	2	3	3	4	4
Gap size	3	4	5	4	8	12	18	27	32	48

Table 10.2 Second Gap Size for Different Cell Bandwidths (Only Applicable for Cell Bandwidths of 50 RBs and Beyond)

	Bandwidth	
	50–63	**64–110**
Gap size	9	16

As another example, for a cell bandwidth corresponding to 50 resource blocks (gap size equal to 27 according to Table 10.1), only 46 resource blocks would be available for distributed transmission.

In addition to the gap size outlined in Table 10.1, for wider cell bandwidths (50 RBs and beyond), there is a possibility to use a second, smaller frequency gap with a size of the order of one-fourth of the cell bandwidth (see Table 10.2). The use of the smaller gap enables restriction of the distributed transmission to only a part of the overall cell bandwidth. Selection between the larger gap according to Table 10.1 and the smaller gap according to Table 10.2 is indicated by an additional bit in the resource allocation on PDCCH.

10.2 DOWNLINK REFERENCE SIGNALS

Downlink reference signals are predefined signals occupying specific resource elements within the downlink time–frequency grid. The LTE specification includes several types of downlink reference signals that are transmitted in different ways and used for different purposes by the receiving terminal:

- *Cell-specific reference signals* (CRS) are transmitted in every downlink subframe and in every resource block in the frequency domain, thus covering the entire cell bandwidth. The cell-specific reference signals can be used by the terminal for channel estimation for coherent demodulation of any downlink physical channel except for PMCH and for PDSCH in the case of *transmission modes 7, 8, or 9*. As described in Section 10.3, these transmission modes correspond to so-called *non-codebook-based precoding*. The cell-specific reference signals can also be used by the terminal to acquire *channel-state information* (CSI). Finally, terminal measurements on cell-specific reference signals are used as the basis for cell-selection and handover decisions.

- *Demodulation reference signals* (DM-RS), also sometimes referred to as *UE-specific reference signals*, are specifically intended to be used by terminals for channel estimation for PDSCH in the case of transmission modes 7, 8, or 9. The label "*UE-specific*" relates to the fact that each demodulation reference signal is intended for channel estimation by a single terminal. That specific reference signal is then only transmitted within the resource blocks assigned for PDSCH transmission to that terminal.
- *CSI reference signals* (CSI-RS) are specifically intended to be used by terminals to acquire *channel-state information* (CSI) in the case when demodulation reference signals are used for channel estimation.[5] CSI-RS have a significantly lower time/frequency density, thus implying less overhead, compared to the cell-specific reference signals.
- *MBSFN reference signals* are intended to be used for channel estimation for coherent demodulation in the case of MCH transmission using so-called *MBSFN* (see Chapter 15 for more details on MCH transmission).
- *Positioning reference signals* were introduced in LTE release 9 to enhance *LTE positioning functionality*, more specifically to support the use of terminal measurements on multiple LTE cells to estimate the geographical position of the terminal. The positioning reference symbols of a certain cell can be configured to correspond to empty resource elements in neighboring cells, thus enabling high-SIR conditions when receiving neighbor-cell positioning reference signals.

10.2.1 Cell-Specific Reference Signals

Cell-specific reference signals, introduced in the first release of LTE (release 8), are the most basic downlink reference signals in LTE. There can be one, two, or four cell-specific reference signals in a cell, defining one, two, or four corresponding antenna ports.

10.2.1.1 Structure of a Single Reference Signal

Figure 10.8 illustrates the structure of a single cell-specific reference signal. As can be seen, it consists of *reference symbols* of predefined values inserted within the first and third last[6] OFDM symbol of each slot and with a frequency-domain spacing of six subcarriers. Furthermore, there is a frequency-domain staggering of three subcarriers for the reference symbols within the third last OFDM symbol. Within each resource-block pair, consisting of 12 subcarriers during one 1 ms subframe, there are thus eight reference symbols.

In general, the values of the reference symbols vary between different reference-symbol positions and also between different cells. Thus, a cell-specific reference signal can be seen as a *two-dimensional cell-specific sequence*. The period of this sequence equals one 10 ms frame. Furthermore, regardless of the cell bandwidth, the reference-signal sequence is defined assuming the maximum possible LTE carrier bandwidth corresponding to 110 resource blocks in the frequency domain. Thus, the basic reference-signal sequence has a length of 8880 symbols.[7] For cell bandwidths less than the maximum possible value, only the reference symbols within that bandwidth are actually transmitted. The reference symbols in the center part of the band will therefore be the same, regardless of the actual cell bandwidth. This allows for the terminal to estimate the channel corresponding to the center

[5] More specifically, CSI-RS are only used in the case of transmission mode 9.
[6] This corresponds to the fifth and fourth OFDM symbols of the slot for normal and extended cyclic prefixes respectively.
[7] Four reference symbols per resource block, 110 resource blocks per slot, and 20 slots per frame.

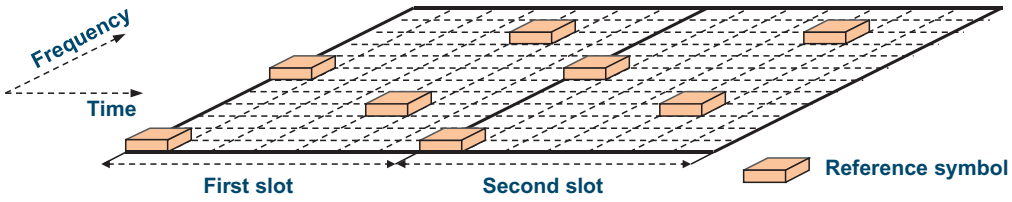


FIGURE 10.8

Structure of cell-specific reference signal within a pair of resource blocks.

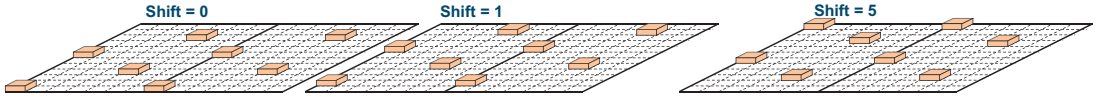


FIGURE 10.9

Different reference-signal frequency shifts.

part of the carrier, where, for example, the basic system information of the cell is transmitted on the BCH transport channel, without knowing the cell bandwidth. Information about the actual cell bandwidth, measured as number of resource blocks, is then provided on the BCH.

There are 504 different reference-signal sequences defined for LTE, where each sequence corresponds to one of 504 different *physical-layer cell identities*. As will be described in more detail in Chapter 14, during the so-called *cell-search procedure* the terminal detects the physical-layer identity of the cell as well as the cell frame timing. Thus, from the cell-search procedure, the terminal knows the reference-signal sequence of the cell (given by the physical-layer cell identity) as well as the start of the reference-signal sequence (given by the frame timing).

The set of reference-symbol positions outlined in Figure 10.8 is only one of six possible *frequency shifts* of the reference symbols, as illustrated in Figure 10.9. The frequency shift to use in a cell depends on the physical-layer identity of the cell such that each shift corresponds to 84 different cell identities. Thus, the six different frequency shifts jointly cover all 504 different cell identities. By properly assigning physical-layer cell identities to different cells, different reference-signal frequency shifts may be used in neighboring cells. This can be beneficial, for example, if the reference symbols are transmitted with higher energy compared to other resource elements, also referred to as *reference-signal power boosting*, in order to improve the reference-signal SIR. If reference signals of neighboring cells were transmitted using the same time/frequency resource, the boosted reference symbols of one cell would be interfered by equally boosted reference symbols of all neighboring cells,[8] implying no gain in the reference-signal SIR. However, if different frequency shifts are used for the reference-signal transmissions of neighboring cells, the reference symbols of one cell will at least partly be interfered by non-reference symbols of neighboring cells, implying an improved reference-signal SIR in the case of reference-signal boosting.

[8]This assumes that the cell transmissions are frame-timing aligned.

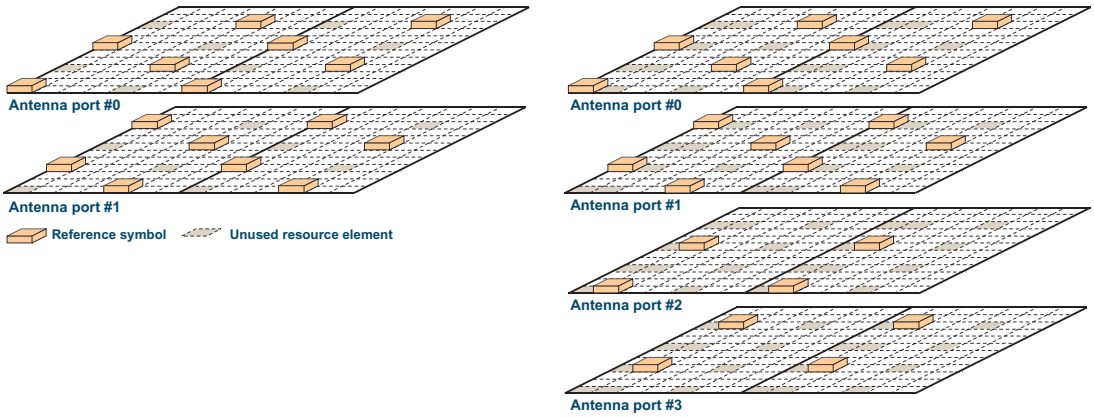


FIGURE 10.10

Structure of cell-specific reference signals in the case of multiple reference signals. Two reference signals corresponding to two antenna ports (left). Four reference signals corresponding to four antenna ports (right).

10.2.1.2 *Multiple Reference Signals*

Figure 10.10 illustrates the reference-signal structure in the case of multiple, more specifically two and four, cell-specific reference signals, and corresponding multiple antenna ports, within a cell:[9]

- In the case of two reference signals within a cell (left part of Figure 10.10), the second reference signal is frequency multiplexed with the first reference signal, with a frequency-domain offset of three subcarriers.
- In the case of four reference signals (right part of Figure 10.10), the third and fourth reference signals are frequency multiplexed and transmitted within the *second* OFDM symbol of each slot, thus being time multiplexed with the first and second reference signals.

Obviously, the reference-symbol density for the third and fourth reference signals is lower, compared to the density of the first and second reference signals. The reason for this is to reduce the reference-signal overhead in the case of four reference signals. More specifically, while the first and second reference signals each correspond to a relative overhead of approximately 5% (four reference symbols within a resource block consisting of a total of 84 resource elements), the relative overhead of the third and fourth reference signals is only half of that or approximately 2.5%. This obviously has an impact on the potential of the terminal to track very fast channel variations. However, this can be justified based on an expectation that, for example, high-order spatial multiplexing will mainly be applied to scenarios with low mobility.

It can also be noted that in a resource element carrying reference signals for a certain transmission port, nothing is being transmitted on the antenna ports corresponding to the other reference signals. Thus, a cell-specific reference signal is not interfered by transmissions on other antenna ports. Multi-antenna transmission schemes, such as spatial multiplexing, to a large extent rely on good channel

[9]It is not possible to configure a cell with three cell-specific reference signals.

estimates to suppress interference between the different layers at the receiver side. However, in the channel estimation itself there is obviously no such suppression. Reducing the interference to the reference signals of an antenna port is therefore important in order to allow for good channel estimation, and corresponding good interference suppression, at the receiver side.

Note that, in MBSFN subframes, only the reference signals in the two first OFDM symbols of the subframe, corresponding to the control region of the MBSFN subframe, are actually transmitted. Thus, there is no transmission of cell-specific reference signals within the MBSFN part of the MBSFM subframe.

10.2.2 Demodulation Reference Signals

In contrast to cell-specific reference signals, a demodulation reference signal (DM-RS) is intended for a specific terminal and is only transmitted in the resource blocks assigned for transmission to that terminal. Demodulation reference signals are intended to be used for channel estimation for PDSCH transmissions for the case when cell-specific reference signals are not to be used – that is, for non-codebook-based precoding (see Section 10.3.3).

Demodulation reference signals were introduced in the first release of LTE (release 8). However, use of demodulation reference signals was then limited to single-layer transmission – that is, no spatial multiplexing – with at most one reference signal for each terminal. In LTE release 9, transmission based on demodulation reference signals was extended to support also dual-layer transmission, requiring up to two simultaneous reference signals (one for each layer). Transmission based on demodulation reference signals was then further extended in LTE release 10 to support up to eight-layer transmission, corresponding to up to eight reference signals.

Actually, the DM-RS structure introduced in LTE release 9 was not a straightforward extension of the release-8 demodulation reference signals but rather a new structure, supporting both single-layer and dual-layer transmission. Already at the time of LTE release 9, it was relatively clear that the LTE radio-access technology should be further extended to support up to eight-layer spatial multiplexing in release 10. It was also quite clear that this extension would be difficult to achieve based on the release-8 DM-RS structure. Rather than extending the release-8 structure to support two reference signals and then introduce a completely new structure for release 10, it was decided instead to introduce a new, more future-proof structure already in release 9. Here we will focus on the DM-RS structure introduced in LTE release 9, including the release-10 extension to support up to eight simultaneous reference signals.

Figure 10.11 illustrates the DM-RS structure for the case of one or two reference signals.[10] As can be seen, there are 12 reference symbols within a resource-block pair. In contrast to cell-specific reference signals, for which the reference symbols of one antenna port correspond to unused resource elements for the other antenna ports (see Figure 10.10), in the case of two demodulation reference signals all 12 reference symbols in Figure 10.11 are transmitted *for both reference signals* – that is, *on both antenna ports*. Interference between the reference signals is instead handled by applying mutually orthogonal patterns, also referred to as *orthogonal cover codes* (OCC), to pairs of consecutive reference symbols, as illustrated in the lower right corner of the figure.

[10] In the case of TDD, the DM-RS structure is slightly modified in the DwPTS due to the shorter duration of the DwPTS compared with normal downlink subframes.

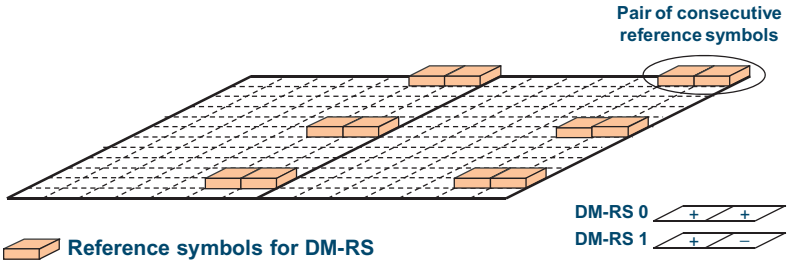


FIGURE 10.11

Structure of demodulation reference signals (DM-RS) for the case of one or two reference signals, including orthogonal cover codes to separate the two reference signals.

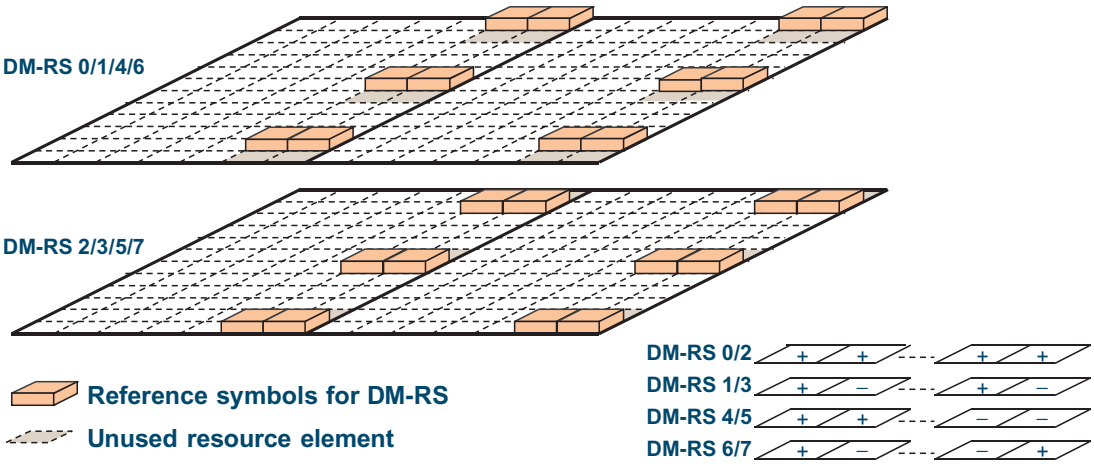


FIGURE 10.12

Demodulation-reference-signal structure for the case of more than two reference signals.

In addition to the mutually orthogonal patterns, one can also apply a pseudo-random sequence to the reference symbols. This sequence is the same for both reference signals and thus does not impact the orthogonality between the transmitted reference signals. Rather, the pseudo-random sequence is intended to separate different demodulation reference signals targeting different terminals in the case of so-called MU-MIMO transmission, as described in Section 10.3.4.1.

Figure 10.12 illustrates the extended DM-RS structure introduced in LTE release 10 to support more than two reference signals. In this case, there are 24 reference symbols within a resource-block pair. The reference signals are frequency multiplexed in groups of four reference signals while, within each group, the reference signals are separated by means of mutually orthogonal patterns covering four reference symbols (two pairs of consecutive reference symbols). It should be noted that orthogonality between the full set of eight reference signals requires that the channel does not vary over the set of reference symbols over which the orthogonal pattern spans. As the four reference symbols are

not consecutive in time, this implies somewhat stronger limitations on the amount of channel variations that can be tolerated without losing the reference-signal orthogonality. However, more than four demodulation reference signals is only applicable to the case of spatial multiplexing with more than four layers, a transmission configuration that is typically anyway only applicable to low-mobility scenarios. Also note that the orthogonal patterns are selected such that, for four or less reference signals, orthogonality is achieved already over pairs of reference symbols. Thus, for three and four reference signals, the constraints on channel variations are the same as for two reference signals according to Figure 10.11.

When demodulation reference signals are transmitted within a resource block, PDSCH mapping to the time–frequency grid of the resource block will be modified to avoid the resource elements in which the reference signals are transmitted. Although this modified mapping is not "understood" by earlier-release terminals not supporting demodulation reference signals, this is not a problem as demodulation reference signals will only be transmitted in resource blocks that are scheduled for PDSCH transmission to terminals of later releases supporting demodulation reference signals and thus "understanding" the modified PDSCH mapping. As will be seen below, the situation is somewhat different in the case of CSI-RS.

As the number of transmitted layers may vary dynamically, the number of transmitted demodulation reference signals may also vary. Thus, the transmission may dynamically change between the DM-RS structures in Figures 10.11 and 10.12. The terminal is informed about the number of transmitted layers (the "transmission rank") as part of the scheduling assignment and will thus know the DM-RS structure and associated PDSCH mapping for each subframe.

10.2.3 CSI Reference Signals

Support for CSI reference signals (CSI-RS) was introduced in LTE release 10. CSI-RS is intended to be used by terminals to acquire channel-state information when demodulation reference signals are used for channel estimation. More specifically, CSI-RS are to be used in transmission mode 9.[11]

As described in Section 10.2.1, the cell-specific reference signals, already available in the first release of LTE, can also be used to acquire channel-state information. There are at least two reasons why CSI-RS was introduced in release 10 as a complement to the already supported cell-specific reference signals:

- In LTE release 8 there could be at most four cell-specific reference signals in a cell. As already mentioned, multi-antenna transmission was extended in LTE release 10 to support downlink spatial multiplexing with up to eight layers, corresponding to eight transmit antennas at the base station. Thus, there was a need to extend the LTE CSI capabilities beyond what was possible with the release 8 cell-specific reference signals.
- The time-frequency density of the cell-specific reference signals was selected to allow for channel estimation for coherent demodulation even with the most extreme channel conditions, including very fast channel variations in both the time and frequency domains. As a consequence, each

[11] The reason why CSI-RS are not used for transmission modes 7 and 8 is simply that these transmission modes were introduced in LTE releases 8 and 9 respectively, and CSI-RS was not introduced until LTE release 10, together with the introduction of transmission mode 9.

Petitioners' Exhibit 1003, p. 517
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

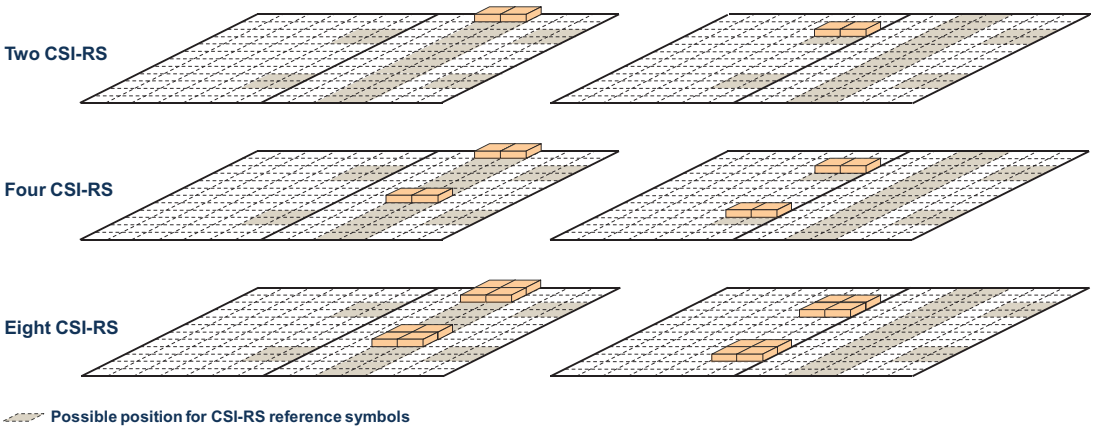


FIGURE 10.13

Examples of reference-signal positions for different number of CSI-RS within a cell. In the case of a single CSI-RS, the same structure as for two CSI-RS is used.

cell-specific reference signal implies a relatively high overhead (approximately 5% and 2.5% for the first/second and third/fourth reference signals respectively). On the other hand, in the case of a reference signal only targeting CSI, such high time-frequency density, and correspondingly relatively large overhead, is not necessary. Thus, rather than extending the cell-specific reference signals it was found to be more efficient to introduce a new type of reference signals (CSI-RS) only targeting CSI, with a flexible and, in general, lower time/frequency density and corresponding lower overhead per reference signal.

10.2.3.1 CSI-RS Structure

A cell can be configured with one, two, four, or eight CSI-RS. The exact CSI-RS structure, including the exact set of resource elements used for CSI-RS in a resource block, depends on the number of CSI-RS configured within the cell and may also be different for different cells. More specifically, within a resource-block pair there are 40 *possible* positions for the reference symbols of CSI-RS and, in a given cell, a subset of the corresponding resource elements is used for CSI-RS transmission, as described below and exemplified in Figure 10.13.[12]

- In the case of two CSI-RS within a cell, the CSI-RS consists of two consecutive reference symbols per resource-block pair, as illustrated in the upper part of Figure 10.13. The two CSI-RS are separated by applying mutually *orthogonal cover codes* (OCC) to the two reference symbols, similar to demodulation reference signals described in Section 10.2.2. Thus, there is a possibility for 20 different CSI-RS configurations, two of which are shown in Figure 10.13, based on the 40 *possible* reference-symbol positions.

[12]For TDD, there are additional *possible* locations for reference symbols for CSI-RS beyond what is illustrated in Figure 10.13.

- In the case of four/eight CSI-RS, the CSI-RS are pair-wise frequency multiplexed, as illustrated in the middle/lower part of Figure 10.13. Thus, there is a possibility for ten/five different CSI-RS configurations, each supporting four/eight CSI-RS.

In the case of a single CSI-RS, the same structure as for two CSI-RS (upper part of Figure 10.13) is used, although with only one of the orthogonal cover codes. The overhead of a single CSI-RS, in terms of occupied resource elements, is thus the same as for two CSI-RS.

In the time domain, the CSI-RS can be transmitted with different periods, ranging from a period of 5 ms (every fifth subframe) to 80 ms (every eighth frame). With a 5 ms period, the overhead per CSI-RS is thus roughly 0.12% per CSI-RS (one resource element per CSI-RS per resource-block pair, but only in every fifth subframe), with longer periods implying correspondingly less overhead.

The exact subframe in which CSI-RS is transmitted in a cell can also be configured, allowing for separation of CSI-RS transmissions between cells also in the time domain, in addition to using different sets of resource elements within the same subframe, as illustrated in Figure 10.13.

In subframes in which CSI-RS is transmitted, it is transmitted in every resource block in the frequency domain. In other words, a CSI-RS transmission covers the entire cell bandwidth.

As mentioned above, when demodulation reference signals are transmitted within a resource block, the corresponding resource elements on which the reference signals are transmitted are explicitly avoided when mapping PDSCH symbols to the resource block. This "modified" PDSCH mapping, which is obviously not "understood" by earlier-release terminals, is possible as demodulation reference signals can be assumed to be transmitted only in resource blocks in which terminals supporting such reference signals are scheduled – that is, terminals of release 10 or later.[13] Expressed alternatively, an earlier-release terminal can be assumed never to be scheduled in a resource block in which demodulation reference signals are transmitted and thus in which the modified PDSCH mapping is used.

The situation is somewhat different for CSI-RS. As CSI-RS is transmitted within all resource blocks in the frequency domain, it would imply a strong scheduler constraint to assume that release-8/9 terminals could never be scheduled in a resource block in which CSI-RS is transmitted. If the PDSCH mapping were modified to explicitly avoid the resource elements in which CSI-RS is transmitted, the mapping would not be recognized by a release-8/9 terminal. Instead, in the case of resource blocks scheduled to release-8/9 terminals, the PDSCH is mapped exactly according to release 8 – that is, the mapping is not modified to avoid the resource elements on which CSI-RS is to be transmitted. The CSI-RS is then simply transmitted on top of the corresponding PDSCH symbols.[14] This will obviously impact the PDSCH demodulation performance, as some PDSCH symbols will be highly corrupted. However, the remaining PDSCH symbols will not be impacted and the PDSCH will still be decodable, although with somewhat reduced performance.

On the other hand, if a release-10 terminal is scheduled in a resource block in which CSI-RS is transmitted, the PDSCH mapping is modified to explicitly avoid the resource elements on which the CSI-RS is transmitted, similar to demodulation reference signals. Thus, if CSI-RS is transmitted in a resource block, the PDSCH mapping to that resource block will be somewhat different depending on the release of the terminal being scheduled in the resource block.

[13] Partly also for terminals of release 9, but then only for a maximum of two DM-RS.

[14] In practice, the base station would probably not transmit PDSCH in these resource elements in order to avoid interference to the CSI-RS transmission. The key thing is that the mapping of the remaining PDSCH symbols is in line with release 8.

Petitioners' Exhibit 1003, p. 519
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

It should be noted that release-8 mapping also has to be used for transmission of, for example, system information and paging messages, as such transmissions must be possible to receive also by release-8/9 terminals.

10.2.3.2 Muted CSI-RS

Figure 10.13 illustrated the set of resource elements that can *potentially* be used for CSI-RS, a subset of which is used to create the different CSI-RS within a cell. In normal operation, the remaining resource elements highlighted in Figure 10.13 are used for PDSCH transmission within the cell.

However, it is also possible to additionally configure one or several subsets of the resource elements outlined in Figure 10.13 as *muted CSI-RS*. A muted CSI-RS has the same structure as a normal (non-muted) CSI-RS except that nothing is actually transmitted on the corresponding resource elements. A muted CSI-RS can thus be seen as a normal (non-muted) CSI-RS *with zero power*.

The intention with muted CSI-RS is to be able to create "transmission holes" corresponding to actual CSI-RS transmissions in other (neighboring) cells. This serves two purposes:

1. To make it possible for a terminal to receive CSI-RS of neighboring cells, without being severely interfered by transmissions in its own cell. CSI estimation on neighboring cells would be of interest if support for different multi-cell-transmission techniques such as *CoMP* (see Chapter 20) were introduced in future LTE releases.
2. To reduce the interference to CSI-RS transmissions in other cells. This is especially applicable to so-called *heterogeneous network deployments* where overlapping cell layers with cells of substantially different power are to coexist in the same spectrum. Interference handling in heterogeneous deployments is further discussed in Chapter 13.

There can be one or multiple sets of muted CSI-RS in a cell. In the case of interference avoidance to neighboring cells (corresponding to point 2 above), there is typically sufficient with a single set of muted CSI-RS as one should typically avoid interference to a single lower-power cell layer. When muted CSI-RS are used to remove own-cell interference in order to be able to better receive CSI-RS from neighboring cells (point 1 above), multiple sets of muted CSI-RS are typically needed as different neighboring cells can be assumed to use mutually different CSI-RS configurations.

10.3 MULTI-ANTENNA TRANSMISSION

As illustrated in Figure 10.14, multi-antenna transmission in LTE can, in general, be described as a mapping from the output of the data modulation to the different antennas ports. The input to the antenna mapping thus consists of the modulation symbols (QPSK, 16QAM, 64QAM) corresponding to the one or two transport blocks. To be more specific, there is one transport block per TTI except for spatial multiplexing, in which case there may be two transport blocks per TTI (see also Section 10.3.2).

The output of the antenna mapping is a set of symbols for each antenna port. The symbols of each antenna port are subsequently applied to the OFDM modulator – that is, mapped to the basic OFDM time–frequency grid corresponding to that antenna port.

The different multi-antenna transmission schemes correspond to different so-called *transmission modes*. There are currently nine different transmission modes defined for LTE. They differ in terms of the specific structure of the antenna mapping of Figure 10.14 but also in terms of what reference

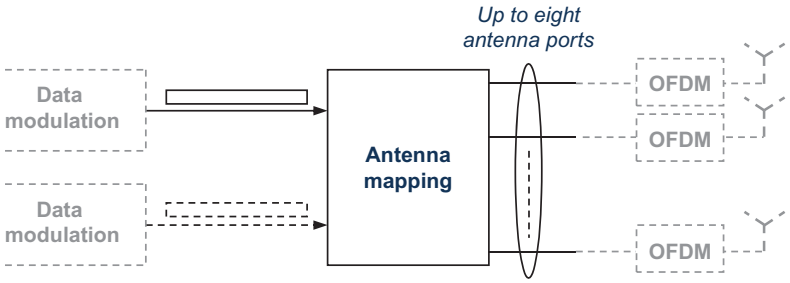


FIGURE 10.14

General structure for LTE downlink multi-antenna transmission. Modulation symbols corresponding to one or two transport blocks mapped to up to eight antenna ports.

signals are assumed to be used for demodulation (cell-specific reference signals or demodulation reference signals respectively) and the type of CSI feedback they rely on. Transmission mode 1 corresponds to single-antenna transmission while the remaining transmission modes correspond to different multi-antenna transmission schemes, including transmit diversity, beam-forming, and spatial multiplexing. Actually, LTE supports both beam-forming and spatial multiplexing as part of more general *antenna precoding*. There are two approaches to downlink antenna precoding, which differ depending on whether cell-specific reference signals or demodulation reference signals are used for channel estimation. These two approaches can also be referred to as *codebook-based precoding* and *non-codebook-based precoding* respectively, the reason for these specific names being further clarified below.

The list below summarizes the currently defined transmission modes and the associated multi-antenna transmission schemes. The different multi-antenna transmission schemes are described in more detail in the sections below.

- **Transmission mode 1:** Single-antenna transmission.
- **Transmission mode 2:** Transmit diversity.
- **Transmission mode 3:** *Open-loop* codebook-based precoding in the case of more than one layer, transmit diversity in the case of rank-one transmission.
- **Transmission mode 4:** *Closed-loop* codebook-based precoding.
- **Transmission mode 5:** Multi-user-MIMO version of transmission mode 4.
- **Transmission mode 6:** Special case of closed-loop codebook-based precoding limited to single-layer transmission.
- **Transmission mode 7:** Release-8 non-codebook-based precoding supporting only single-layer transmission.
- **Transmission mode 8:** Release-9 non-codebook-based precoding supporting up to two layers.
- **Transmission mode 9:** Release-10 non-codebook-based precoding supporting up to eight layers.

Strictly speaking, transmission modes are only applicable for DL-SCH transmission. Thus, a certain transmission mode should not be seen as identical to a certain multi-antenna transmission configuration. Rather, a certain multi-antenna transmission scheme is applied to DL-SCH transmission

according to the list above when the corresponding transmission mode is configured for DL-SCH transmission. However, the same multi-antenna transmission scheme may also be applied to other types of transmissions, such as transmission of BCH and L1/L2 control signaling.[15] However, this does not mean that the corresponding transmission mode is applied to such transmissions.

It should also be mentioned that, although a certain multi-antenna transmission scheme can be seen as being associated with a certain transmission mode, for transmission modes 3–9 there is a possibility for fall-back to transmit diversity without implying that the configured transmission mode is changed.

10.3.1 Transmit Diversity

Transmit diversity can be applied to any downlink physical channel. However, it is especially applicable to transmissions that cannot be adapted to varying channel conditions by means of link adaptation and/or channel-dependent scheduling, and thus for which diversity is more important. This includes transmission of the BCH and PCH transport channels, as well as L1/L2 control signaling. Actually, as already mentioned, transmit diversity is the *only* multi-antenna transmission scheme applicable to these channels. Transmit diversity is also used for transmission of DL-SCH when transmission mode 2 is configured. Furthermore, as also already mentioned, transmit diversity is a fall-back "mode" for transmission mode 3 and higher. More specifically, a scheduling assignment using DCI format 1A (see Section 10.4.4) implies the use of transmit diversity regardless of the configured transmission mode.

Transmit diversity assumes the use of cell-specific reference signals for channel estimation. Thus, a transmit-diversity signal is always transmitted on the same antenna ports as the cell-specific reference signals. Actually, if a cell is configured with two cell-specific reference signals, transmit diversity for two antenna ports *must be used* for BCH and PCH, as well as for the L1/L2 control signaling. Similarly, if four cell-specific reference signals are configured for the cell, transmit diversity for four antenna ports has to be used for the transmission of these channels. In this way, a terminal does not have to be explicitly informed about what multi-antenna transmission scheme is used for these channels. Rather, this is given implicitly from the number of cell-specific reference signals configured for a cell.[16]

10.3.1.1 Transmit Diversity for Two Antenna Ports

In the case of two antenna ports, LTE transmit diversity is based on *Space-Frequency Block Coding* (SFBC), as described in Chapter 5. As can be seen from Figure 10.15, SFBC implies that two consecutive modulation symbols S_i and S_{i+1} are mapped directly to frequency-adjacent resource elements on the first antenna port. On the second antenna port the frequency-swapped and transformed symbols $-S_{i+1}^*$ and S_i^* are mapped to the corresponding resource elements, where "*" denotes complex conjugate.

Figure 10.15 also indicates how the antenna ports on which a transmit-diversity signal is being transmitted correspond to the cell-specific reference signals, more specifically CRS 0 and CRS 1 in

[15] Actually, only single-antenna transmission and transmit diversity is applicable to BCH and L1/L2 control signaling.

[16] Actually, the situation is partly the opposite, i.e. the terminal blindly detects the number of antenna ports used for BCH transmission and, from that, decides on the number of cell-specific reference signals configured within the cell.

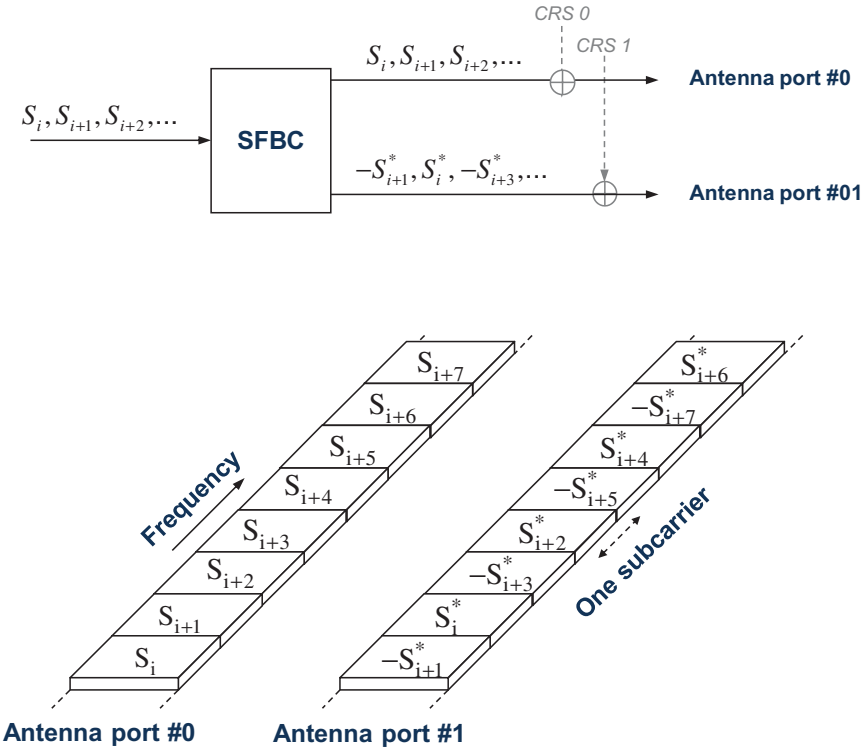


FIGURE 10.15

Transmit diversity for two antenna ports – SFBC.

the case of two antenna ports. Note that one should not interpret this such that the CRS is specifically transmitted for this transmit-diversity signal. The cell-specific reference signals are always transmitted and can be jointly used by multiple transmissions within a cell.

10.3.1.2 *Transmit Diversity for Four Antenna Ports*

In the case of four antenna ports, LTE transmit diversity is based on a combination of SFBC and *Frequency-Switched Transmit Diversity* (FSTD). As can be seen in Figure 10.16, combined SFBC/FSTD implies that pairs of modulation symbols are transmitted by means of SFBC with transmission alternating between pairs of antenna ports (antenna ports 0 and 2 and antenna ports 1 and 3 respectively). For the resource elements where transmission is on one pair of antenna ports, there is no transmission on the other pair of antenna ports. Thus, combined SFBC/FSTD in some sense operates on groups of four modulation symbols and corresponding groups of four frequency-consecutive resource elements on each antenna port. As mentioned in Section 10.4.1, this is the reason for the use of *resource-element groups*, each consisting of four resource elements, when defining the mapping of the L1/L2 control signaling to the physical resource.

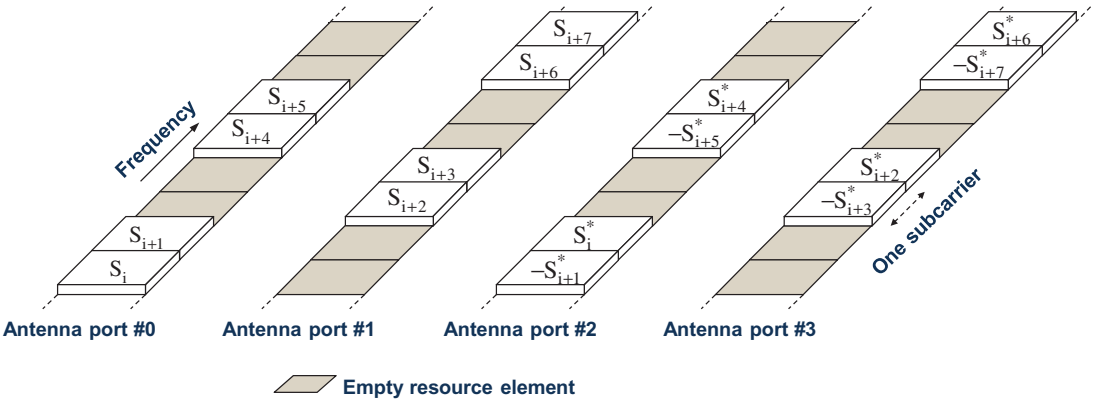


FIGURE 10.16

Transmit diversity for four antenna ports – combined SFBC/FSTD.

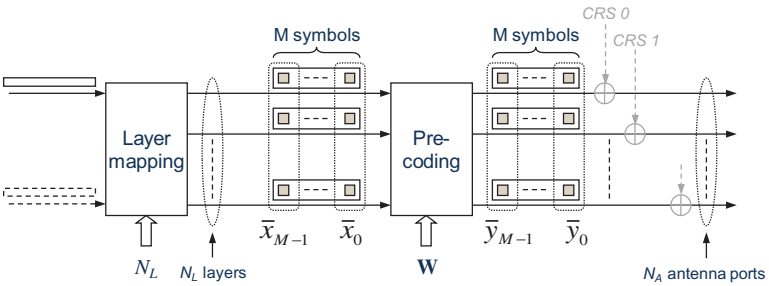


FIGURE 10.17

The basic structure of LTE codebook-based antenna precoding. The figure also indicates how cell-specific reference signals (CRS) are applied after precoding.

10.3.2 Codebook-Based Precoding

The basic processing for codebook-based precoding is illustrated in Figure 10.17. The modulation symbols corresponding to one or two transport blocks are first mapped to N_L *layers*. The number of layers may range from a minimum of one layer up to a maximum number of layers equal to the number of antenna ports.[17] The layers are then mapped to the antenna ports by means of the *precoder functionality*. As codebook-based precoding relies on the cell-specific reference signals for channel estimation, and there are at most four cell-specific reference signals in a cell, codebook-based precoding allows for a maximum of four antenna ports and, as a consequence, a maximum of four layers.

The mapping to layers is outlined in Figure 10.18 for the case of an initial transmission. There is one transport block in the case of a single layer ($N_L = 1$) and two transport blocks for two or more

[17] In practice, the number of layers is also limited by, and should not exceed, the number of receive antennas available at the terminal.

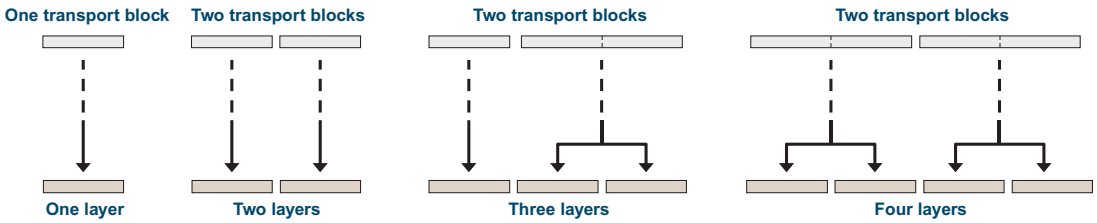


FIGURE 10.18

Transport-block-to-layer mapping for codebook-based antenna precoding (initial transmission).

layers ($N_L > 1$). In the case of a hybrid-ARQ retransmission, if only one of two transport blocks needs to be retransmitted and that transport block was mapped to two layers for the initial transmission, the retransmission may also be carried out on two layers. Thus, in the case of a retransmission, a single transport block may also be transmitted using two layers.

The mapping to layers is such that the number of modulation symbols on each layer is the same and equal to the number of symbols to be transmitted on each antenna port. Thus, in the case of three layers, there should be twice as many modulation symbols corresponding to the second transport block (mapped to the second and third layers) compared to the first transport block (mapped to the first layer). This is ensured by the selection of an appropriate transport-block size in combination with the rate-matching functionality. In the case of four layers, the first transport block is mapped to the first and second layers while the second transport block is mapped to the third and fourth layers. In this case, the number of modulation symbols should thus be the same for the two transport blocks. For one transport block being mapped to two layers, the modulated symbols corresponding to the transport block are mapped to the layers in an alternating fashion – that is, every second modulation symbol is mapped to the first and second layer respectively.

In the case of multi-antenna precoding the number of layers is also often referred to as the *transmission rank*.[18] The transmission rank can vary dynamically, for example based on the number of layers that can be supported by the channel. The latter is sometimes also referred to as the *channel rank*.

After layer mapping, a set of N_L symbols (one symbol from each layer) is linearly combined and mapped to the antenna ports. This combination/mapping can be described by a *precoder matrix* $\mathbf{W}$ of size $N_A \times N_L$, where N_A is the number of antenna ports. More specifically, the vector $\bar{y}_i$ of size N_A, consisting of one symbol for each antenna port, is given by $\bar{y}_i = \mathbf{W} \cdot \bar{x}_i$, where the vector $\bar{x}_i$ of size N_L consists of one symbol from each layer. As the number of layers can vary dynamically, also the number of columns of the precoder matrix will vary dynamically. Specifically, in the case of a single layer, the precoder matrix $\mathbf{W}$ is a vector of size $N_A \times 1$ that provides beam-forming for a single modulation symbol.

Figure 10.17 also indicates how the cell-specific reference signals are applied after antenna precoding. Channel estimation based on the cell-specific reference signals will thus reflect the channel for each antenna port *not including the precoding*. As a consequence, the terminal receiver must have

[18] In the LTE specification, transmit diversity is actually also described as transmission using *multiple layers*. However, transmit diversity is still a *single-rank* transmission scheme.

explicit knowledge about what precoding has been applied at the transmitter side in order to properly process the received signal and recover the different layers. Once again, the figure should not be interpreted such that cell-specific reference signals are inserted specifically for a given PDSCH transmission.

There are two operational modes for codebook-based precoding, *closed-loop operation* and *open-loop operation*. These two modes differ in terms of the exact structure of the precoder matrix and how the matrix is selected by the network and made known to the terminal.

10.3.2.1 Closed-Loop Operation

In case of closed-loop precoding it is assumed that the network selects the precoder matrix based on feedback from the terminal.

Based on measurements on the cell-specific reference signals, the terminal selects a suitable transmission rank and corresponding precoder matrix. Information about the selected rank and precoder matrix is then reported to the network in the form of a *Rank Indication* (RI) and a *Precoder-Matrix Indication* (PMI), as described in Section 11.4. It is important to understand though that the RI and PMI are only recommendations and the network does not need to follow the RI/PMI provided by the terminal when selecting the actual transmission rank and precoder matrix to be used for transmission to the terminal. When not following the terminal recommendation, the network must explicitly inform the terminal what precoder matrix is used for the downlink transmission. On the other hand, if the network uses the precoder matrix recommended by the terminal, only a confirmation that the network is using the recommended matrix is signaled.

To limit the signaling on both uplink and downlink only a limited set of precoder matrices, also referred to as the *codebook*, is defined for each transmission rank for a given number of antenna ports. Both the terminal (when reporting PMI) and the network (when selecting the actual precoder matrix to use for the subsequent downlink transmission to the terminal) should select a precoder matrix from the corresponding codebook. Thus, for terminal PMI reporting, as well as when the network informs the terminal about the actual precoder matrix used for the downlink transmission, only the index of the selected matrix needs to be signaled.

As LTE supports multi-antenna transmission using two and four antenna ports, codebooks are defined for:

- Two antenna ports and one and two layers, corresponding to precoder matrices of size 2×1 and 2×2 respectively.
- Four antenna ports and one, two, three, and four layers, corresponding to precoder matrices of size 4×1, 4×2, 4×3, and 4×4 respectively.

As an example, the precoder matrices specified for the case of two antenna ports are illustrated in Table 10.3. As can be seen, there are four 2×1 precoder matrices for single-layer transmission and three 2×2 precoder matrices for two-layer transmission. In the same way, sets of 4×1, 4×2, 4×3, and 4×4 matrices are defined for the case of four antenna ports and one, two, three, and four layers respectively. It should be pointed out that the first rank-2 (2×2) matrix in Table 10.3 is not used in closed-loop operation but only for *open-loop precoding*, as described in the next section.

Even if the network is following the precoder-matrix recommendation provided by the terminal, the network may, for different reasons, decide to use a lower rank for the transmission, so-called *rank*

Table 10.3 Precoder Matrices for Two Antenna Ports and One and Two Layers (the First 2 × 2 Matrix Is Only Used for Open-Loop Precoding)

One layer	$\frac{1}{\sqrt{2}}\begin{bmatrix}+1\\+1\end{bmatrix}$	$\frac{1}{\sqrt{2}}\begin{bmatrix}+1\\-1\end{bmatrix}$	$\frac{1}{\sqrt{2}}\begin{bmatrix}+1\\+j\end{bmatrix}$	$\frac{1}{\sqrt{2}}\begin{bmatrix}+1\\-j\end{bmatrix}$
Two layers	$\frac{1}{\sqrt{2}}\begin{bmatrix}+1 & 0\\0 & +1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}+1 & +1\\+1 & -1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}+1 & +1\\+j & -j\end{bmatrix}$	

override. In that case the network will use a subset of the columns of the recommended precoder matrix. The network precoder confirmation will then include explicit information about the set of columns being used or, equivalently, about the set of layers being transmitted.

There is also a possibility to apply closed-loop precoding strictly limited to single-layer (rank-1) transmission. This kind of multi-antenna transmission is associated with *transmission mode 6*. The reason for defining an additional transmission mode limited to single-layer transmission rather than relying on the general closed-loop precoding associated with transmission mode 4 is that, by strictly limiting to single-layer transmission, the signaling overhead on both downlink and uplink can be reduced. Transmission mode 6 can, for example, be configured for terminals with low SINR for which multi-layer transmission would anyway not apply.

10.3.2.2 Open-Loop Operation

Open-loop precoding does not rely on any detailed precoder recommendation being reported by the terminal and does not require any explicit network signaling of the actual precoder used for the downlink transmission. Instead, the precoder matrix is selected in a predefined and deterministic way known to the terminal in advance. One use of open-loop precoding is in high-mobility scenarios where accurate feedback is difficult to achieve due to the latency in the PMI reporting.

The basic transmission structure for open-loop precoding is aligned with the general codebook-based precoding outlined in Figure 10.17 and only differs from closed-loop precoding in the structure of the precoding matrix **W**.

In the case of open-loop precoding, the precoder matrix can be described as the product of two matrices $\mathbf{W}'$ and **P**, where $\mathbf{W}'$ and **P** are of size $N_A \times N_L$ and $N_L \times N_L$ respectively:

$$\mathbf{W} = \mathbf{W}' \cdot \mathbf{P} \cdot \tag{10.1}$$

In the case of two antenna ports, the matrix $\mathbf{W}'$ is the normalized 2 × 2 identity matrix:[19]

$$\mathbf{W}' = \frac{1}{\sqrt{2}}\begin{bmatrix}+1 & 0\\0 & +1\end{bmatrix}. \tag{10.2}$$

[19] As non-codebook-based precoding is not used for rank-1 transmission (see below), there is no need for any matrix $\mathbf{W}'$ of size 2 × 1.

In the case of four antenna ports, $\mathbf{W}'$ is given by cycling through four of the defined $4 \times N_L$ precoder matrices and is different for consecutive resource elements.

The matrix $\mathbf{P}$ can be expressed as $\mathbf{P} = \mathbf{D}_i \cdot \mathbf{U}$, where $\mathbf{U}$ is a constant matrix of size $N_L \times N_L$ and $\mathbf{D}_i$ is a matrix of size $N_L \times N_L$ that varies between subcarriers (indicated by the index i). As an example, the matrices $\mathbf{U}$ and $\mathbf{D}_i$ for the case of two layers ($N_L = 2$) are given by:

$$\mathbf{U} = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & e^{-j2\pi/2} \end{bmatrix}, \quad \mathbf{D}_i = \begin{bmatrix} 1 & 0 \\ 0 & e^{-j2\pi i/2} \end{bmatrix}. \tag{10.3}$$

The basic idea with the matrix $\mathbf{P}$ is to average out any differences in the channel conditions as seen by the different layers.

Similar to closed-loop precoding, the transmission rank for open-loop precoding can also vary dynamically down to a minimum of two layers. Transmission mode 3, associated with open-loop precoding, also allows for rank-1 transmission. In that case, transmit diversity as described in Section 10.3.1 is used – that is, SFBC for two antenna ports and combined SFBC/FSTD for four antenna ports.

10.3.3 Non-Codebook-Based Precoding

Similar to codebook-based precoding, non-codebook-based precoding is only applicable to DL-SCH transmission. Non-codebook-based precoding was introduced in LTE release 9 but was then limited to a maximum of two layers. The extension to eight layers was then introduced as part of release 10. The release-9 scheme, associated with transmission mode 8, is a subset of the extended release-10 scheme (transmission mode 9).

There is also a release-8 non-codebook-based precoding defined, associated with transmission mode 7. Transmission mode 7 relies on the release-8 demodulation reference signals mentioned but not described in detail in Section 10.2.2 and only supports single-layer transmission. In this description we will focus on non-codebook-based precoding corresponding to transmission modes 8 and 9.

The basic principles for non-codebook-based precoding can be explained based on Figure 10.19 (where the precoder is intentionally shaded; see below). As can be seen, this figure is very similar to the corresponding figure illustrating codebook-based precoding (Figure 10.17), with layer mapping of modulation symbols corresponding to one or two transport blocks followed by precoding. The layer mapping also follows the same principles as that of codebook-based precoding (see Figure 10.18) but is extended to support up to eight layers. In particular, at least for an initial transmission, there are two transport blocks per TTI except for the case of a single layer, in which case there is only one transport block within the TTI. Similar to codebook-based precoding, for hybrid-ARQ retransmissions there may in some cases be a single transport block also in the case of multi-layer transmission.

The main difference in Figure 10.19 compared to Figure 10.17 (codebook-based precoding) is the presence of demodulation reference signals (DM-RS) before the precoding. The transmission of precoded reference signals allows for demodulation and recovery of the transmitted layers at the receiver side *without explicit receiver knowledge of the precoding applied at the transmitter side*. Put simply, channel estimation based on precoded demodulation reference signals will reflect the channel experienced by the layers, *including the precoding*, and can thus be used directly for coherent demodulation of the different layers. There is thus no need to signal any precoder-matrix information

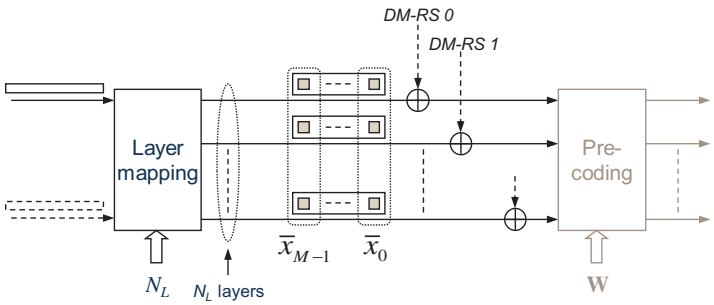


FIGURE 10.19

Basic principles for non-codebook-based antenna precoding.

to the terminal, which only needs to know the number of layers – that is, the transmission rank. As a consequence, the network can select an arbitrary precoder and there is no need for any explicit codebook to select from. This is the reason for the term *non-codebook-based* precoding. It should be noted though that non-codebook-based precoding may still rely on codebooks for the terminal feedback, as described below.

The possibility to select an arbitrary precoder matrix for the transmission is also the reason why the precoder is shaded in Figure 10.19. The precoder part of Figure 10.19 is not visible in the LTE specification and, strictly speaking, in the case of non-codebook-based precoding the antenna mapping defined according to Figure 10.14 consists of only the layer mapping. This also means that the antenna ports defined in Figure 10.14 correspond to the different layers in Figure 10.19 or, expressed differently, precoding occurs *after* the antenna ports.

Still, there must be a way for the network to select a suitable precoder matrix for the transmission. There are essentially two ways by which this can be done in the case of non-codebook-based precoding.

The network may estimate the uplink channel state, for example based on transmission of uplink sounding reference signals as described in the next chapter, and rely on uplink/downlink channel reciprocity when selecting the precoder matrix to use for the downlink transmission. This is especially of interest for TDD operation for which the use of the same frequency for uplink and downlink transmission typically leads to a higher degree of downlink/uplink channel reciprocity. It should be noted though that if the terminal uses multiple receive antennas, it also has to transmit on multiple antennas in order for uplink measurements to fully reflect the downlink channel state.

Alternatively, the network may rely on terminal feedback for precoder-matrix selection. For transmission modes 8 and 9, this feedback is actually very similar to the corresponding feedback for closed-loop codebook-based precoding. In particular, the feedback is based on the same precoder matrices as for codebook-based precoding (see Table 10.3 for an example) but extended to handle up to eight antenna ports. Furthermore, for transmission mode 9, the terminal measurements should be based on CSI-RS, as described in Section 10.2.3, rather than the cell-specific reference signals.

Thus, despite the name, non-codebook-based precoding may also use defined codebooks. However, in contrast to codebook-based precoding, the codebooks are then only used for the terminal PMI reporting and not for the actual downlink transmission.

Petitioners' Exhibit 1003, p. 529
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

10.3.4 Downlink Multi-User MIMO

Spatial multiplexing implies the transmission of multiple layers – that is, multiple parallel transmissions on the same time–frequency resource, to the same terminal. The presence of multiple antennas at both the transmitter and receiver sides in combination with transmitter and/or receiver signal processing is then used to suppress interference between the different layers.

Spatial multiplexing is also often referred to as *Multi-Input-Multi-Output* (MIMO) transmission, reflecting the fact that the channel in the case of spatial multiplexing can be seen as having *multiple inputs*, corresponding to the multiple transmit antennas, and *multiple outputs*, corresponding to the multiple receive antennas. The more specific term *Single-User MIMO* (SU-MIMO) is also often used for reasons that will become obvious below.

The term *Multi-User* MIMO (MU-MIMO) is, in 3GPP, used to denote transmission to *different* terminals using the same time–frequency resource, in practice relying on multiple antennas at the transmitter (network) side to separate the two transmissions.

In principle, one could realize MU-MIMO as a direct extension to spatial multiplexing, with the different layers simply being intended for different terminals. The set of terminals would demodulate and perhaps also decode the full set of layers. The data on a layer not intended for a specific terminal would then just be discarded by that terminal after demodulation/decoding.

However, such an approach would imply that all terminals involved in the MU-MIMO transmission would need to know about the full set of layers being transmitted. It would also imply that one would need to have exactly the same resource assignment for all terminals involved in the MU-MIMO transmission. All terminals would also need to include the full set of receive antennas necessary to receive the overall multi-layer transmission.

Instead, 3GPP has chosen an MU-MIMO approach that does not require terminal knowledge about the presence of the other transmissions, allows for only partly overlapping resource assignments, and, at least in principle, does not require the presence of multiple receive antennas at the mobile terminal.[20] There are two approaches to MU-MIMO specified in 3GPP, one being an integrated part of transmission modes 8 and 9 corresponding to non-codebook-based precoding, and one being based on codebook-based precoding but associated with a special transmission mode, *transmission mode 5*.

10.3.4.1 MU-MIMO within Transmission Modes 8/9

The only thing that is needed to support MU-MIMO as part of transmission modes 8 and 9 – that is, within the concept of non-codebook precoding – is to be able to assign different demodulation reference signals for the transmissions to the different terminals. As discussed in Section 10.2.2, for transmission mode 8 it is possible to define two orthogonal reference signals by means of two mutually orthogonal patterns, or *orthogonal cover codes* (OCC). In the case of spatial multiplexing, these OCC and corresponding reference signals are used for the transmission of the two layers. However, they can also be assigned to different users to enable MU-MIMO transmission within transmission mode 8.

In addition, as also mentioned in Section 10.2.2, a pseudo-random sequence is applied to the demodulation reference signals. This sequence is not terminal specific in the sense that each terminal

[20]Note, though, that the LTE performance requirements in general assume the presence of at least two receive antennas at the mobile terminal.

Petitioners' Exhibit 1003, p. 530
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

has its own sequence. Rather, there are only two sequences available and information on what pseudo-random sequence is used for a certain demodulation reference signal to a certain terminal is provided in the scheduling assignment together with information about the OCC.

In total, this allows for four different reference signals that can be assigned for four different transmissions being transmitted in parallel to different terminals using MU-MIMO. This assumes no spatial multiplexing on a per-link basis – that is, the transmission to each terminal consists of a single layer. One can also combine MU-MIMO with spatial multiplexing by transmitting two layers to a single terminal, in which case the number of multiplexed terminals is reduced correspondingly as the OCC are then used to separate the two layers transmitted to a single terminal. Obviously, the transmission of multiple layers to the same terminal requires the use of multiple receive antennas at the terminal.

Finally, although MU-MIMO does not rely on any terminal knowledge of the other, parallel, transmissions, nothing prevents a terminal from assuming that there are transmissions on the other "layers", corresponding to the other demodulation reference signals, and applying receiver-side signal processing to suppress the potential interference from those *possibly* present transmissions. Such suppression would then, once again, be based on the presence of multiple receive antennas at the mobile terminal.

10.3.4.2 MU-MIMO Based on CRS

The above-described MU-MIMO transmission is part of transmission modes 8 and 9 and thus became available in LTE release 9, with further extension in release 10. However, already in LTE release 8, MU-MIMO was possible by a minor modification of transmission mode 4 – that is, closed-loop codebook-based beam-forming, leading to *transmission mode 5*. The only difference between transmission modes 4 and 5 is the signaling of an additional power offset between PDSCH and the cell-specific reference signals (CRS).

In general, for transmission modes relying on CRS (as well as when relying on DM-RS) for channel estimation the terminal will use the reference signal as a phase reference but also as a power/amplitude reference for the demodulation of signals transmitted by means of higher-order modulation (16QAM and 64QAM). Thus, for proper demodulation of higher-order modulation, the terminal needs to know the power offset between the CRS and the PDSCH.

The terminal is informed about this power offset by means of higher-layer signaling. However, what is then provided is the offset between CRS power and the overall PDSCH power, including all layers. In the case of spatial multiplexing, the overall PDSCH power has to be divided between the different layers, and it is the relation between the CRS power and the per-layer PDSCH power that is relevant for demodulation.

In the case of pure spatial multiplexing (no MU-MIMO) – that is, transmission modes 3 and 4 – the terminal knows about the number of layers and thus indirectly about the offset between the CRS power and the per-layer PDSCH power.

In the case of MU-MIMO, the total available power will typically also be divided between the transmissions to the different terminals, with less PDSCH power being available for each transmission. However, terminals are not aware of the presence of parallel transmissions to other terminals and are thus not aware of any per-PDSCH power reduction. For this reason, transmission mode 5 includes the explicit signaling of an *additional power offset* of -3 dB to be used by the terminal in addition to the CRS/PDSCH power offset signaled by higher layers.

Transmission mode 5 is limited to single-rank transmission and, in practice, limited to two users being scheduled in parallel, as there is only a single -3 dB offset defined.

Petitioners' Exhibit 1003, p. 531
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Note that the above power-offset signaling is not needed for MU-MIMO based on demodulation reference signals (transmission modes 8 and 9) as, in this case, each transmission has its own set of reference signals. The power per reference signal will thus scale with the number of layers and transmissions, similar to the PDSCH power and the reference-signal to per-layer PDSCH power ratio will remain constant.

10.4 DOWNLINK L1/L2 CONTROL SIGNALING

To support the transmission of downlink and uplink transport channels, there is a need for certain *associated downlink control signaling*. This control signaling is often referred to as *downlink L1/L2 control signaling*, indicating that the corresponding information partly originates from the physical layer (Layer 1) and partly from Layer 2 MAC. Downlink L1/L2 control signaling consists of downlink scheduling assignments, including information required for the terminal to be able to properly receive, demodulate, and decode the DL-SCH[21] on a component carrier, uplink scheduling grants informing the terminal about the resources and transport format to use for uplink (UL-SCH) transmission, and hybrid-ARQ acknowledgements in response to UL-SCH transmissions. In addition, the downlink control signaling can also be used for the transmission of power-control commands for power control of uplink physical channels, as well as for certain special purposes such as MBSFN notifications.

As illustrated in Figure 10.20, the downlink L1/L2 control signaling is transmitted within the first part of each subframe. Thus, each subframe can be said to be divided into a *control region* followed by a *data region*, where the control region corresponds to the part of the subframe in which the L1/L2 control signaling is transmitted. To simplify the overall design, the control region always occupies an integer number of OFDM symbols, more specifically one, two, or three OFDM symbols (for narrow cell bandwidths, 10 resource blocks or less, the control region consists of two, three, or four OFDM symbols to allow for a sufficient amount of control signaling). In the case of carrier aggregation, there is one control region per component carrier.

The size of the control region expressed in number of OFDM symbols, or, equivalently, the start of the data region, can be dynamically varied on a per-subframe basis independently for each component carrier.[22] Thus, the amount of radio resources used for control signaling can be dynamically adjusted to match the instantaneous traffic situation. For a small number of users being scheduled in a subframe, the required amount of control signaling is small and a larger part of the subframe can be used for data transmission (larger data region).

The reason for transmitting the control signaling at the beginning of the subframe is to allow for terminals to decode downlink scheduling assignments as early as possible. Processing of the data region – that is, demodulation and decoding of the DL-SCH transmission – can then begin before the end of the subframe. This reduces the delay in the DL-SCH decoding and thus the overall downlink transmission delay. Furthermore, by transmitting the L1/L2 control channel at the beginning of the subframe – that is, by allowing for early decoding of the L1/L2 control information – terminals that

[21] L1/L2 control signaling is also needed for the reception, demodulation, and decoding of the PCH transport channel.
[22] The start of the data region is semi-statically configured when using cross-carrier scheduling (see Section 10.4.1).

Petitioners' Exhibit 1003, p. 532
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

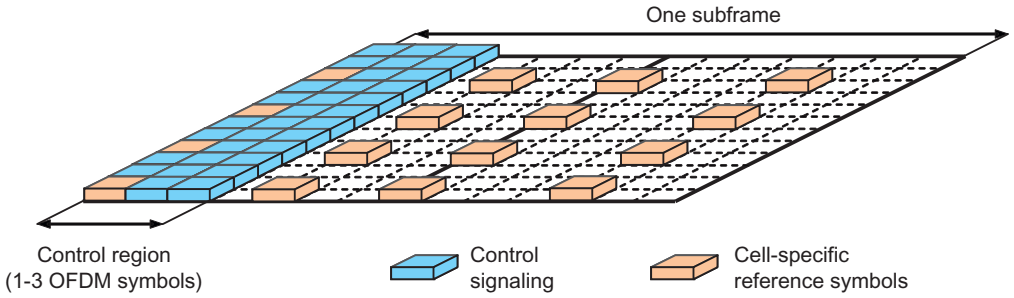


FIGURE 10.20

LTE time–frequency grid illustrating the split of the subframe into (variable-sized) control and data regions.

are not scheduled in the subframe may power down the receiver circuitry for a part of the subframe, allowing for a reduced terminal power consumption.

The downlink L1/L2 control signaling consists of four different physical-channel types:

- The *Physical Control Format Indicator Channel* (PCFICH), informing the terminal about the size of the control region (one, two, or three OFDM symbols). There is one and only one PCFICH on each component carrier or, equivalently, in each cell.
- The *Physical Downlink Control Channel* (PDCCH), used to signal downlink scheduling assignments and uplink scheduling grants. Each PDCCH typically carries signaling for a single terminal, but can also be used to address a group of terminals. Multiple PDCCHs can exist in each cell.
- The *Physical Hybrid-ARQ Indicator Channel* (PHICH), used to signal hybrid-ARQ acknowledgements in response to uplink UL-SCH transmissions. Multiple PHICHs can exist in each cell.
- The *Relay Physical Downlink Control Channel* (R-PDCCH), used for relaying. A detailed discussion can be found in Chapter 16 in conjunction with the overall description of relays; at this stage it suffices to note that the R-PDCCH is not transmitted in the control region.

The maximum size of the control region is normally three OFDM symbols (four in the case of narrow cell bandwidths), as mentioned above. However, there are a few exceptions to this rule. When operating in TDD mode, the control region in subframes 1 and 6 is restricted to at most two OFDM symbols since, for TDD, the primary synchronization signal (see Chapter 14) occupies the third OFDM symbol in those subframes. Similarly, for MBSFN subframes (see Chapter 9), the control region is restricted to a maximum of two OFDM symbols.

10.4.1 Physical Control Format Indicator Channel

The PCFICH indicates the size of the control region in terms of the number of OFDM symbols – that is, indirectly where in the subframe the data region starts. Correct decoding of the PCFICH information is thus essential. If the PCFICH is incorrectly decoded, the terminal will neither know how to process the control channels nor where the data region starts for the corresponding subframe.[23]

[23]Theoretically, the terminal could blindly try to decode all possible control channel formats and, from which format that was correctly decoded, deduce the starting position of the data region, but this can be a very complex procedure.

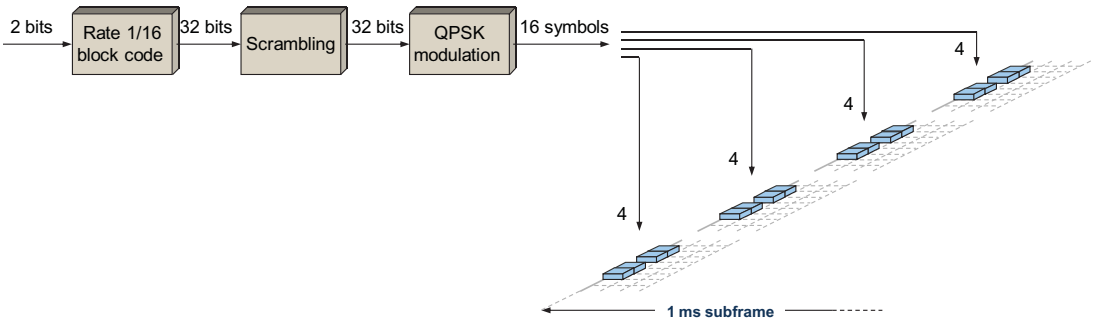


FIGURE 10.21

Overview of the PCFICH processing.

The PCFICH consists of two bits of information, corresponding to the three[24] control-region sizes of one, two, or three OFDM symbols (two, three or four for narrow bandwidths), which are coded into a 32-bit codeword. The coded bits are scrambled with a cell- and subframe-specific scrambling code to randomize inter-cell interference, QPSK modulated, and mapped to 16 resource elements. As the size of the control region is unknown until the PCFICH is decoded, the PCFICH is always mapped to the first OFDM symbol of each subframe.

The mapping of the PCFICH to resource elements in the first OFDM symbol in the subframe is done in groups of four resource elements, with the four groups being well separated in frequency to obtain good diversity. Furthermore, to avoid collisions between PCFICH transmissions in neighboring cells, the location of the four groups in the frequency domain depends on the physical-layer cell identity.

The transmission power of the PCFICH is under control of the eNodeB. If necessary for coverage in a certain cell, the power of the PCFICH can be set higher than for other channels by "borrowing" power from, for example, simultaneously transmitted PDCCHs. Obviously, increasing the power of the PCFICH to improve the performance in an interference-limited system depends on the neighboring cells not increasing their transmit power on the interfering resource elements. Otherwise, the interference would increase as much as the signal power, implying no gain in received SIR. However, as the PCFICH-to-resource-element mapping depends on the cell identity, the probability of (partial) collisions with PCFICH in neighboring cells in synchronized networks is reduced, thereby improving the performance of PCFICH power boosting as a tool to control the error rate.

The overall PCFICH processing is illustrated in Figure 10.21.

To describe the mapping of the PCFICH, and L1/L2 control signaling in general, to resource elements, some terminology is required. As mentioned above, the mapping is specified in terms of groups of four resource elements, so-called *resource-element groups*. To each resource-element group, a *symbol quadruplet* consisting of four (QPSK) symbols is mapped. The main motivation behind this, instead of simply mapping the symbols one by one, is the support of transmit diversity. As discussed in Section 10.3, transmit diversity with up to four antenna ports is specified for L1/L2

[24]The fourth combination is reserved for future use.

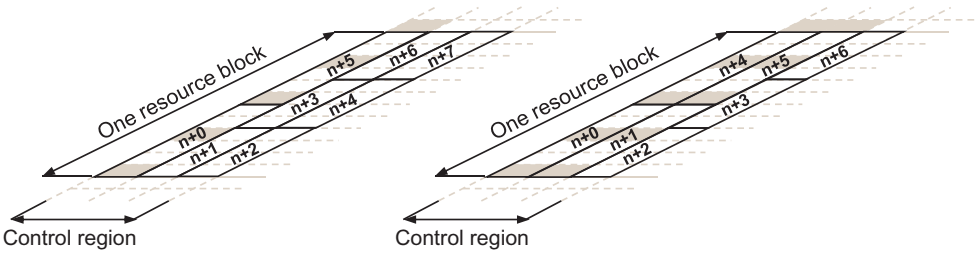


FIGURE 10.22

Numbering of resource-element groups in the control region (assuming a size of three OFDM symbols).

control signaling. Transmit diversity for four antenna ports is specified in terms of groups of four symbols (resource elements) and, consequently, the L1/L2 control-channel processing is also defined in terms of symbol quadruplets.

The definition of the resource-element groups assumes that reference symbols corresponding to two antenna ports are present in the first OFDM symbol, regardless of the actual number of antenna ports configured in the cell. This simplifies the definition and reduces the number of different structures to handle. Thus, as illustrated in Figure 10.22, in the first OFDM symbol there are two resource-element groups per resource block, as every third resource element is reserved for reference signals (or non-used resource elements corresponding to reference symbols on the other antenna port). As also illustrated in Figure 10.22, in the second OFDM symbol (if part of the control region) there are two or three resource-element groups depending on the number of antenna ports configured. Finally, in the third OFDM symbol (if part of the control region) there are always three resource-element groups per resource block. Figure 10.22 also illustrates how resource-element groups are numbered in a time-first manner within the size of the control region.

Returning to the PCFICH, four resource-element groups are used for the transmission of the 16 QPSK symbols. To obtain good frequency diversity the resource-element groups should be well spread in frequency and cover the full downlink cell bandwidth. Therefore, the four resource-element groups are separated by one-fourth of the downlink cell bandwidth in the frequency domain, with the starting position given by physical-layer cell identity. This is illustrated in Figure 10.23, where the PCFICH mapping to the first OFDM symbol in a subframe is shown for three different physical-layer cell identities in the case of a downlink cell bandwidth of eight resource blocks. As seen in the figure, the PCFICH mapping depends on the physical-layer cell identity to reduce the risk of inter-cell PCFICH collisions. The cell-specific shifts of the reference symbols, described in Section 10.2.1, are also seen in the figure.

For terminals capable of carrier aggregation, there is one PCFICH per component carrier. Independent signaling of the control-region size on the different component carriers is used, implying that the control region may be of different size on different component carriers. Hence, in principle the terminal needs to receive the PCFICH on each of the component carriers it is scheduled upon. Furthermore, as different component carriers may have different physical-layer cell identities, the location and scrambling may differ across component carriers.

Petitioners' Exhibit 1003, p. 535
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

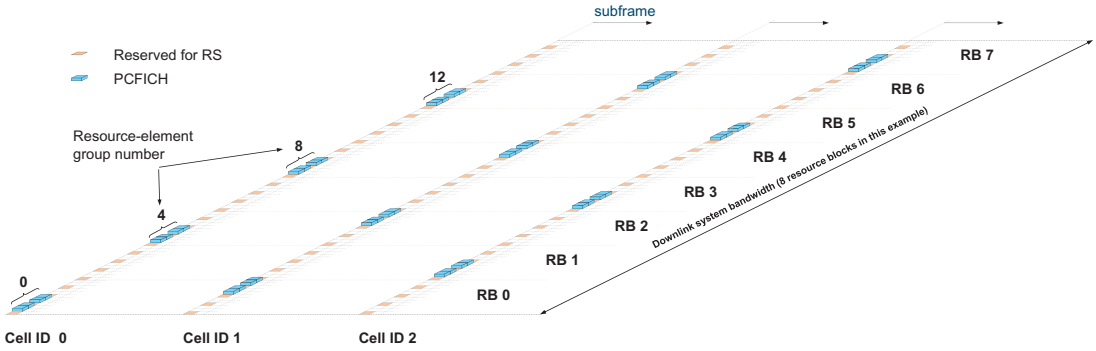


FIGURE 10.23

Example of PCFICH mapping in the first OFDM symbol for three different physical-layer cell identities.

If cross-carrier scheduling is used (see Section 10.4.6) – that is, control signaling related to a certain PDSCH transmission is transmitted on a component carrier other than the PDSCH itself – the terminal needs to know the starting position for the data region on the carrier upon which the PDSCH is transmitted. Using the PCFICH on the component carrier carrying the PDSCH would be possible in principle, although it would increase the probability of incorrectly decoding the PDSCH since there are two PCFICH instances, one for the PDCCH decoding on one component carrier and one for PDSCH reception on the other component carrier. This would be problematic, especially since the main use of cross-carrier scheduling is enhanced support of heterogeneous deployments (see Chapter 13), where some of the component carriers may be subject to strong interference. Therefore, for cross-carrier scheduled transmissions, the start of the data region is not obtained from the PCFICH on that component carrier, but is configured on a semi-static basis. The semi-statically configured value may differ from the value signaled on the PCFICH on the component carrier carrying the PDSCH transmission.

10.4.2 Physical Hybrid-ARQ Indicator Channel

The PHICH is used for transmission of hybrid-ARQ acknowledgements in response to UL-SCH transmission. There is one PHICH transmitted per received transport block and TTI – that is, when uplink spatial multiplexing is used on a component carrier, two PHICHs are used to acknowledge the transmission, one per transport block.

For proper operation of the hybrid-ARQ protocol, as discussed in Chapter 12, the error rate of the PHICH should be sufficiently low. The operating point of the PHICH is not specified and is up to the network operator to decide upon, but typically ACK-to-NAK and NAK-to-ACK error rates of the order of 10^{-2} and 10^{-3}–10^{-4} respectively are targeted. The reason for the asymmetric error rates is that an NAK-to-ACK error would imply loss of a transport block at the MAC level, a loss that has to be recovered by RLC retransmissions with the associated delays, while an ACK-to-NAK error only implies an unnecessary retransmission of an already correctly decoded transport block. To meet these error-rate targets without excessive power, it is beneficial to control the PHICH transmission power as a function of the radio-channel quality of the terminal to which the PHICH is directed. This has influenced the design of the PHICH structure.

Petitioners' Exhibit 1003, p. 536
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

In principle, a PHICH could be mapped to a set of resource elements exclusively used by this PHICH. However, taking the dynamic PHICH power setting into account, this could result in significant variations in transmission power between resource elements, which can be challenging from an RF implementation perspective. Therefore, it is preferable to spread each PHICH on multiple resource elements to reduce the power differences while at the same time providing the energy necessary for accurate reception. To fulfill this, a structure where several PHICHs are code multiplexed on to a set of resource elements is used in LTE. The hybrid-ARQ acknowledgement (one single bit of information per transport block) is repeated three times, followed by BPSK modulation on either the I or the Q branch and spreading with a length-four orthogonal sequence. A set of PHICHs transmitted on the same set of resource elements is called a PHICH group, where a PHICH group consists of eight PHICHs in the case of normal cyclic prefix. An individual PHICH can thus be uniquely represented by a single number from which the number of the PHICH group, the number of the orthogonal sequence within the group, and the branch, I or Q, can be derived.

For extended cyclic prefix, which is typically used in time-dispersive environments, the radio channel may not be flat over the frequency spanned by a length-four sequence. A non-flat channel would negatively impact the orthogonality between the sequences. Hence, for extended cyclic prefix, orthogonal sequences of length two are used for spreading, implying only four PHICHs per PHICH group. However, the general structure remains the same as for the normal cyclic prefix.

After forming the composite signal representing the PHICHs in a group, cell-specific scrambling is applied and the 12 scrambled symbols are mapped to three resource-element groups. Similarly to the other L1/L2 control channels, the mapping is described using resource-element groups to be compatible with the transmit diversity schemes defined for LTE.

The overall PHICH processing is illustrated in Figure 10.24.

The requirements on the mapping of PHICH groups to resource elements are similar to those for the PCFICH, namely to obtain good frequency diversity and to avoid collisions between neighboring cells in synchronized networks. Hence, each PHICH group is mapped to three resource-element groups, separated by approximately one-third of the downlink cell bandwidth. In the first OFDM

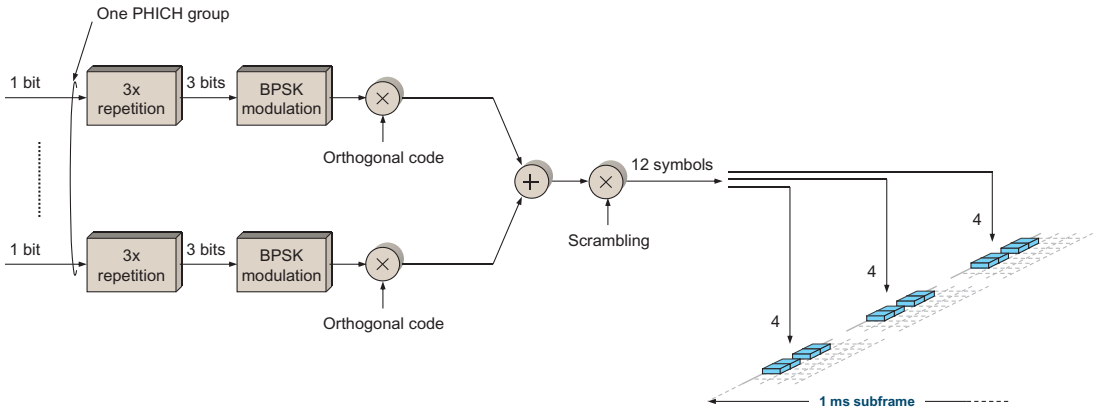


FIGURE 10.24

PHICH structure.

symbol in the control region, resources are first allocated to the PCFICH, the PHICHs are mapped to resource elements not used by the PCFICH, and finally, as will be discussed further below, the PDCCHs are mapped to the remaining resource elements.

Typically, the PHICH is transmitted in the first OFDM symbol only, which allows the terminal to attempt to decode the PHICH even if it failed decoding of the PCFICH. This is advantageous as the error requirements on the PHICH typically are stricter than for PCFICH. However, in some propagation environments, having a PHICH duration of a single OFDM symbol would unnecessarily restrict the coverage. To alleviate this, it is possible to semi-statically configure a PHICH duration of three OFDM symbols. In this case, the control region is three OFDM symbols long in all subframes to fulfill the general principle of separating the control region from data in the time domain only. Obviously, the value transmitted on the PCFICH will be fixed (and can be ignored) in this case. For narrow bandwidths, where the control region can be up to four OFDM symbols long, there is still a need to use the PCFICH to differentiate between a size-three and size-four control region.

As a general principle, LTE transmits the PHICH on the same component carrier that was used for the scheduling grant for the corresponding uplink data transmission. Not only is this principle general in the sense that it can handle symmetric as well as asymmetric carrier aggregation scenarios, it is also beneficial from a terminal power consumption perspective as the terminal only need monitor the component carriers it monitors for uplink scheduling grants (especially as the PDCCH may override the PHICH to support adaptive retransmissions, as discussed in Chapter 12).

The association between PUSCH transmission in an uplink subframe and the corresponding downlink PHICH resource is discussed in Chapter 12. At this stage, it is sufficient to note that, for TDD configuration zeros, uplink transmissions in multiple subframes may need to be acknowledged in one downlink subframe. Consequently, the amount of resources for PHICH may differ between subframes in the case of TDD.

The PHICH configuration is part of the system information transmitted on the PBCH; one bit indicates whether the duration is one or three OFDM symbols and two bits indicate the amount of resources in the control region reserved for PHICHs, expressed as a fraction of the downlink cell bandwidth in terms of resource blocks. Having the possibility to configure the amount of PHICH resources is useful as the PHICH capacity depends on, for example, whether the network uses multi-user MIMO or not. The PHICH configuration must reside on the PBCH, as it needs to be known in order to properly process the PDCCHs for reception of the part of the system information on the DL-SCH. For TDD, the PHICH information provided on the PBCH is not sufficient for the terminal to know the exact set of resources used by PHICH, as there is also a dependency on the uplink/downlink allocation, provided as part of the system information transmitted on the PDSCH. In order to receive the system information on the DL-SCH, which contains the uplink/downlink allocation, the terminal therefore has to blindly process the PDCCHs under different PHICH configuration hypotheses.

10.4.3 Physical Downlink Control Channel

The PDCCH is used to carry downlink control information (DCI) such as scheduling decisions and power-control commands. More specifically, the DCI includes:

- Downlink scheduling assignments, including PDSCH resource indication, transport format, hybrid-ARQ information, and control information related to spatial multiplexing (if applicable). A downlink scheduling assignment also includes a command for power control of the PUCCH used for transmission of hybrid-ARQ acknowledgements in response to downlink scheduling assignments.

Petitioners' Exhibit 1003, p. 538
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Uplink scheduling grants, including PUSCH resource indication, transport format, and hybrid-ARQ-related information. An uplink scheduling grant also includes a command for power control of the PUSCH.
- Power-control commands for a set of terminals as a complement to the commands included in the scheduling assignments/grants.

The different types of control information, both between the groups above as well as within the groups, correspond to different DCI message sizes. For example, supporting spatial multiplexing with non-contiguous allocation of resource blocks in the frequency domain requires a larger scheduling message in comparison with an uplink grant allowing for frequency-contiguous allocations only. The DCI is therefore categorized into different *DCI formats*, where a format corresponds to a certain message size and usage. The DCI formats are summarized in Table 10.4, sorted in approximate order of the relative size. The actual message size depends on, among other factors, the cell bandwidth as, for larger bandwidths, a larger number of bits is required to indicate the resource-block allocation. The number of cell-specific reference signals in the cell and whether cross-carrier scheduling is configured or not will also affect the absolute size of most DCI formats. Hence, a given DCI format may have different sizes depending on the overall configuration of the cell. This will be discussed further below; at this stage it suffices to note that formats 0, 1A, 3, and 3A have the same message size.[25]

Table 10.4 DCI Formats

	Usage				
Size	**Uplink Grant**		**Downlink Assignment**		**Power Control**
Small	–		1C	Special purpose compact assignment	–
	0	Single layer	1A	Contiguous allocations only	3, 3A
…	–		1B	Codebook-based beam-forming using CRS	–
	–		1D	Multi-user MIMO using CRS	–
	4	Spatial multiplexing	–		–
	–		1	Flexible allocations	–
	–		2A	Open-loop spatial multiplexing using CRS	–
	–		2B	Dual-layer transmission using DM-RS	–
	–		2C	Multi-layer transmission using DM-RS	–
Large	–		2	Closed-loop spatial multiplexing using CRS	–

[25]The smaller of DCI formats 0 and 1A is padded to ensure the same payload size. Which of 0 and 1A is padded depends on the uplink and downlink cell bandwidths; in the case of identical uplink and downlink bandwidths in a cell there is a single bit of padding in format 0.

One PDCCH carries one DCI message with one of the formats above. As multiple terminals can be scheduled simultaneously, on both downlink and uplink, there must be a possibility to transmit multiple scheduling messages within each subframe. Each scheduling message is transmitted on a separate PDCCH, and consequently there are typically multiple simultaneous PDCCH transmissions within each cell. Furthermore, to support different radio-channel conditions, link adaptation can be used, where the code rate of the PDCCH is selected to match the radio-channel conditions.

For carrier aggregation, scheduling assignments/grants are transmitted individually per component carrier. PDCCH transmission for carrier aggregation is further elaborated upon in Section 10.4.6.

10.4.4 Downlink Scheduling Assignment

Downlink scheduling assignments are valid for the same subframe in which they are transmitted. The scheduling assignments use one of the DCI formats 1, 1A, 1B, 1C, 1D, 2, 2A, 2B, or 2C and the DCI formats used depend on the transmission mode configured (the relation between transmission modes and DCI formats is further described in Section 10.4.9). The reason for supporting multiple formats with different message sizes for the same purpose is to allow for a trade-off in control-signaling overhead and scheduling flexibility. Parts of the contents are the same for the different DCI formats, as seen in Table 10.5, but obviously there are also differences due to the different capabilities.

DCI format 1 is the basic downlink assignment format in the absence of spatial multiplexing (transmission modes 1, 2, and 7). It supports non-contiguous allocations of resource blocks and the full range of modulation-and-coding schemes.

DCI format 1A, also known as the "compact" downlink assignment, supports allocation of frequency-contiguous resource blocks only and can be used in all transmission modes. Contiguous allocations reduce the payload size of the control information with a somewhat reduced flexibility in resource allocations. The full range of modulation-and-coding schemes is supported.

DCI format 1B is used to support codebook-based beam-forming described in Section 10.3.2, with a low control-signaling overhead (transmission mode 6). The content is similar to DCI format 1A with the addition of bits for signaling of the precoding matrix. As codebook-based beam-forming can be used to improve the data rates for cell-edge terminals, it is important to keep the related DCI message size small so as not to unnecessarily limit the coverage.

DCI format 1C is used for various special purposes such as random-access response, paging, and transmission of system information. Common for these applications is simultaneous reception of a relatively small amount of information by *multiple* users. Hence, DCI format 1C supports QPSK only, has no support for hybrid-ARQ retransmissions, and does not support closed-loop spatial multiplexing. Consequently, the message size for DCI format 1C is very small, which is beneficial for coverage and efficient transmission of the type of system messages for which it is intended. Furthermore, as only a small number of resource blocks can be indicated, the size of the corresponding indication field in DCI format 1C is independent of the cell bandwidth.

DCI format 1D is used to support multi-user MIMO (transmission mode 5) scheduling of one codeword with precoder information. To support dynamic sharing of the transmission power between the terminals sharing the same resource block in multi-user MIMO, one bit of power offset information is included in DCI format 1D, as described in Section 10.3.4.2.

DCI format 2 is an extension for DCI format 1 to support closed-loop spatial multiplexing (transmission mode 4). Thus, information about the number of transmission layers and the index of the

Table 10.5 DCI Formats Used for Downlink Scheduling

Field		DCI Format								
		1	1A	1B	1C	1D	2	2A	2B	2C
Resource information	Carrier indicator	•	•	•		•	•	•	•	•
	Resource block assignment type	0/1	2	2	2′	2	0/1	0/1	0/1	0/1
HARQ process number		•	•	•		•	•	•	•	•
First transport block	MCS	•	•	•	•	•	•	•	•	•
	RV	•	•	•		•	•	•	•	•
	NDI	•	•	•		•	•	•	•	•
Second transport block	MCS						•	•	•	•
	RV						•	•	•	•
	NDI						•	•	•	•
Multi-antenna information	PMI confirmation			•						
	Precoding information			•		•	•	•		
	Transport block swap flag						•	•		
	Power offset					•				
	DM-RS scrambling								•	
	# Layers/DM-RS scrambling									•
Downlink assignment index		•	•	•		•	•	•	•	•
PUCCH power control		•	•	•		•	•	•	•	•
Flag for 0/1A differentiation			•							
Padding (only if needed)		(•)	(•)	(•)		(•)	(•)	(•)	(•)	(•)
Identity		•	•	•	•	•	•	•	•	•

Petitioners' Exhibit 1003, p. 541
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

precoder matrix used are jointly encoded in the precoding information field. Some of the fields in DCI format 1 have been duplicated to handle the two transport blocks transmitted in parallel in the case of spatial multiplexing.

DCI format 2A is similar to DCI format 2 except that it supports open-loop spatial multiplexing (transmission mode 3) instead of closed-loop spatial multiplexing. The precoder information field is used to signal the number of transmission layers only, hence the field has a smaller size than in DCI format 2. Furthermore, since DCI format 2A is used for scheduling of multi-layer transmissions only, the precoder information field is only necessary in the case of four transmit antenna ports (a two-antenna-port setup cannot be used for more than two transmission layers).

DCI format 2B was introduced in release 9 in order to support dual-layer spatial multiplexing in combination with beam-forming using DM-RS (transmission mode 8). Since scheduling with DCI format 2B relies on DM-RS, precoding/beam-forming is transparent to the terminal and there is no need to signal a precoder index. The number of layers can be controlled by disabling one of the transport blocks. Two different scrambling sequences for the DM-RS can be used, as described in Section 10.2.2.

DCI format 2C was introduced in release 10 and is used to support spatial multiplexing using DM-RS (transmission mode 9). To some extent, it can be seen as a generalization of format 2B to support spatial multiplexing of up to eight layers. DM-RS scrambling and the number of layers are jointly signaled by a single three-bit field.

Many information fields in the different DCI formats are, as already mentioned, common among several of the formats, while some types of information exist only in certain formats. The information in the DCI formats used for downlink scheduling can be organized into different groups, as shown in Table 10.5, with the fields present varying between the DCI formats. The contents of the different DCI formats are explained in more detail below:

- Resource information, consisting of:
  - Carrier indicator (0 or 3 bit). This field is only present if cross-carrier scheduling is enabled via RRC signaling and is used to indicate the component carrier the downlink control information relates to (see Section 10.4.6).
  - Resource-block allocation. This field indicates the resource blocks on one component carrier upon which the terminal should receive the PDSCH. The size of the field depends on the cell bandwidth and on the DCI format, more specifically on the resource indication type, as discussed in Section 10.4.4.1. Resource allocation types 0 and 1, which are the same size, support non-contiguous resource-block allocations, while resource allocation type 2 has a smaller size but supports contiguous allocations only. DCI format 1C uses a restricted version of type 2 in order to further reduce control signaling overhead.
- Hybrid-ARQ process number (3 bit for FDD, 4 bit for TDD), informing the terminal about the hybrid-ARQ process to use for soft combining. Not present in DCI format 1C.
- For the first (or only) transport block:[26]
  - Modulation-and-coding scheme (5 bit), used to provide the terminal with information about the modulation scheme, the code rate, and the transport-block size, as described further below. DCI format 1C has a restricted size of this field as only QPSK is supported.

[26] A transport block can be disabled by setting the modulation-and-coding scheme to zero and the redundancy version to one in the DCI.

  - New-data indicator (1 bit), used to clear the soft buffer for initial transmissions. Not present in DCI format 1C as this format does not support hybrid ARQ.
  - Redundancy version (2 bit).
- For the second transport block (only present in DCI format supporting spatial multiplexing):
  - Modulation-and-coding scheme (5 bit).
  - New-data indicator (1 bit).
  - Redundancy version (2 bit).
- Multi-antenna information. The different DCI formats are intended for different multi-antenna schemes and which of the fields below that are included depends on the DCI format shown in Table 10.5.
  - PMI confirmation (1 bit), present in format 1B only. Indicates whether the eNodeB uses the (frequency-selective) precoding matrix recommendation from the terminal or if the recommendation is overridden by the information in the PMI field.
  - Precoding information, provides information about the index of the precoding matrix used for the downlink transmission and, indirectly, about the number of transmission layers.
  - Transport block swap flag (1 bit), indicating whether the two codewords should be swapped prior to being fed to the hybrid-ARQ processes. Used for averaging the channel quality between the codewords.
  - Power offset between the PDSCH and cell-specific reference signals used to support dynamic power sharing between multiple terminals for multi-user MIMO.
  - Reference-signal scrambling sequence, used to control the generation of quasi-orthogonal reference-signal sequences, as discussed in Section 10.2.2.
  - Number of layers and reference-signal scrambling sequence (jointly encoded information in release 10).
- Downlink assignment index (2 bit), informing the terminal about the number of downlink transmissions for which a single hybrid-ARQ acknowledgement should be generated according to Section 12.1.3. Present for TDD only.
- Transmit-power control for PUCCH (2 bit). For scheduling of a secondary component carrier in the case of carrier aggregation, these bits are reused as *acknowledgement resource indicator* (ARI) – see Chapter 11.
- DCI format 0/1A indication (1 bit), used to differentiate between DCI formats 1A and 0 as the two formats have the same message size. This field is present in DCI formats 0 and 1A only. DCI formats 3 and 3A, which have the same size, are separated from DCI formats 0 and 1A through the use of a different RNTI.
- Padding; the smaller of DCI formats 0 and 1A is padded to ensure the same payload size irrespective of the uplink and downlink cell bandwidths. Padding is also used to ensure that the DCI size is different for different DCI formats (this is rarely required in practice as the payload sizes are different due to the different amounts of information). Finally, padding is used to avoid certain DCI sizes that may cause ambiguous decoding.[27]

[27]For a small set of specific payload sizes, the control signaling may be correctly decoded at an aggregation level other than the one used by the transmitter. Since the PHICH resource is derived from the first CCE used for the PDCCH, this may result in incorrect PHICH being monitored by the terminal. To overcome this, padding is used if necessary to avoid the problematic payload sizes.

Petitioners' Exhibit 1003, p. 543
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Identity (RNTI) of the terminal for which the PDSCH transmission is intended (16 bit). As described in Section 10.4.8, the identity is not explicitly transmitted but implicitly included in the CRC calculation. There are different RNTIs defined depending on the type of transmission (unicast data transmission, paging, power-control commands, etc.).

10.4.4.1 Signaling of Downlink Resource-Block Allocations

Focusing on the signaling of resource-block allocations, there are three different possibilities, types 0, 1, and 2, as indicated in Table 10.5. Resource-block allocation types 0 and 1 both support non-contiguous allocations of resource blocks in the frequency domain, whereas type 2 supports contiguous allocations only. A natural question is why multiple ways of signaling the resource-block allocations are supported, a question whose answer lies in the number of bits required for the signaling. The most flexible way of indicating the set of resource blocks the terminal is supposed to receive the downlink transmission upon is to include a bitmap with size equal to the number of resource blocks in the cell bandwidth. This would allow for an arbitrary combination of resource blocks to be scheduled for transmission to the terminal but would, unfortunately, also result in a very large bitmap for the larger cell bandwidths. For example, in the case of a downlink cell bandwidth corresponding to 100 resource blocks, the downlink PDCCH would require 100 bits for the bitmap alone, to which the other pieces of information need to be added. Not only would this result in a large control-signaling overhead, but it could also result in downlink coverage problems as more than 100 bits in one OFDM symbol correspond to a data rate exceeding 1.4 Mbit/s. Consequently, there is a need for a resource allocation scheme requiring a smaller number of bits while keeping sufficient allocation flexibility.

In resource allocation type 0, the size of the bitmap has been reduced by pointing not to individual resource blocks in the frequency domain, but to groups of contiguous resource blocks, as shown at the top of Figure 10.25. The size of such a group is determined by the downlink cell bandwidth; for the smallest bandwidths there is only a single resource block in a group, implying that an arbitrary set of resource blocks can be scheduled, whereas for the largest cell bandwidths groups of four resource blocks are used (in the example in Figure 10.25, the cell bandwidth is 25 resource blocks, implying a group size of two resource blocks). Thus, the bitmap for the system with a downlink cell bandwidth of 100 resource blocks is reduced from 100 to 25 bits. A drawback is that the scheduling granularity is reduced; single resource blocks cannot be scheduled for the largest cell bandwidths using allocation type 0.

However, also in large cell bandwidths, frequency resolution of a single resource block is sometimes useful, for example to support small payloads. Resource allocation type 1 addresses this by dividing the total number of resource blocks in the frequency domain into dispersed subsets, as shown in the middle of Figure 10.25. The number of subsets is given from the cell bandwidth with the number of subsets in type 1 being equal to the group size in type 0. Thus, in Figure 10.25, there are two subsets, whereas for a cell bandwidth of 100 resource blocks there would have been four different subsets. Within a subset, a bitmap indicates the resource blocks in the frequency domain upon which the downlink transmission occurs.

To inform the terminal whether resource allocation type 0 or 1 is used, the resource allocation field includes a flag for this purpose, denoted “type” to the left in Figure 10.25. For type 0, the only additional information is the bitmap discussed above. For type 1, on the other hand, in addition to the bitmap

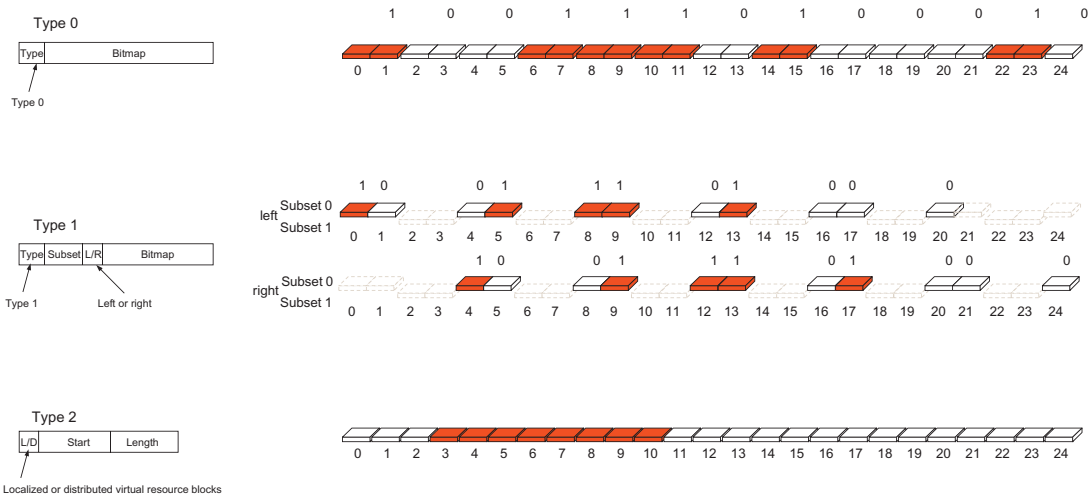


FIGURE 10.25

Illustration of resource-block allocation types (cell bandwidth corresponding to 25 resource blocks used in this example).

itself, information about the subset for which the bitmap relates is also required. As one of the requirements in the design of resource allocation type 1 was to maintain the same number of bits in the allocation as for type 0 without adding unnecessary overhead,[28] the bitmap in resource allocation type 1 is smaller than in type 0 to allow for the signaling of the subset number. However, a consequence of a smaller bitmap is that not all resource blocks in the subset can be addressed simultaneously. To be able to address all resources with the bitmap, there is a flag indicating whether the bitmap relates to the "left" or "right" part of the resource blocks, as depicted in the middle part of Figure 10.25.

Unlike the other two types of resource-block allocation signaling, type 2 does not rely on a bitmap. Instead, it encodes the resource allocation as a start position and length of the resource-block allocation. Thus, it does not support arbitrary allocations of resource blocks but only frequency-contiguous allocations, thereby reducing the number of bits required for signaling the resource-block allocation. The number of bits required for resource-signaling type 2 compared to type 0 or 1 is shown in Figure 10.26 and, as shown, the difference is fairly large for the larger cell bandwidths.

All three resource-allocation types refer to *virtual* resource blocks (see Section 10.1.1.8 for a discussion of resource-block types). For resource-allocation types 0 and 1, the virtual resource blocks are of localized type and the virtual resource blocks are directly mapped to physical resource blocks. For resource-allocation type 2, on the other hand, both localized and distributed virtual resource blocks are supported. One bit in the resource allocation field indicates whether the allocation signaling refers to localized or distributed resource blocks.

[28] Allowing different sizes would result in an increase in the number of blind decoding attempts required in the terminal.

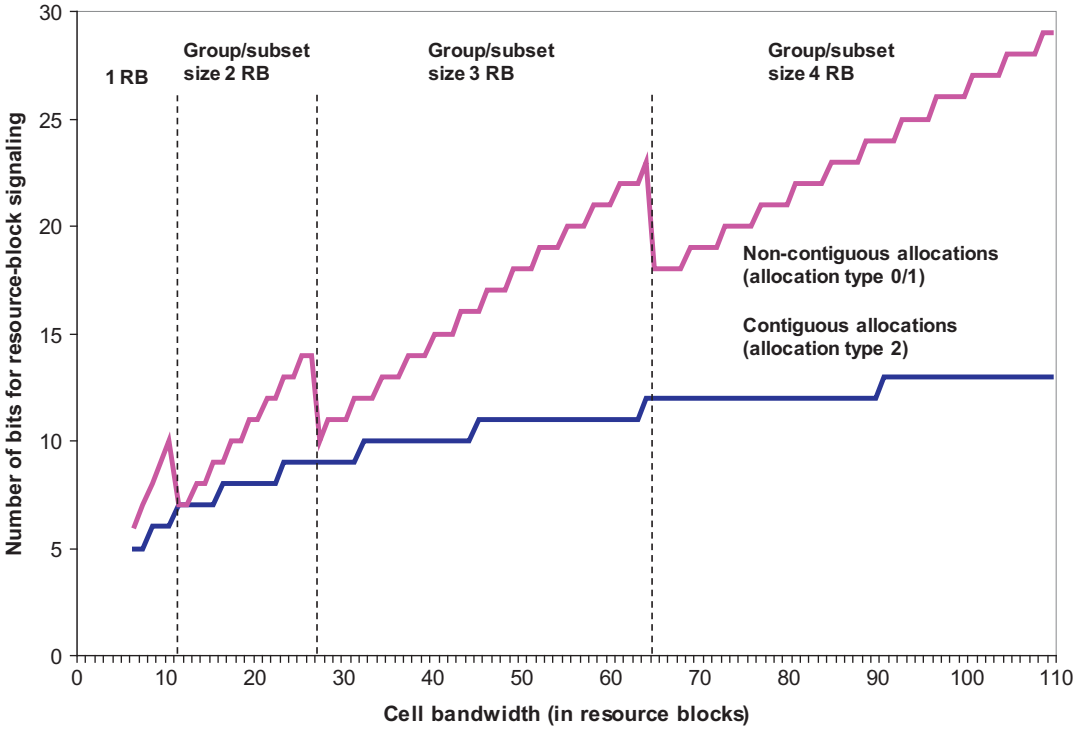


FIGURE 10.26

Number of bits used for downlink resource-allocation signaling for downlink allocation types 0/1 and 2.

10.4.4.2 *Signaling of Transport-Block Sizes*

Proper reception of a downlink transmission requires, in addition to the set of resource blocks, knowledge about the modulation scheme and the transport-block size, information (indirectly) provided by a five-bit field in the different DCI formats. Of the 32 combinations, 29 are used to signal the modulation-and-coding scheme whereas three are reserved, the purpose of which is described later. Together, the modulation-and-coding scheme and the number of resource blocks assigned provide the transport-block size on the DL-SCH. Thus, the possible transport-block sizes can be described as a table with 29 rows and 110 columns, one column for each number of resource blocks possible to transmit upon (the number of columns follows from the maximum downlink component carrier bandwidth of 110 resource blocks).

Each modulation-and-coding scheme represents a particular combination of modulation scheme and channel-coding rate or, equivalently, a certain spectral efficiency measured in the number of information bits per modulation symbol. Although the 29-by-110 table of transport-block sizes in principle could be filled directly from the modulation-and-coding scheme and the number of resource blocks, this would result in arbitrary transport-block sizes, which is not desirable. First, as all the higher-layer protocol layers are byte aligned, the resulting transport-block sizes should be an integer

number of bytes. Secondly, common payloads, for example RRC signaling messages and VoIP, should be possible to transmit without padding. Aligning with the QPP interleaver sizes is also beneficial, as this would avoid the use of filler bits (see Section 10.1.1.3). Finally, the same transport-block size should ideally appear for several different resource-block allocations, as this allows the number of resource blocks to be changed between retransmission attempts, providing increased scheduling flexibility. Therefore, a "mother table" of transport-block sizes is first defined, fulfilling the requirements above. Each entry in the 29-by-110 table is picked from the mother table such that the resulting spectral efficiency is as close as possible to the spectral efficiency of the signaled modulation-and-coding scheme. The mother table spans the full range of transport-block sizes possible, with an approximately constant worst-case padding.

From a simplicity perspective, it is desirable if the transport-block sizes do not vary with the configuration of the system. The set of transport-block sizes is therefore independent of the actual number of antenna ports and the size of the control region.[29] The design of the table assumes a control region of three OFDM symbols and two antenna ports, the "reference configuration". If the actual configuration is different, the resulting code rate for the DL-SCH will be slightly different as a result of the rate-matching procedure. However, the difference is small and of no practical concern. Also, if the actual size of the control region is smaller than the three-symbol assumption in the reference configuration, the spectral efficiencies will be somewhat smaller than the range indicated by the modulation-and-coding scheme signaled as part of the DCI. Thus, information about the modulation scheme used is obtained directly from the modulation-and-coding scheme, whereas the exact code rate and rate matching is obtained from the implicitly signaled transport-block size together with the number of resource elements used for DL-SCH transmission.

For bandwidths smaller than the maximum of 110 resource blocks, a subset of the table is used. More specifically, in case of a cell bandwidth of N resource blocks, the first N columns of the table are used. Also, in the case of spatial multiplexing, a single transport block can be mapped to up to four layers. To support the higher data rates this facilitates, the set of supported transport-block sizes needs to be extended beyond what is possible in the absence of spatial multiplexing. The additional entries are in principle obtained by multiplying the sizes with the number of layers to which a transport block is mapped and adjusting the result to match the QPP interleaver size.

The 29 combinations of modulation-and-coding schemes each represent a reference spectral efficiency in the approximate range of 0.1–5.9 bits/s/symbol.[30] There is some overlap in the combinations in the sense that some of the 29 combinations represent the same spectral efficiency. The reason is that the best combination for realizing a specific spectral efficiency depends on the channel properties; sometimes higher-order modulation with a low code rate is preferable over lower-order modulation with a higher code rate, sometimes the opposite is true. With the overlap, the eNodeB can select the best combination, given the propagation scenario. As a consequence of the overlap, two of the rows in the 29-by-110 table are duplicates and result in the same spectral efficiency but with different modulation schemes, and there are only 27 unique rows of transport-block sizes.

Returning to the three reserved combinations in the modulation-and-coding field mentioned at the beginning, those entries can be used for retransmissions only. In the case of a retransmission, the

[29] For DwPTS, the transport-block size is scaled by a factor of 0.75 compared to the values found in the table, motivated by the DwPTS having a shorter duration than a normal subframe.

[30] The exact values vary slightly with the number of resource blocks allocated due to rounding.

Petitioners' Exhibit 1003, p. 547
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

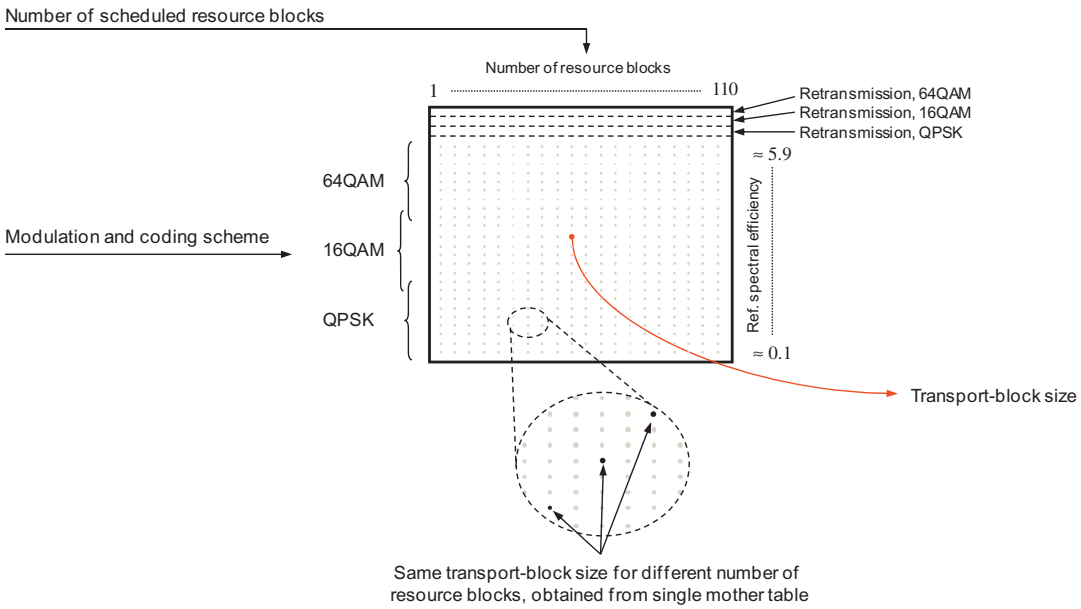


FIGURE 10.27

Computing the transport-block size.

transport-block size is, by definition, unchanged and fundamentally there is no need to signal this piece of information. Instead, the three reserved values represent the modulation scheme, QPSK, 16QAM or 64QAM, which allows the scheduler to use an (almost) arbitrary combination of resource blocks for the retransmission. Obviously, using any of the three reserved combinations assumes that the terminal properly received the control signaling for the initial transmission; if this is not the case, the retransmission should explicitly indicate the transport-block size.

The derivation of the transport-block size from the modulation-and-coding scheme and the number of scheduled resource blocks is illustrated in Figure 10.27.

10.4.5 Uplink Scheduling Grants

Uplink scheduling grants use one of DCI formats 0 or 4, where DCI format 4 was added in release 10 to support uplink spatial multiplexing. The basic resource-allocation scheme for the uplink is single-cluster allocations where the resource blocks are contiguous in the frequency domain, although release 10 added support for multi-cluster transmissions of up to two clusters on a single component carrier.

DCI format 0 is used for scheduling uplink transmissions not using spatial multiplexing on one component carrier. It has the same size control-signaling message as the "compact" downlink assignment (DCI format 1A). A flag in the message is used to inform the terminal whether the message is an uplink scheduling grant (DCI format 0) or a downlink scheduling assignment (DCI format 1A).

Table 10.6 DCI Formats for Uplink Scheduling Grants

Field		DCI Format	
		0	4
Resource information	Carrier indicator	•	•
	Multi-cluster flag	•	•
	Resource block assignment	0	1
First transport block	MCS/RV	•	•
	NDI	•	•
Second transport block	MCS/RV		•
	NDI		•
DMRS phase rotation		•	•
Precoding information			•
CSI request		•	•
SRS request			•
Uplink index/DAI		•	•
PUSCH power control		•	•
Flag for 0/1A differentiation		•	
Padding (only if needed)		(•)	(•)
Identity		•	•

DCI format 4 is used for uplink transmissions using spatial multiplexing on one component carrier. Consequently, the size of DCI format 4 is larger than that of DCI format 0, as additional information fields are required.

Many information fields are common to the two DCI formats, but there are also differences, as shown in Table 10.6. The contents of the different DCI formats are explained in more detail below:

- Resource information, consisting of:
  - Carrier indicator (0 or 3 bit). This field is only present if cross-carrier scheduling is enabled via RRC signaling and is used to indicate the uplink component carrier the grant relates to (see Section 10.4.6).
  - Multi-cluster flag (1 bit), indicating whether one or two clusters of resource blocks are used for the uplink transmission. This flag is not present in releases prior to release 10. In previous releases, the downlink bandwidth is, in practice, always at least as large as the uplink bandwidth, implying that one padding bit is used for DCI format 0 in those releases to align with the size of format 1A. The padding bit could therefore be replaced by the multi-cluster flag in release 10 without sacrificing backwards compatibility. In DCI format 4, supported in release 10 only, the multi-cluster flag is always present.
  - Resource-block allocation, including hopping indication. This field indicates the resource blocks upon which the terminal should transmit the PUSCH using uplink resource-allocation type 0 (DCI format 0) or type 1 (DCI format 4), as described in Section 10.4.5.1. The size of

the field depends on the cell bandwidth. For single-cluster allocations, uplink frequency hopping, as described in Chapter 11, can be applied to the uplink PUSCH transmission.

- For the first (or only) transport block:
  - Modulation-and-coding scheme including redundancy version (5 bit), used to provide the terminal with information about the modulation scheme, the code rate, and the transport-block size. The signaling of the transport-block size uses the same transport-block table as for the downlink – that is, the modulation-and-coding scheme together with the number of scheduled resource blocks provides the transport-block size. However, as the support of 64QAM in the uplink is not mandatory for all terminals, terminals not capable of 64QAM use 16QAM when 64QAM is indicated in the modulation-and-coding field. The use of the three reserved combinations is slightly different than for the downlink; the three reserved values are used for implicit signaling of the redundancy version, as described below. A transport block can be disabled by signaling a specific combination of modulation-and-coding scheme and number of resource blocks. Disabling one transport block is used when retransmitting a single transport block only.
  - New-data indicator (1 bit), used to indicate to the terminal whether transmission of a new transport block or retransmission of the previous transport block is granted.
- For the second transport block (DCI format 4 only):
  - Modulation-and-coding scheme including redundancy version (5 bit).
  - New-data indicator (1 bit).
- Phase rotation of the uplink demodulation reference signal[31] (3 bit), used to support multi-user MIMO, as described in Chapter 11. By assigning different reference-signal phase rotations to terminals scheduled on the same time–frequency resources, the eNodeB can estimate the uplink channel response from each terminal and suppress the inter-terminal interference by the appropriate processing.
- Precoding information, used to signal the precoder to use for the uplink transmission.
- Channel-state request flag (1 or 2 bit). The network can explicitly request an aperiodic channel-state report to be transmitted on the UL-SCH by setting this bit(s) in the uplink grant. In the case of carrier aggregation, two bits are used to indicate which downlink component carrier the CSI should be reported for (see Chapter 12).
- SRS request (2 bit), used to trigger aperiodic sounding using one of up to three preconfigured settings, as discussed in Chapter 11.
- Uplink index/DAI (2 bit). This field is present only when operating in TDD. For uplink–downlink configuration 0 (uplink-heavy configuration), it is used as an uplink index to signal for which uplink subframe(s) the grant is valid, as described in Chapter 13. For other uplink–downlink configurations, it is used as downlink assignment index to indicate the number of downlink transmissions the eNodeB expects hybrid-ARQ acknowledgement for.
- Transmit-power control for PUSCH (2 bit).
- DCI format 0/1A indication (1 bit), used to differentiate between DCI formats 1A and 0 as the two formats have the same message size. This field is present in DCI formats 0 and 1A only.

[31] In release 10, this field can also be used to select the orthogonal cover sequence used for uplink reference signals (see Chapter 11 for details).

Petitioners' Exhibit 1003, p. 550
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Padding; the smaller of DCI formats 0 and 1A is padded to ensure the same payload size irrespective of the uplink and downlink cell bandwidths. Padding is also used to ensure that the DCI size is different for different DCI formats (this is rarely required in practice as the payload sizes are different due to the different amounts of information). Finally, padding is used to avoid certain DCI sizes that may cause ambiguous decoding.
- Identity (RNTI) of the terminal for which the grant is intended (16 bit). As described in Section 10.4.8, the identity is not explicitly transmitted but implicitly included in the CRC calculation.

There is no explicit signaling of the redundancy version in the uplink scheduling grants. This is motivated by the use of a synchronous hybrid-ARQ protocol in the uplink; retransmissions are normally triggered by a negative acknowledgement on the PHICH and not explicitly scheduled as for downlink data transmissions. However, as described in Chapter 12, there is a possibility to explicitly schedule retransmissions. This is useful in a situation where the network will explicitly move the retransmission in the frequency domain by using the PDCCH instead of the PHICH. Three values of the modulation-and-coding field are reserved to mean redundancy versions one, two, and three. If one of those values is signaled, the terminal should assume that the same modulation and coding as the original transmission is used. The remaining entries are used to signal the modulation-and-coding scheme to use and also imply that redundancy version zero should be used. The difference in usage of the reserved values compared to the downlink scheduling assignments implies that the modulation scheme, unlike the downlink case, cannot change between uplink (re)transmission attempts.

10.4.5.1 Signaling of Uplink Resource-Block Allocations

The basic uplink resource-allocation scheme is single-cluster allocations – that is, allocations contiguous in the frequency domain – but release 10 also provides the possibility for multi-cluster uplink transmissions.

Single-cluster allocations use uplink resource-allocation type 0, which is identical to downlink resource allocation type 2 described in Section 10.4.4.1 except that the single-bit flag indicating localized/distributed transmission is replaced by a single-bit hopping flag. The resource allocation field in the DCI provides the set of virtual resource blocks to use for uplink transmission. The set of physical resource blocks to use in the two slots of a subframe is controlled by the hopping flag, as described in Chapter 11.

Multi-cluster allocations with up to two clusters were introduced in release 10, using uplink resource-allocation type 1. In resource-allocation type 1, the starting and ending positions of two clusters of frequency-contiguous resource blocks are encoded into an index. Uplink resource-allocation type 1 does not support frequency hopping (diversity is achieved through the use of two clusters instead). Indicating two clusters of resources naturally requires additional bits compared to the single-cluster case. At the same time, the total number of bits used for resource-allocation type 1 should be identical to that of type 0 (this is similar to the situation for the downlink allocation types 0 and 1; without aligning the sizes a new DCI format with a corresponding negative impact on the number of blind decodings is necessary). Since frequency hopping is not supported for allocation type 1, the bit otherwise used for the hopping flag can be reused for extending the resource-allocation field. However, despite the extension of the resource-allocation field by one bit, the number of bits is not sufficient to provide a single-resource-block resolution in the two clusters for all bandwidths. Instead, similar to downlink resource allocation type 0, groups of resource blocks are used and the starting and ending positions of the two clusters are

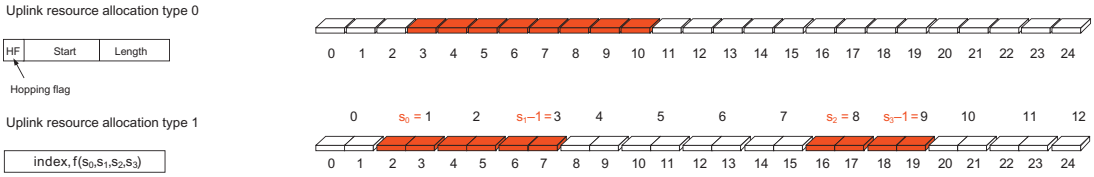


FIGURE 10.28

Illustration of uplink resource-block allocation types (uplink bandwidth corresponding to 25 resource blocks used in this example).

given in terms of group numbers. The size of such a group is determined by the uplink carrier bandwidth in a similar way as for the downlink; for the smallest bandwidths there is only a single resource block in a group, implying that an arbitrary (as long as the limit of at most two clusters is observed) set of resource blocks can be scheduled, whereas for the largest cell bandwidths groups of four resource blocks are used (in the example in Figure 10.28, the cell bandwidth is 25 resource blocks, implying a group size of two resource blocks).

10.4.6 Carrier Aggregation and Cross-Carrier Scheduling

Carrier aggregation, where a terminal receives or transmits on multiple component carriers, is an integral part of LTE from release 10 onwards. Clearly, for a terminal supporting multiple component carriers, the terminal needs to know to which component carrier a certain DCI relates. This information can either be implicit or explicit, depending on whether cross-carrier scheduling is used or not, as illustrated in Figure 10.29. Enabling cross-carrier scheduling is done individually via RRC signaling on a per-terminal and per-component-carrier basis.

In the absence of cross-carrier scheduling, downlink scheduling assignments are valid for the component carrier upon which they are transmitted. Similarly, for uplink grants, there is an association between downlink and uplink component carriers such that each uplink component carrier has an associated downlink component carrier. The association is provided as part of the system information. Thus, from the uplink–downlink association, the terminal will know to which uplink component carrier the downlink control information relates to.

In the presence of cross-carrier scheduling, where downlink PDSCH or uplink PUSCH is transmitted on an (associated) component carrier other than the PDCCH, the carrier indicator in the PDCCH provides information about the component carrier used for the PDSCH or PUSCH.

Whether cross-carrier scheduling is used or not is, as already mentioned, configured using higher-layer signaling; if cross-carrier scheduling is not configured then no carrier indication field is included in the DCI. Thus, most of the DCI formats come in two "flavors", with and without the carrier indication field, and which "flavor" the terminal is supposed to monitor is determined by enabling/disabling support for cross-carrier scheduling.

To signal which component carrier a grant relates to, the component carriers are numbered. The primary component carrier is always given the number zero, while the different secondary component carriers are assigned a unique number each through UE-specific RRC signaling. Hence, even if the

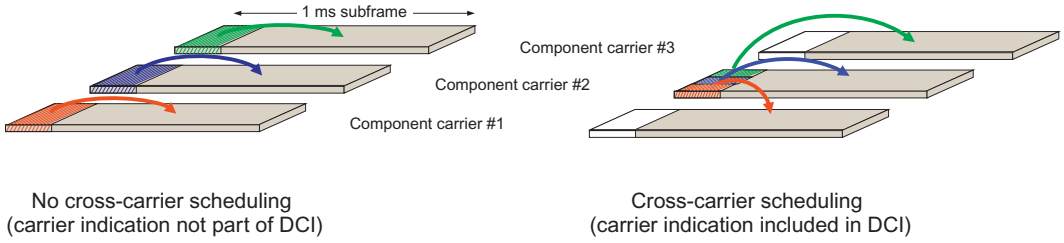


FIGURE 10.29

Cross-carrier scheduling.

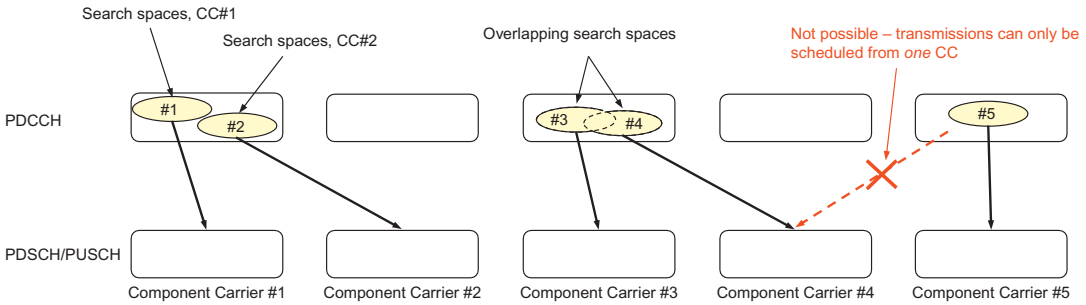


FIGURE 10.30

Example of scheduling of multiple component carriers (search spaces are discussed in Section 10.4.9).

terminal and the eNodeB may have different understandings of the component carrier numbering during a brief period of reconfiguration, at least transmissions on the primary component carrier can be scheduled.

Irrespective of whether cross-carrier scheduling is used or not, PDSCH/PUSCH on a component carrier can only be scheduled from *one* component. Thus, for each PDSCH/PUSCH component carrier there is an associated component carrier, configured via UE-specific RRC signaling, where the corresponding DCI can be transmitted. Figure 10.30 illustrates one example hereof, where PDSCH/PUSCH transmissions on component carrier 1 are scheduled using PDCCHs transmitted on component carrier 1. In this case, as cross-carrier scheduling is not used, there is no carrier indicator in the corresponding DCI formats. PDSCH/PUSCH transmissions on component carrier 2 are cross-carrier scheduled from PDCCHs transmitted on component carrier 1. Hence, the DCI formats in the UE-specific search space for component carrier 2 include the carrier indicator.

Note also, as transmissions on a component carrier can be scheduled by PDCCHs on *one* component carrier only, component carrier 4 cannot be scheduled by PDCCHs on component carrier 5 as the semi-static association between the component carriers used for PDCCH transmission and the actual data transmission has associated data on component carrier 4, with PDCCHs on component carrier 3 in this example.

10.4.7 Power-Control Commands

As a complement to the power-control commands provided as part of the downlink scheduling assignments and the uplink scheduling grants, there is the potential to transmit a power-control command using DCI formats 3 (single-bit command per terminal) or 3A (two-bit command per terminal). The main motivation for DCI format 3/3A is to support power control for semi-persistent scheduling. The power-control message is directed to a group of terminals using an RNTI specific for that group. Each terminal can be allocated two power-control RNTIs, one for PUCCH power control and the other for PUSCH power control. Although the power-control RNTIs are common to a group of terminals, each terminal is informed through RRC signaling which bit(s) in the DCI message it should follow. No carrier indicator is used for formats 3 and 3A.

10.4.8 PDCCH Processing

Having discussed the contents of L1/L2 control signaling in terms of the different DCI formats, the transmission of the DCI message on a PDCCH can be described. The processing of downlink control signaling is illustrated in Figure 10.31. A CRC is attached to each DCI message payload. The identity of the terminal (or terminals) addressed – that is, the RNTI – is included in the CRC calculation and not explicitly transmitted. Depending on the purpose of the DCI message (unicast data transmission, power-control command, random-access response, etc.), different RNTIs are used; for normal unicast data transmission, the terminal-specific C-RNTI is used.

Upon reception of DCI, the terminal will check the CRC using its set of assigned RNTIs. If the CRC checks, the message is declared to be correctly received and intended for the terminal. Thus, the identity of the terminal that is supposed to receive the DCI message is implicitly encoded in the CRC and not explicitly transmitted. This reduces the amount of bits necessary to transmit on the PDCCH as, from a terminal point of view, there is no difference between a corrupt message whose CRC will not check and a message intended for another terminal.

After CRC attachment, the bits are coded with a rate-1/3 tail-biting convolutional code and rate-matched to fit the amount of resources used for PDCCH transmission. Tail-biting convolutional coding is similar to conventional convolutional coding with the exception that no tail bits are used. Instead, the convolutional encoder is initialized with the last bits of the message prior to the encoding process. Thus, the starting and ending states in the trellis in an MLSE (Viterbi) decoder are identical.

After the PDCCHs to be transmitted in a given subframe have been allocated to the desired resource elements (the details of which are given below), the sequence of bits corresponding to all the PDCCH resource elements to be transmitted in the subframe, including the unused resource elements, is scrambled by a cell- and subframe-specific scrambling sequence to randomize inter-cell interference, followed by QPSK modulation and mapping to resource elements.

To allow for simple yet efficient processing of the control channels in the terminal, the mapping of PDCCHs to resource elements is subject to a certain structure. This structure is based on so-called *Control-Channel Elements* (CCEs), which in essence is a convenient name for a set of 36 useful resource elements (nine resource-element groups as defined in Section 10.4.1). The number of CCEs, one, two, four, or eight, required for a certain PDCCH depends on the payload size of the control information (DCI payload) and the channel-coding rate. This is used to realize link adaptation for the PDCCH; if the channel conditions for the terminal to which the PDCCH is intended are

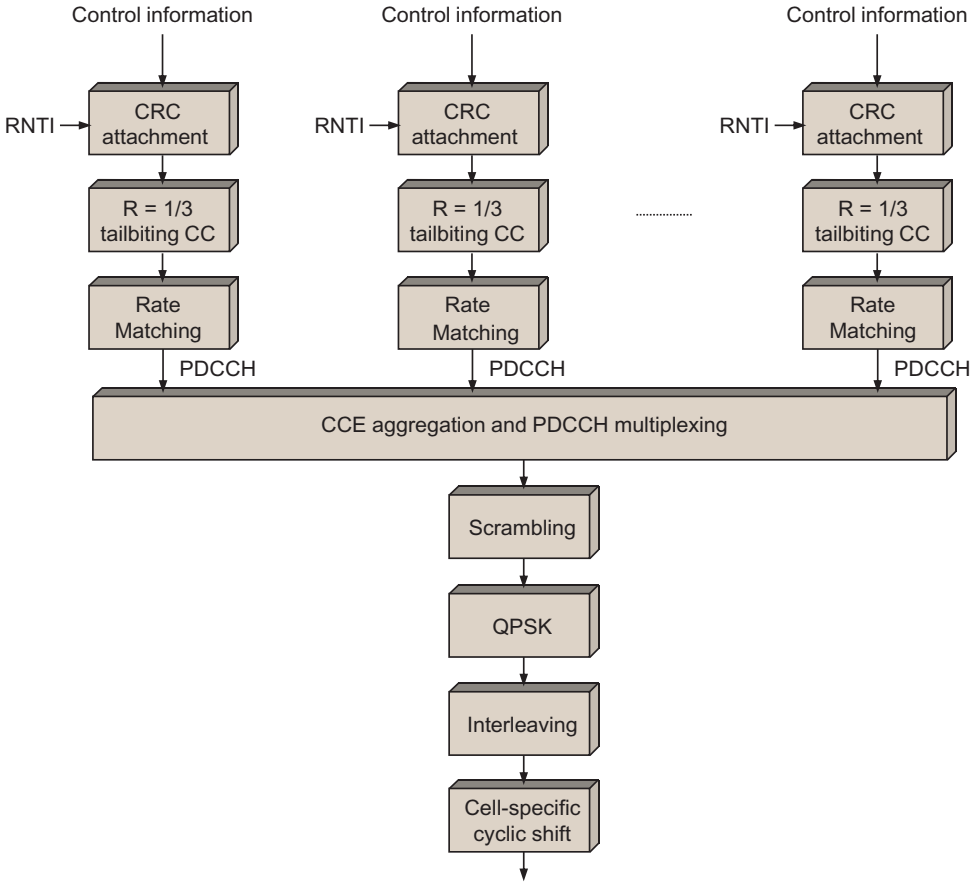


FIGURE 10.31

Processing of L1/L2 control signaling.

disadvantageous, a larger number of CCEs needs to be used compared to the case of advantageous channel conditions. The number of CCEs used for a PDCCH is also referred to as the aggregation level.

The number of CCEs available for PDCCHs depends on the size of the control region, the cell bandwidth, the number of downlink antenna ports, and the amount of resources occupied by PHICH. The size of the control region can vary dynamically from subframe to subframe as indicated by the PCFICH, whereas the other quantities are semi-statically configured. The CCEs available for PDCCH transmission can be numbered from zero and upward, as illustrated in Figure 10.32. A specific PDCCH can thus be identified by the numbers of the corresponding CCEs in the control region.

As the number of CCEs for each of the PDCCHs may vary and is not signaled, the terminal has to blindly determine the number of CCEs used for the PDCCH it is addressed upon. To reduce the complexity of this process somewhat, certain restrictions on the aggregation of contiguous CCEs have been specified. For example, an aggregation of eight CCEs can only start on CCE numbers evenly

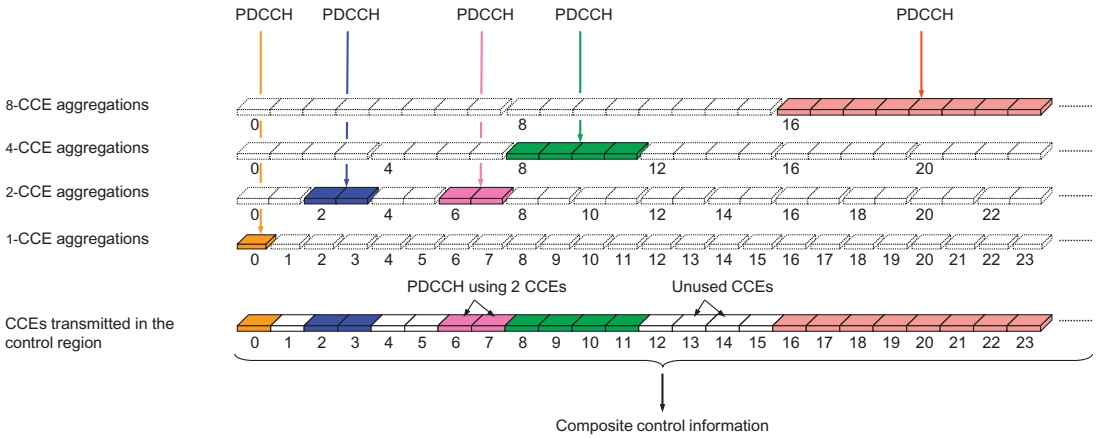


FIGURE 10.32

CCE aggregation and PDCCH multiplexing.

divisible by 8, as illustrated in Figure 10.32. The same principle is applied to the other aggregation levels. Furthermore, some combinations of DCI formats and CCE aggregations that result in excessively high channel-coding rates are removed.

The sequence of CCEs should match the amount of resources available for PDCCH transmission in a given subframe – that is, the number of CCEs varies according to the value transmitted on the PCFICH. In many cases, not all the PDCCHs that can be transmitted in the control region are used. Nevertheless, unused PDCCHs are part of the interleaving and mapping process in the same way as any other PDCCH. At the terminal, the CRC will not check for those "dummy" PDCCHs. Preferably, the transmission power is set to zero for those unused PDCCHs; the power can be used by other control channels.

The mapping of the modulated composite control information is, for the same reason as for the other control channels, described in terms of symbol quadruplets being mapped to resource-element groups. Thus, the first step of the mapping stage is to group the QPSK symbols into symbol quadruplets, each consisting of four consecutive QPSK symbols. In principle, the sequence of quadruplets could be mapped directly to the resource elements in sequential order. However, this would not exploit all the frequency diversity available in the channel and diversity is important for good performance. Furthermore, if the same CCE-to-resource-element mapping is used in all neighboring cells, a given PDCCH will persistently collide with one and the same PDCCH in the neighboring cells assuming a fixed PDCCH format and inter-cell synchronization. In practice, the number of CCEs per PDCCH varies in the cell as a function of the scheduling decisions, which gives some randomization to the interference, but further randomization is desirable to obtain a robust control-channel design. Therefore, the sequence of quadruplets is first interleaved using a block interleaver to allow exploitation of the frequency diversity, followed by a cell-specific cyclic shift to randomize the interference between neighboring cells. The output from the cell-specific shift is mapped to resource-element groups in a time-first manner, as illustrated in Figure 10.22, skipping resource-element groups used for PCFICH and PHICH. Time-first mapping

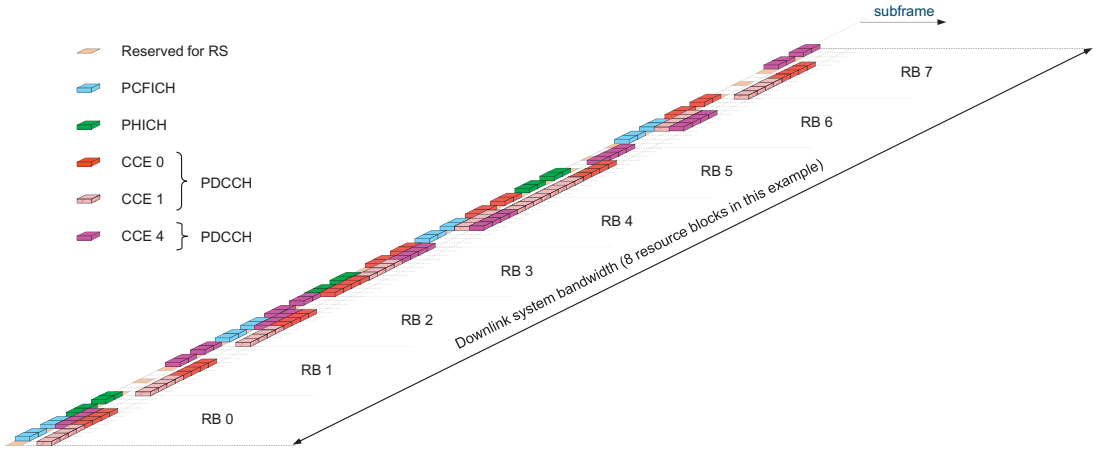


FIGURE 10.33

Example of mapping of PCFICH, PHICH, and PDCCH.

preserves the interleaving properties; with frequency-first over multiple OFDM symbols, resource-element groups that are spread far apart after the interleaving process may end up close in frequency, although on different OFDM symbols.

The interleaving operation described above, in addition to enabling exploitation of the frequency diversity and randomizing the inter-cell interference, also serves the purpose of ensuring that each CCE spans virtually all the OFDM symbols in the control region. This is beneficial for coverage as it allows flexible power balancing between the PDCCHs to ensure good performance for each of the terminals addressed. In principle, the energy available in the OFDM symbols in the control region can be balanced arbitrarily between the PDCCHs. The alternative of restricting each PDCCH to a single OFDM symbol would imply that power cannot be shared between PDCCHs in different OFDM symbols.

Similarly to the PCFICH, the transmission power of each PDCCH is under the control of the eNodeB. Power adjustments can therefore be used as a complementary link adaptation mechanism in addition to adjusting the code rate. Relying on power adjustments alone might seem a tempting solution but, although possible in principle, it can result in relatively large power differences between resource elements. This may have implications on the RF implementation and may violate the out-of-band emission masks specified. Hence, to keep the power differences between the resource elements reasonable, link adaptation through adjusting the channel code rate, or equivalently the number of CCEs aggregated for a PDCCH, is necessary. The two mechanisms for link adaptation, power adjustments and different code rates, complement each other.

To summarize and to illustrate the mapping of PDCCHs to resource elements in the control region, consider the example shown in Figure 10.33. In this example, the size of the control region in the subframe considered equals three OFDM symbols. Two downlink antenna ports are configured (but, as explained above, the mapping would be identical in the case of a single antenna port). One PHICH group is configured and three resource-element groups are therefore used by the PHICHs. The cell identity is assumed to be identical to zero in this case.

The mapping can then be understood as follows: First, the PCFICH is mapped to four resource-element groups, followed by allocating the resource-element groups required for the PHICH. The resource-element groups left after the PCFICH and PHICH are used for the different PDCCHs in the system. In this particular example, one PDCCH is using CCE numbers 0 and 1, while another PDCCH is using CCE number 4. Consequently, there is a relatively large amount of unused resource-element groups in this example; either they can be used for additional PDCCHs or the power otherwise used for the unused CCEs could be allocated to the PDCCHs in use (as long as the power difference between resource elements is kept within the limits set by the RF requirements). Furthermore, depending on the inter-cell interference situation, fractional loading of the control region may be desirable, implying that some CCEs are left unused to reduce the average inter-cell interference.

10.4.9 Blind Decoding of PDCCHs

As described above, each PDCCH supports multiple formats and the format used is a priori unknown to the terminal. Therefore, the terminal needs to blindly detect the format of the PDCCHs. The CCE structure described in the previous section helps in reducing the number of blind decoding attempts, but is not sufficient. Hence, it is required to have mechanisms to limit the CCE aggregations that the terminal is supposed to monitor. Clearly, from a scheduling point of view, restrictions in the allowed CCE aggregations are undesirable as they may influence the scheduling flexibility and require additional processing at the transmitter side. At the same time, requiring the terminal to monitor all possible CCE aggregations, also for the larger cell bandwidths, is not attractive from a terminal-complexity point of view. To impose as few restrictions as possible on the scheduler while at the same time limit the maximum number of blind decoding attempts in the terminal,[32] LTE defines so-called *search spaces*, which describe the set of CCEs the terminal is supposed to monitor for scheduling assignments/grants relating to a certain component carrier. Search spaces are discussed below, starting with the case of a single component carrier and later extended to the case of multiple component carriers.

A search space is a set of candidate control channels formed by CCEs on a given aggregation level, which the terminal is supposed to attempt to decode. As there are multiple aggregation levels, corresponding to one, two, four, and eight CCEs, a terminal has multiple search spaces. In each subframe, the terminals will attempt to decode all the PDCCHs that can be formed from the CCEs in each of its search spaces. If the CRC checks, the content of the control channel is declared as valid for this terminal and the terminal processes the information (scheduling assignment, scheduling grants, etc.). Clearly, the network can only address a terminal if the control information is transmitted on a PDCCH formed by the CCEs in one of the terminal's search spaces. For example, terminal A in Figure 10.34 cannot be addressed on a PDCCH starting at CCE number 20, whereas terminal B can. Furthermore, if terminal A is using CCEs 16–23, terminal B cannot be addressed on aggregation level 4 as all CCEs in its level-4 search space are blocked by the use for the other terminals. From this it can be intuitively understood that for efficient utilization of the CCEs in the system, the search spaces should differ between terminals. Each terminal in the system therefore has a *terminal-specific* search space at each aggregation level.

[32] In release 8/9, the number of blind decoding attempts is 44 per subframe, while for release 10 with uplink spatial multiplexing the number is 60 (assuming a single component carrier).

Petitioners' Exhibit 1003, p. 558
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

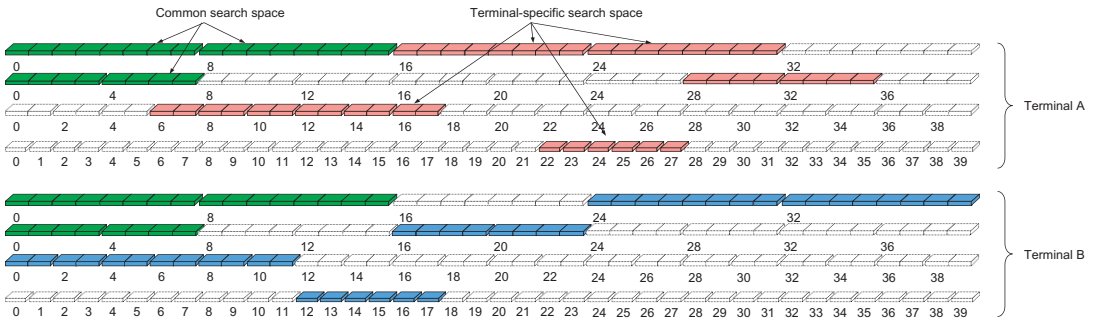


FIGURE 10.34

Principal illustration of search spaces in two terminals.

As the terminal-specific search space is typically smaller than the number of PDCCHs the network could transmit at the corresponding aggregation level, there must be a mechanism determining the set of CCEs in the terminal-specific search space for each aggregation level. One possibility would be to let the network configure the terminal-specific search space in each terminal. However, this would require explicit signaling to each of the terminals and possibly reconfiguration at handover. Instead, the terminal-specific search spaces in LTE are defined without explicit signaling through a function of the terminal identity and implicitly the subframe number. Dependence on the subframe number results in the terminal-specific search spaces being time varying, which helps resolve blocking between terminals. If a given terminal cannot be scheduled in a subframe as all the CCEs that the terminal is monitoring have already been used for scheduling other terminals in the same subframe, the time-varying definition of the terminal-specific search spaces is likely to resolve the blocking in the next subframe.

In several situations, there is a need to address a group of, or all, terminals in the system. One example hereof is dynamic scheduling of system information, another is transmission of paging messages, both described in Chapter 14. Transmission of explicit power-control commands to a group of terminals is a third example. To allow all terminals to be addressed at the same time, LTE has defined *common search spaces* in addition to the terminal-specific search spaces. A common search space is, as the name implies, common, and all terminals in the cell monitor the CCEs in the common search spaces for control information. Although the motivation for the common search space is primarily transmission of various system messages, it can be used to schedule individual terminals as well. Thus, it can be used to resolve situations where scheduling of one terminal is blocked due to lack of available resources in the terminal-specific search space. Unlike unicast transmissions, where the transmission parameters of the control signaling can be tuned to match the channel conditions of a specific terminal, system messages typically need to reach the cell border. Furthermore, the data rate of the associated DL-SCH transmission is typically modest. Consequently, the common search spaces are only defined for aggregation levels of four and eight CCEs and only for the smallest DCI formats, 0/1A/3/3A and 1C. There is no support for DCI formats with spatial multiplexing in the common search space. This helps to reduce the number of blind decoding attempts in the terminal used for monitoring the common search space.

Petitioners' Exhibit 1003, p. 559
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 10.7 Downlink DCI Formats Monitored in Different Search Spaces for C-RNTI

Mode	Monitored DCI Formats in Search Space			Description
	Common	UE-Specific	UE-Specific	
1	1A	1A	1	Single antenna transmission
2	1A	1A	1	Transmit diversity
3	1A	1A	2A	Open-loop spatial multiplexing
4	1A	1A	2	Closed-loop spatial multiplexing
5	1A	1A	1D	Multi-user MIMO
6	1A	1A	1B	Single layer codebook-based precoding
7	1A	1A	1	Single-layer transmission using DM-RS
8	1A	1A	2B	Dual-layer transmission using DM-RS
9	1A	1A	2C	Multi-layer transmission using DM-RS

Figure 10.34 illustrates the terminal-specific and common search spaces in two terminals in a certain subframe. The terminal-specific search spaces are different in the two terminals and will, as described above, vary from subframe to subframe. Furthermore, the terminal-specific search spaces partially overlap between the two terminals in this subframe (CCEs 24–31 on aggregation level 8) but, as the terminal-specific search space varies between subframes, the overlap in the next subframe is most likely different.

The downlink DCI formats to decode in the terminal-specific search space depend on the *transmission mode* configured for the terminal. Transmission modes are described in Section 10.3 and, in principle, correspond to different multi-antenna configurations. As an example, there is no need to attempt to decode DCI format 2 when the terminal has not been configured for spatial multiplexing, which helps to reduce the number of blind decoding attempts. Configuration of the transmission mode is done via RRC signaling. As the exact subframe number when this configuration takes effect in the terminal is not specified and may vary depending on, for example, RLC retransmissions, there is a (short) period when the network and the terminal may have different understandings of which transmission mode is configured. Therefore, in order not to lose the possibility of communicating with the terminal, it is necessary to have at least one DCI format that is decoded irrespective of the transmission mode. For downlink transmissions, DCI format 1A serves this purpose and the network can therefore always transmit data to the terminal using this DCI format. Another function of format 1A is to reduce overhead for transmissions when full flexibility in resource-block assignment is not needed.

In Table 10.7, the DCI monitoring is described for the case of a single component carrier. For multiple component carriers, the above procedures are applied in principle to each of the activated[33] downlink component carriers. Hence, in principle there is one UE-specific search space per aggregation level and per (activated) component carrier upon which PDSCH can be received (or PUSCH transmitted), although there are some carrier-aggregation-specific modifications. Clearly, for terminals configured to use carrier aggregation, this results in an increase in the number of blind decoding

[33] Individual component carriers can be activated/deactivated as discussed in Chapter 12.

Petitioners' Exhibit 1003, p. 560
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

attempts compared to a terminal not using carrier aggregation, as scheduling assignments/grants for each of the component carriers need to be monitored.

The common search space is only defined for transmissions on the primary component carrier. As the main function of the common search space is to handle scheduling of system information intended for multiple terminals, and such information must be receivable by all terminals in the cell, scheduling in this case uses the common search space. For this reason, the carrier indication field is never present in DCI formats monitored in the common search space.

As mentioned before, there is one UE-specific search space per aggregation level and component carrier[34] used for the PDSCH/PUSCH. This is illustrated in Figure 10.30, where PDSCH/PUSCH transmissions on component carrier 1 are scheduled using PDCCHs transmitted on component carrier 1. No carrier indicator is assumed in the UE-specific search space for component carrier 1 as cross-carrier scheduling is not used. For component carrier 2, on the other hand, a carrier indicator is assumed in the UE-specific search space as component carrier 2 is cross-carrier scheduled from PDCCHs transmitted on component carrier 1.

Search spaces for different component carriers may overlap in some subframes. In Figure 10.30, this happens for the UE-specific search spaces for component carriers 3 and 4. The terminal will handle the two search spaces independently, assuming (in this example) a carrier indicator for component carrier 4 but not for component carrier 3. If the UE-specific and common search spaces relating to different component carriers happen to overlap for some aggregation level when cross-carrier scheduling is configured, the terminal only needs to monitor the common search space. The reason for this is to avoid ambiguities; if the component carriers have different bandwidths a DCI format in the common search space may have the same payload size as another DCI format in the UE-specific search space relating to another component carrier.

[34]If the DCI formats for two different component carriers have the same size, then search spaces can be shared such that, in the example in Figure 10.30, component carrier 2 can be scheduled from search spaces 2 *and* 1. This comes "for free" as the DCI formats in search space 1 need to be monitored anyway and the carrier-indicator field points to the component carrier for which the grant/assignment is intended.

Petitioners' Exhibit 1003, p. 561
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CHAPTER

Uplink Physical-Layer Processing

11

This chapter provides a description of the basic physical-layer functionality of the LTE uplink. It essentially follows the same outline as the corresponding downlink description provided in the previous chapter with detailed descriptions regarding transport-channel processing (Section 11.1), the reference-signal structure (Section 11.2), multi-antenna transmission (Section 11.3), and the uplink L1/L2 control-channel structure (Section 11.4). Physical aspects directly related to some specific uplink functions and procedures such as random access will be provided in later chapters. The chapter ends with a discussion on the uplink timing-alignment procedure in Section 11.5.

11.1 TRANSPORT-CHANNEL PROCESSING

This section describes the physical-layer processing applied to the uplink shared channel (UL-SCH) and the subsequent mapping to the uplink physical resource in the form of the basic OFDM time–frequency grid. The UL-SCH is the only uplink transport-channel type in LTE[1] and is used for the transmission of all uplink higher-layer information (both data and control).

11.1.1 Processing Steps

Figure 11.1 outlines the different steps of the UL-SCH physical-layer processing. Similar to the downlink, in the case of uplink carrier aggregation the different component carriers correspond to separate transport channels with separate physical-layer processing. Also, most of the uplink processing steps outlined in Figure 11.1 are identical to the corresponding steps for the downlink transport-channel processing outlined in Section 10.1.

The different steps of the uplink transport-channel processing are summarized below. For a more detailed overview of the different steps, the reader is referred to the corresponding downlink description in Section 10.1.

- *CRC insertion per transport block*. A 24-bit CRC is calculated for and appended to each uplink transport block.
- *Code-block segmentation and per-code-block CRC insertion*. In the same way as for the downlink, code-block segmentation, including per-code-block CRC insertion, is applied for transport blocks larger than 6144 bits.

[1]Strictly speaking, the LTE Random-Access Channel is also defined as a transport-channel type, see Chapter 8. However, RACH only includes a layer-1 preamble and carries no actual transport-channel data.

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 562
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

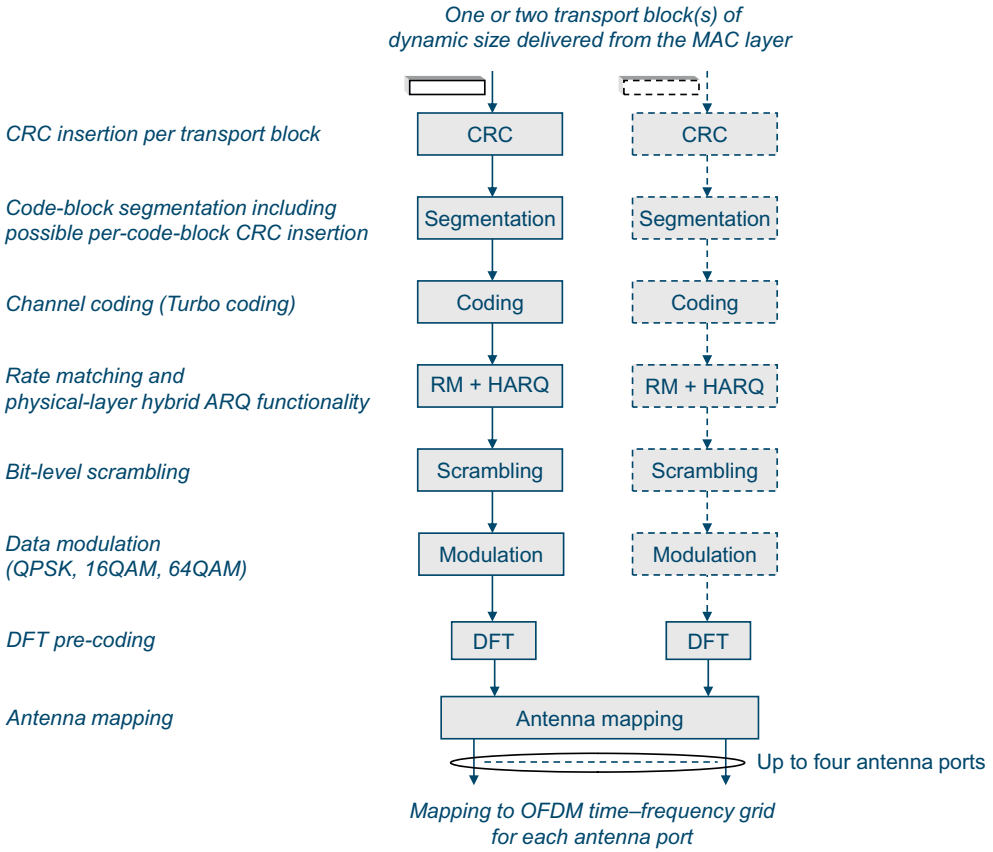


FIGURE 11.1

Physical-layer processing for UL-SCH.

- *Channel coding*. Rate-1/3 Turbo coding with QPP-based inner interleaving is also used for the uplink.
- *Rate matching and physical-layer hybrid-ARQ functionality*. The physical-layer part of the uplink rate-matching and hybrid-ARQ functionality is essentially the same as the corresponding downlink functionality, with sub-block interleaving and insertion into a circular buffer followed by bit selection with four redundancy versions. Note that there are some important differences between the downlink and uplink hybrid-ARQ protocols, such as asynchronous versus synchronous operation as described in Chapter 12. However, these differences are not visible in terms of the physical-layer processing.
- *Bit-level scrambling*. The aim of uplink scrambling is the same as for the downlink – that is, to randomize the interference and thus ensure that the processing gain provided by the channel code can be fully utilized.

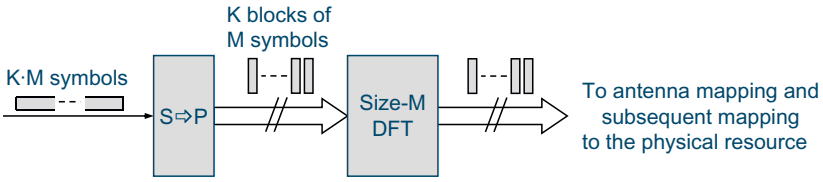


FIGURE 11.2

DFT precoding *K* blocks of *M* modulation symbols.

- *Data modulation*. Similar to the downlink, QPSK, 16QAM, and 64QAM modulation can also be used for uplink transport-channel transmission.
- *DFT precoding.* As illustrated in Figure 11.2, the modulation symbols, in blocks of M symbols, are fed through a size-M DFT, where M corresponds to the number of subcarriers assigned for the transmission. The reason for the precoding is to reduce the cubic metric for the transmitted signal. From an implementation-complexity point of view, the DFT size should preferably be constrained to a power of 2. However, such a constraint would limit the scheduler flexibility in terms of the amount of resources that can be assigned for an uplink transmission and, from a flexibility point of view, all possible DFT sizes should preferably be allowed. For LTE, a middle way has been adopted where the DFT size, and thus also the size of the resource allocation, is limited to products of the integers 2, 3, and 5. Thus, for example, DFT sizes of 60, 72, and 96 are allowed but a DFT size of 84 is not allowed.[2] In this way, the DFT can be implemented as a combination of relatively low-complex radix-2, radix-3, and radix-5 FFT processing.
- *Antenna mapping. The antenna mapping maps the output of the DFT precoder to antenna ports* for subsequent mapping to the physical resource (the OFDM time–frequency grid). In the first releases of LTE (release 8 and 9), only single-antenna transmission was supported for the uplink.[3] However, as part of LTE release 10, multi-antenna transmission, more specifically antenna precoding with up to four antennas ports, is supported in the uplink. More details about LTE uplink multi-antenna transmission are provided in Section 11.3.

11.1.2 Mapping to the Physical Resource

The scheduler assigns a set of resource-block pairs to be used for the uplink transmission, more specifically for transmission of the PUSCH physical channel that carries the UL-SCH transport channel. Each such resource-block pair spans 14 OFDM symbols (one subframe) in time.[4] However, as will be described in Section 11.2.1, two of these symbols are used for *uplink demodulation reference signals* and are thus not available for PUSCH transmission. Furthermore, one additional symbol may be

[2]As uplink resource assignments are always done in terms of resource blocks of size 12 subcarriers, the DFT size is always a multiple of 12.
[3]Actually, uplink *antenna selection* has been part of the LTE specification since release 8. However, it is an optional terminal feature that has, as of today, not been implemented in any commercial terminals.
[4]Twelve symbols in the case of extended cyclic prefix.

reserved for the transmission of *sounding reference signals* (Section 11.2.2). Thus, 11 or 12 OFDM symbols are available for PUSCH transmission within each resource-block pair.

Figure 11.3 illustrates how $K \cdot M$ DFT-precoded symbols at the output of the antenna mapping are mapped to the basic OFDM time–frequency grid, where K is the number of available OFDM symbols within a subframe (11 or 12 according to above) and M is the assigned bandwidth in number of subcarriers. As there are 12 subcarriers within a resource-block pair, $M = N \cdot 12$, where N is the number of assigned resource-block pairs.

Figure 11.3 assumes that the set of assigned resource-block pairs are contiguous in the frequency domain. This is the typical assumption for DFTS-OFDM and was strictly the case for LTE release 8 and 9. Mapping of the DFT-precoded signal to frequency-contiguous resource elements is preferred in order to retain good cubic-metric properties of the uplink transmission. At the same time, such a restriction implies an additional constraint for the uplink scheduler, something which may not always be desirable. Therefore, LTE release 10 introduced the possibility to also assign partly frequency-separated resources for PUSCH transmission. More specifically, in release 10 the assigned uplink resource may consist of a maximum of two frequency-separated *clusters*, as illustrated in Figure 11.4, where each cluster consists of a number of resource-block pairs (*N1* and *N2* resource-block pairs respectively). In the case of such *multi-cluster transmission*, a single DFT precoding spans the overall assigned resource in the frequency domain – that is, both clusters. This means that the total assigned bandwidth in number of subcarriers ($M = M1 + M2$) should be aligned with the restrictions on available DFT sizes described above.

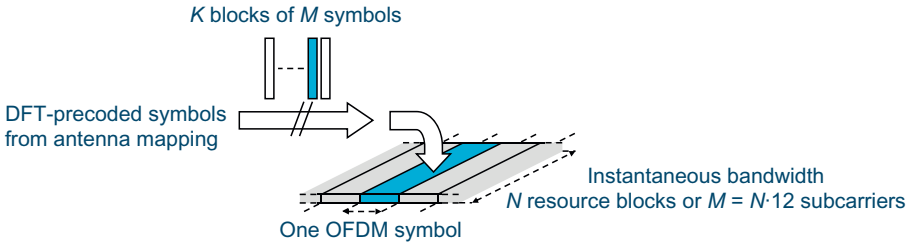


FIGURE 11.3

Mapping to the uplink physical resource.

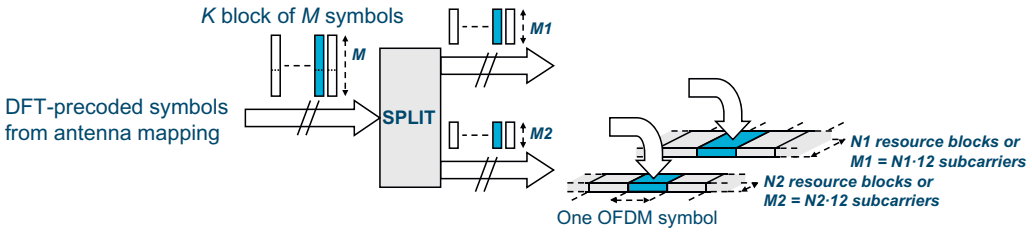


FIGURE 11.4

Uplink multi-cluster transmission.

11.1.3 PUSCH Frequency Hopping

In Chapter 10 it was described how the notion of *virtual resource blocks* (VRBs) in combination with the mapping from VRBs to *physical resource blocks* (PRBs) allowed for downlink distributed transmission – that is, the spreading of a downlink transmission in the frequency domain. As described, downlink distributed transmission consists of two separate steps: (1) a mapping from VRB pairs provided as part of the uplink scheduling grant to PRB pairs such that frequency-consecutive VRB pairs are not mapped to frequency-consecutive PRB pairs and (2) a split of each resource-block pair such that the two resource blocks of the resource-block pair are transmitted with a certain frequency gap in between. This second step can be seen as frequency hopping on a slot basis. In the absence of uplink frequency hopping, each VRB is directly mapped to a PRB.

The notion of VRBs can also be used for the LTE uplink, allowing for frequency-domain-distributed transmission for the uplink. However, in the uplink, where transmission from a terminal should always be over a set of consecutive subcarriers in the absence of multi-cluster transmission, distributing resource-block pairs in the frequency domain, as in the first step of downlink distributed transmission, is not possible. Rather, uplink distributed transmission is similar to the second step of downlink distributed transmission – that is, a frequency separation of the transmissions in the first and second slots of a subframe. Uplink distributed transmission for PUSCH can thus more directly be referred to as *uplink frequency hopping*.

There are two types of uplink frequency hopping defined for PUSCH:

- Sub-band-based hopping according to cell-specific hopping/mirroring patterns.
- Hopping based on explicit hopping information in the scheduling grant.

Uplink frequency hopping is not supported for multi-cluster transmission as, in that case, sufficient diversity can be obtained by the proper location of the two clusters.

11.1.3.1 Hopping Based on Cell-Specific Hopping/Mirroring Patterns

To support sub-band-based hopping according to cell-specific hopping/mirroring patterns, a set of consecutive sub-bands of a certain size is defined from the overall uplink frequency band, as illustrated in Figure 11.5. It should be noted that the sub-bands do not cover the total uplink frequency

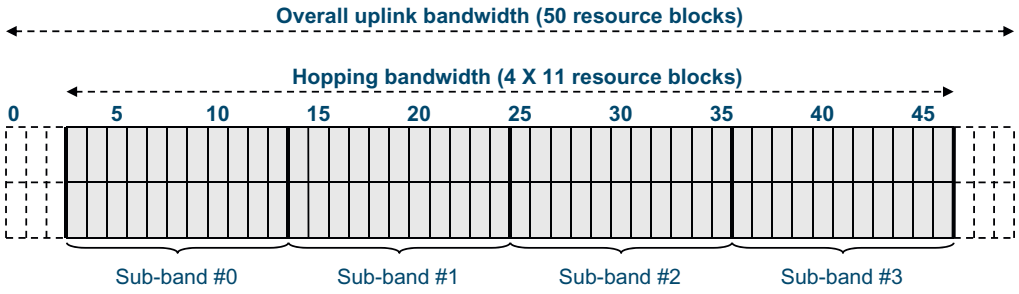


FIGURE 11.5

Definition of sub-bands for PUSCH hopping. The figure assumes a total of four sub-bands, each consisting of 11 resource blocks.

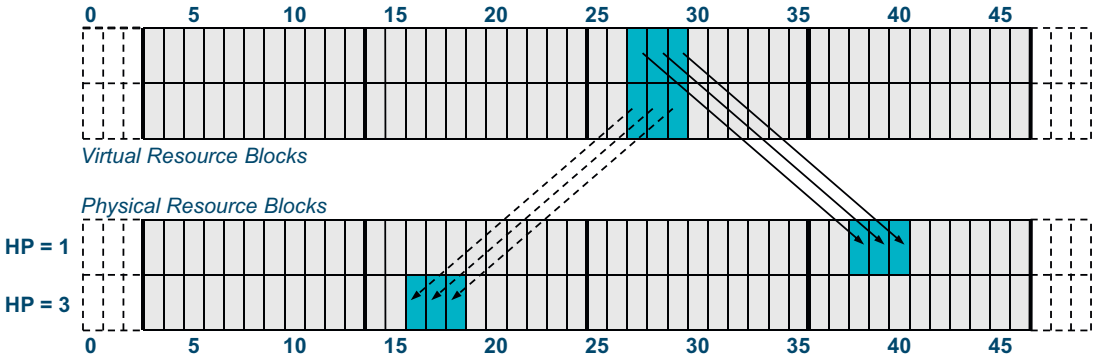


FIGURE 11.6

Hopping according to predefined hopping pattern.

band, mainly due to the fact that a number of resource blocks at the edges of the uplink frequency band are used for transmission of L1/L2 control signaling on the PUCCH. For example, in Figure 11.5 the overall uplink bandwidth corresponds to 50 resource blocks and there are a total of four sub-bands, each consisting of 11 resource blocks. Six resource blocks are not included in the hopping bandwidth and could, for example, be used for PUCCH transmission.

In the case of sub-band-based hopping, the set of virtual resource blocks provided in the scheduling grant are mapped to a corresponding set of physical resource blocks according to a cell-specific hopping pattern. The resource to use for transmission, the *PRBs*, is obtained by shifting the VRBs provided in the scheduling grant by a number of sub-bands according to the hopping pattern, where the hopping pattern can provide different shifts for each slot. As illustrated in Figure 11.6, a terminal is assigned VRBs 27, 28, and 29. In the first slot, the predefined hopping pattern takes the value 1, implying transmission using PRBs one sub-band to the right – that is, PRBs 38, 39, and 40. In the second slot, the predefined hopping pattern takes the value 3, implying a shift of three sub-bands to the right in the figure and, consequently, transmission using resource blocks 16, 17, and 18. Note that the shifting "wraps-around" – that is, in the case of four sub-bands, a shift of three sub-bands is the same as a negative shift of one sub-band. As the hopping pattern is cell specific – that is, the same for all terminals within a cell – different terminals will transmit on non-overlapping physical resources as long as they are assigned non-overlapping virtual resources.

In addition to the hopping pattern, there is also a cell-specific *mirroring pattern* defined in a cell. The mirroring pattern controls, on a slot basis, whether or not mirroring within each sub-band should be applied to the assigned resource. In essence, mirroring implies that the resource blocks within each sub-band are numbered right to left instead of left to right. Figure 11.7 illustrates mirroring in combination with hopping. Here, the mirroring pattern is such that mirroring is not applied to the first slot while mirroring is applied to the second slot.

Both the hopping pattern and the mirroring pattern depend on the physical-layer cell identity and are thus typically different in neighboring cells. Furthermore, the period of the hopping/mirroring patterns corresponds to one frame.

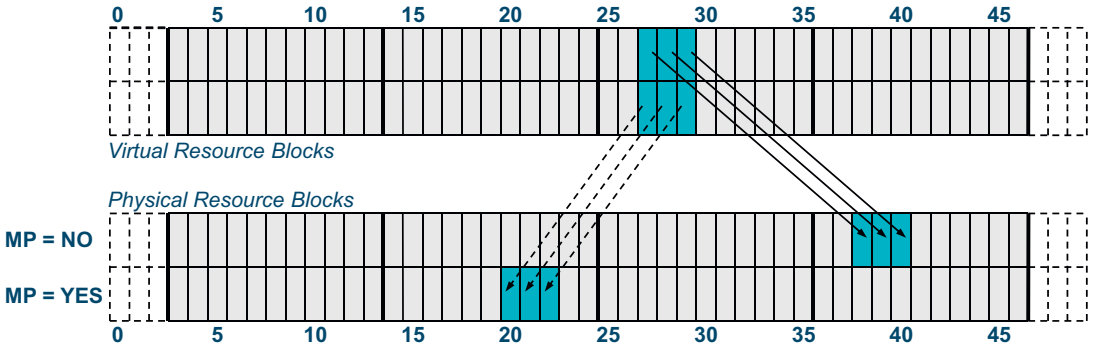


FIGURE 11.7

Hopping/mirroring according to predefined hopping/mirroring patterns. Same hopping pattern as in Figure 11.6.

11.1.3.2 Hopping Based on Explicit Hopping Information

As an alternative to hopping/mirroring according to cell-specific hopping/mirroring patterns as described above, uplink slot-based frequency hopping for PUSCH can also be controlled by *explicit hopping information* provided in the scheduling grant. In such a case the scheduling grant includes:

- information about the resource to use for uplink transmission in the first slot, exactly as in the non-hopping case; and
- additional information about the offset of the resource to use for uplink transmission in the second slot, relative to the resource of the first slot.

Selection between hopping according to cell-specific hopping/mirroring patterns as described above or hopping according to explicit information in the scheduling grant can be done dynamically. More specifically, for cell bandwidths less than 50 resource blocks, there is a single bit in the scheduling grant indicating if hopping should be according to the cell-specific hopping/mirroring patterns or should be according to information in the scheduling grant. In the latter case, the hop is always half of the hopping bandwidth. In the case of larger bandwidths (50 resource blocks and beyond), there are two bits in the scheduling grant. One of the combinations indicates that hopping should be according to the cell-specific hopping/mirroring patterns while the three remaining alternatives indicate hopping of 1/2, +1/4, and −1/4 of the hopping bandwidth. Hopping according to information in the scheduling grant for the case of a cell bandwidth corresponding to 50 resource blocks is illustrated in Figure 11.8. In the first subframe, the scheduling grant indicates a hop of one-half the hopping bandwidth. In the second subframe, the grant indicates a hop of one-fourth the hopping bandwidth (equivalent to a negative hop of three-fourths of the hopping bandwidth). Finally, in the third subframe, the grant indicates a negative hop of one-fourth the hopping bandwidth.

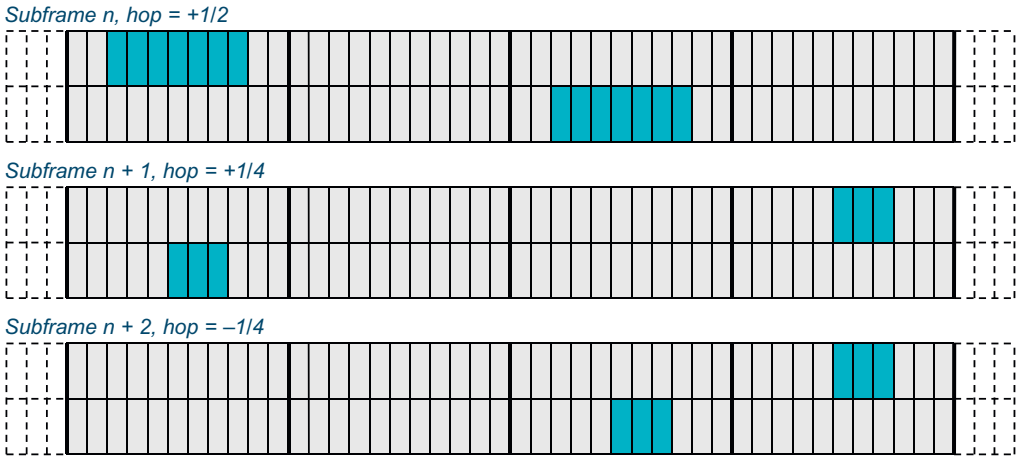


FIGURE 11.8

Frequency hopping according to explicit hopping information.

11.2 UPLINK REFERENCE SIGNALS

Similar to the downlink, reference signals are also transmitted on the LTE uplink. There are two types of reference signals defined for the LTE uplink:

- Uplink *demodulation reference signals* (DM-RS) are intended to be used by the base station for channel estimation for coherent demodulation of the uplink physical channels (PUSCH and PUCCH). Demodulation reference signals are thus only transmitted together with PUSCH or PUCCH and are then transmitted with the same bandwidth as the corresponding physical channel.
- Uplink *sounding reference signals* (SRS) are intended to be used by the base station for channel-state estimation to support uplink channel-dependent scheduling and link adaptation. The SRS can also be used in cases when uplink transmission is needed, although there is no data to transmit. One example is when uplink transmission is needed for the network to be able to control the uplink transmit timing by means of the *uplink-timing-alignment procedure* (Section 11.5). Finally, the uplink SRS can also be used to estimate the downlink channel-state assuming sufficient uplink/downlink reciprocity. This is especially of interest for TDD, where the operation of downlink and uplink on the same carrier frequency typically implies a higher degree of short-term downlink/uplink reciprocity compared to FDD.

11.2.1 Uplink Demodulation Reference Signals

Uplink demodulation reference signals are used for channel estimation for coherent demodulation of the Physical Uplink Shared Channel (PUSCH) to which the UL-SCH transport channel is mapped, as well as for the Physical Uplink Control Channel (PUCCH), which carries different types of L1/L2 control signaling (see Section 11.4). The basic structure for demodulation reference signals is

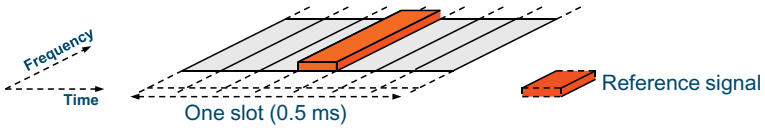


FIGURE 11.9

Transmission of uplink reference signals within a slot in the case of PUSCH transmission.

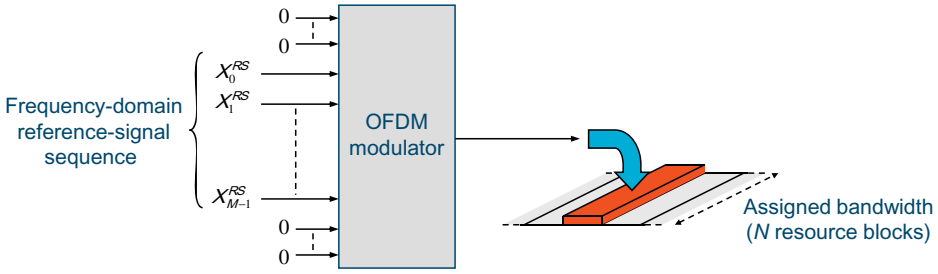


FIGURE 11.10

Generation of uplink reference signal from a frequency-domain reference-signal sequence.

the same for PUSCH and PUCCH transmission, although there are some differences – for example, in terms of the exact set of OFDM symbols in which the reference signals are transmitted.

11.2.1.1 Basic Principles of Uplink DM-RS

Due to the importance of low cubic metric and corresponding high power-amplifier efficiency for uplink transmissions, the principles for uplink reference-signal transmission are different compared to the downlink. In essence, transmitting reference signals in parallel with other uplink transmissions from the same terminal is not suitable for the uplink. Instead, certain OFDM symbols are used exclusively for DM-RS transmission – that is, the reference signals are *time multiplexed* with other uplink transmissions from the same terminal. The structure of the reference signal itself then ensures a low cubic metric in these symbols.

More specifically, in the case of PUSCH transmission a demodulation reference signal is transmitted within the fourth symbol of each uplink slot[5] (Figure 11.9). Within each subframe, there are thus two reference-signal transmissions, one in each slot.

In the case of PUCCH transmission, the number of OFDM symbols used for reference-signal transmission in a slot, as well as the exact position of these symbols, differs between different *PUCCH formats,* as described in Section 11.4.

Regardless of the kind of uplink transmission (PUSCH or PUCCH), the basic structure of each reference-signal transmission is the same. As illustrated in Figure 11.10, an uplink reference signal

[5]The third symbol in the case of extended cyclic prefix.

can be defined as a *frequency-domain reference-signal sequence* applied to consecutive inputs of the OFDM modulator – that is, to consecutive subcarriers.

In general, there is no reason to estimate the channel outside the frequency band of the corresponding PUSCH/PUCCH transmission that is to be coherently demodulated. The bandwidth of the reference signal, corresponding to the length of the reference-signal sequence in Figure 11.10, should thus be equal to the bandwidth of the corresponding PUSCH/PUCCH transmission measured in number of subcarriers. This means that, for PUSCH transmission, it should be possible to generate reference-signal sequences of different length, corresponding to the possible bandwidths of a PUSCH transmission. Note, however, that the length of the reference-signal sequence will always be a multiple of 12, as uplink resource allocations for PUSCH transmission are always done in terms of resource blocks consisting of 12 subcarriers.

As will be described in Section 11.4, PUCCH transmission from a terminal is always carried out over a single resource block in the frequency domain. In the case of PUCCH transmission, the length of the reference-signal sequence is thus always equal to 12.

Uplink reference signals should preferably have the following properties:

- Limited power variations in the frequency domain to allow for similar channel-estimation quality for all frequencies. Note that this is equivalent to good time-domain cross-correlation properties of the transmitted reference signal.
- Limited power variations in the time domain, leading to low cubic metric of the transmitted signal.

Furthermore, sufficient reference-signal sequences of a given length, corresponding to a certain reference-signal bandwidth, should be available in order to avoid an unreasonable planning effort when assigning reference-signal sequences to cells.

So-called *Zadoff–Chu* sequences [71] have the property of constant power in both the frequency and time domains. The elements of a Zadoff–Chu sequence of length M_{ZC} can be expressed as:

$$X_k^{ZC} = e^{-j\pi u \frac{k(k+1)}{M_{ZC}}} \quad 0 \leq k < M_{ZC}, \tag{11.1}$$

where u is the *index* of the Zadoff–Chu sequence within the set of Zadoff–Chu sequences of length M_{ZC}. From the point of view of small power variations in both the frequency and time domains, Zadoff–Chu sequences would thus be excellent as uplink reference-signal sequences. However, there are two reasons why Zadoff–Chu sequences are not suitable for direct use as uplink reference-signal sequences in LTE:

- The number of available Zadoff–Chu sequences of a certain length, corresponding to the number of possible values of the index u in the expression above, equals the number of integers that are relative prime to the sequence length. This implies that to maximize the number of Zadoff–Chu sequences and thus, in the end, to maximize the number of available uplink reference signals, prime-length Zadoff–Chu sequences would be preferred. At the same time, the length of the uplink reference-signal sequences should be a multiple of 12, which is obviously not a prime number.
- For short sequence lengths, corresponding to narrow uplink transmission bandwidths, relatively few reference-signal sequences would be available even if they were based on prime-length Zadoff–Chu sequences.

Instead, for sequence lengths larger than or equal to 36, corresponding to transmission bandwidths larger than or equal to three resource blocks, the reference-signal sequences are defined as *cyclic extensions* of Zadoff–Chu sequences of length M_{ZC}, where M_{ZC} is the largest prime number smaller than or equal to the desired reference-signal sequence length. For example, the largest prime number less than or equal to 36 is 31, implying that reference-signal sequences of length 36 are defined as cyclic extensions of Zadoff–Chu sequences of length 31. The number of available sequences is then equal to 30 – that is, one less than the length of the Zadoff–Chu sequence. For larger sequence lengths, more sequences are available. For example, for a reference-signal sequence length equal to 72, there are 70 sequences available.[6]

For sequence lengths equal to 12 and 24, corresponding to transmission bandwidths of one and two resource blocks respectively, special QPSK-based sequences have instead been found from computer searches and are explicitly listed in the LTE specifications. For each of the two sequence lengths, 30 sequences are available.

11.2.1.2 Phase-Rotated Reference-Signal Sequences

In the previous section it was described how different reference-signal sequences (a minimum of 30 sequences for each sequence length) can be derived, primarily by cyclically extending *different prime-length Zadoff–Chu sequences*. Additional reference-signal sequences can be derived by applying different linear phase rotations to the same basic reference-signal sequence, as illustrated in Figure 11.11, where the basic reference-signal sequence is defined according to the above – that is, a cyclically extended Zadoff–Chu sequence for sequence lengths larger than or equal to 36 and a "special" sequence for shorter sequence lengths.

Applying a linear phase rotation in the frequency domain is equivalent to applying a cyclic shift in the time domain. Thus, although being *defined* as different *frequency-domain phase rotations*, in

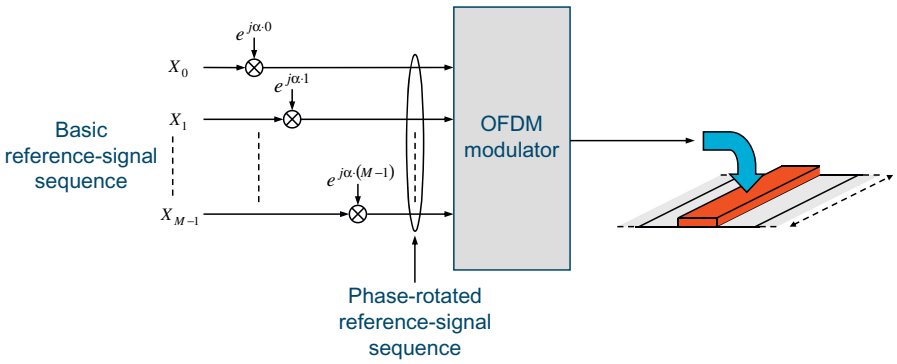


FIGURE 11.11

Generation of uplink reference-signal sequence from linear phase rotation of a basic reference-signal sequence.

[6]The largest prime number smaller than or equal to 72 is 71. The number of sequences is then one less than the length of the Zadoff–Chu sequence, i.e. 70.

the LTE specification this is often referred to as applying different *cyclic shifts*[7] to the same basic reference-signal sequence. Here the term "phase rotation" will be used. However, it should be borne in mind that what is referred to here as "phase rotation" is often referred to as "cyclic shift" in the 3GPP-related literature.

Demodulation reference signals defined from different reference-signal sequences typically have relatively low but still non-zero mutual correlation. In contrast, reference signals defined from different phase rotations of the same basic reference-signal sequence can be made completely orthogonal, thus causing no interference to each other, assuming the parameter α in Figure 11.11 takes a value $m\pi/6$, where m ranges from 0 to 11.[8] Up to 12 orthogonal reference signals can thus be defined from each basic reference-signal sequence.

However, to preserve the orthogonality between these reference signals also at the receiver side, the frequency response of the channel should essentially be constant (non-selective) over the span of 12 subcarriers (one resource block). Alternatively expressed, the main part of the channel time dispersion should not extend beyond the length of the cyclic shift mentioned above. If that is not the case, a subset of the available values for α may be used – for example, only the values $\{0, 2\pi/6, 4\pi/6, \ldots, 10\pi/6\}$ or perhaps even fewer values. Limiting the set of values for α implies orthogonality over a smaller number of subcarriers and thus less sensitivity to channel frequency selectivity.

Another prerequisite for orthogonality between reference signals defined from different phase rotations of the same basic reference-signal sequence is that the reference signals are received well aligned in time. Any timing misalignment between the reference signals will, in the frequency domain, appear as a phase rotation that may counteract the phase rotation applied to separate the reference-signal sequences and cause interference between them.

In general for LTE, uplink transmissions from different terminals within the same cell are typically well time aligned anyway, as this is a prerequisite for retaining the orthogonality between different frequency-multiplexed transmissions. Thus, one possible use of reference signals defined from different phase rotations of the same basic reference-signal sequence is for the case when multiple terminals within the same cell simultaneously transmit on the uplink *using the same frequency resource*. As will be seen in Section 11.4, this is, for example, the case for uplink PUCCH transmissions.

Multiple reference signals are also needed for PUSCH transmission in the case of spatial multiplexing (Section 11.3.1) and multi-user MIMO (Section 11.3.2). As discussed in Section 11.2.1.5, using different phase rotations is one approach by which multiple reference signals can be provided in these cases.

11.2.1.3 Reference-Signal Assignment to Cells

As described above, the design of the LTE reference-signal sequences allows for at least 30 sequences of each sequence length. To assign reference-signal sequences to cells, these sequences are first grouped into 30 *sequence groups* where each group consists of:

- One reference-signal sequence for each sequence length less than or equal to 60, corresponding to a transmission bandwidth of five resource blocks or less.

[7] Not to be confused with the cyclic extension of Zadoff–Chu sequences to generate the basic reference-signal sequences. The cyclic shift discussed here would be a time-domain cyclic shift, equivalent to a frequency-domain phase rotation.

[8] The orthogonality is due to the fact that, for $\alpha = m\pi/6$, there will be an integer number of full-circle rotations over 12 subarriers – that is, over one resource block.

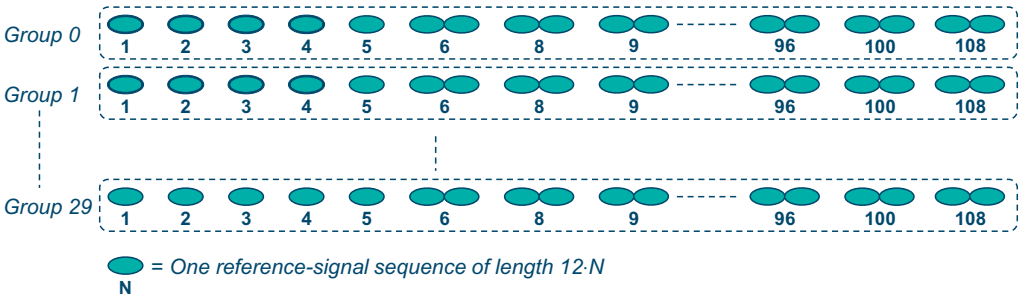


FIGURE 11.12

Grouping of reference-signal sequences into sequence groups. The number indicates the corresponding bandwidth in number of resource blocks.

- Two reference-signal sequences for each sequence length larger than or equal to 72,[9] corresponding to a transmission bandwidth of six resource blocks or more.

The grouping of reference-signal sequences into sequence groups is illustrated in Figure 11.12. It can be noted that the sequence groups do not include any reference-signal sequences corresponding to seven resource blocks. As described in Section 11.1.1, the uplink transmission bandwidths, measured in number of resource blocks, should always be a product of the integers 2, 3, and 5.[10] A resource assignment of size seven resource blocks is thus not a valid resource assignment and there is no need to define reference-signal sequences of the corresponding length. For the same reason, the maximum length of the reference-signal sequences corresponds to 108 resource blocks, rather than 110 resource blocks. Similarly, the second largest sequence length corresponds to 100 resource blocks.

In a given time slot, the uplink reference-signal sequences to use within a cell are taken from one specific sequence group. What group to use within a cell may then be the same for all slots (fixed assignment). Alternatively, what group to use within a cell may vary between slots, also referred to as *group hopping*. The system information indicates if there is a fixed group assignment or if group hopping is to be used.

Regardless of whether a fixed group assignment or group hopping is used, there are certain differences between PUCCH and PUSCH transmission.

In the case of a fixed group assignment, the sequence group to use for PUCCH transmission is given by the physical-layer cell identity (see Chapter 14) modulo 30, where the cell identity ranges from 0 to 503. Thus, cell identities 0, 30, 60, …, 480 correspond to sequence group 0, cell identities 1, 31, 61, …, 481 correspond to sequence group 1, and so on.

In contrast, what sequence group to use for PUSCH transmission is explicitly signaled as part of the cell system information. The reason for explicitly indicating what sequence group to use for

[9]For sequence lengths larger than or equal to 72, there are more than 60 sequences of each length allowing for two sequences per group.

[10]Strictly speaking, the number of subcarriers should be a product of the integers 2, 3, and 5. However, as there are $12 = 3 \cdot 2^2$ subcarriers within one resource block, this is equivalent to a constraint that the number of resource blocks should be a product of the integers 2, 3, and 5.

PUSCH transmission is that it should be possible to use the same sequence group for PUSCH transmission in neighboring cells, despite the fact that such cells typically have different cell identities, resulting in reference-signal orthogonality also *between* cells and a corresponding decrease in interference. In this case, the reference signals for PUSCH transmission would instead be distinguished by different phase rotations, as discussed in Section 11.2.1.2.

In the case of group hopping, an additional cell-specific group-hopping pattern is added to the sequence group. Hence, in the case of reference signals for PUCCH transmission, the sequence group to use in a given slot is given by the value of the group-hopping pattern for that slot plus the cell identity modulo 30. The group-hopping pattern is also given by the cell identity and identical group-hopping patterns are used for PUSCH and PUCCH within a cell.

Thus, to have the same sequence group for PUSCH in two cells:

- The cell identities of the two cells should be different (to have different sequence groups for PUCCH, which should always be the case).
- If group hopping is enabled, the cell identities of the two cells should be such that the same group-hopping pattern is used in the two cells.
- The sequence group for PUSCH (indicated as part of the cell system information) should be the same for the two cells.

11.2.1.4 Sequence Hopping

As can be seen from Figure 11.12, for sequence lengths corresponding to six resource blocks and above, there are two reference-signal sequences in each sequence group. What sequence to use may then either be fixed (always the first sequence within the group) or vary between slots, also referred to as *sequence hopping* (not to be mixed with group hopping as described in Section 11.2.1.3). The purpose of sequence hopping is to randomize the inter-cell interference between reference signals. Sequence hopping can only be enabled if group hopping is not enabled – that is, if there is a fixed assignment of groups to cells.

11.2.1.5 Multiple Demodulation Reference Signals

Support for uplink multi-antenna transmission, more specifically multi-antenna precoding including spatial multiplexing, was introduced in LTE release 10. As will be seen in Section 11.3.1, in the case of spatial multiplexing there is a need for one demodulation reference signal *per layer*. As LTE release 10 supports the transmission of up to four spatially multiplexed layers in parallel, there is thus a need to be able to transmit up to four demodulation reference signals from the same terminal. Such multiple reference signals can be generated by different means:

- Multiple mutually orthogonal reference signals can be generated by using different phase rotations ("cyclic shifts"), as already described in Section 11.2.1.2.
- Two different reference signals can be created from the same reference signal sequence by applying mutually orthogonal patterns, similar to the downlink referred to as *orthogonal cover codes* (OCC), to the two reference-signal transmissions within a subframe, as illustrated in Figure 11.13.

Multiple orthogonal reference signals, as described above, are also used in the case of uplink multi-user MIMO (Section 11.3.2).

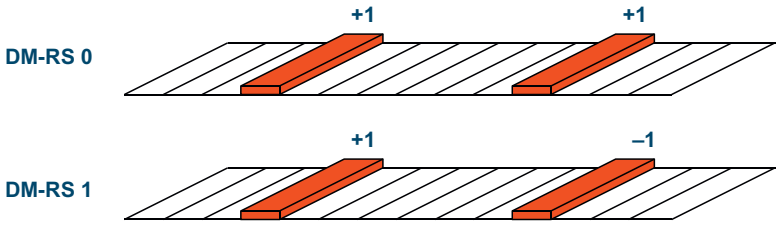


FIGURE 11.13

Generation of multiple demodulation reference signals from orthogonal cover codes.

11.2.2 Uplink Sounding Reference Signals

The demodulation reference signals discussed in Section 11.2.1 are used for channel estimation to allow for coherent demodulation of uplink physical channels (PUSCH or PUCCH). A demodulation reference signal is always transmitted together with and covering the same frequency band as the corresponding physical channel.

In contrast, *sounding reference signals* (SRS) are transmitted on the uplink to allow for the base station to estimate the uplink *channel state* at different frequencies. The channel-state estimates can then, for example, be used by the network scheduler to assign resource blocks of instantaneously good quality for uplink PUSCH transmission (uplink channel-dependent scheduling), as well as to select different transmission parameters such as the instantaneous data rate and different parameters related to uplink multi-antenna transmission. As mentioned earlier, SRS transmission can also be used for uplink timing estimation as well as to estimate downlink channel conditions assuming downlink/uplink channel reciprocity. Thus, an SRS is not necessarily transmitted together with any physical channel and if transmitted together with, for example, PUSCH, the SRS may cover a different, typically larger, frequency span.

There are two types of SRS transmission defined for the LTE uplink: *periodic* SRS transmission, which has been available from the first release of LTE (release 8); and *aperiodic* SRS transmission, introduced in LTE release 10.

11.2.2.1 Periodic SRS Transmission

Periodic SRS transmission from a terminal occurs at regular time intervals, from as often as once every 2 ms (every second subframe) to as infrequently as once every 160 ms (every 16th frame). When SRS is transmitted in a subframe, it occupies the last symbol of the subframe, as illustrated in Figure 11.14. As an alternative, in the case of TDD operation, SRS can also be transmitted within the UpPTS.

In the frequency domain, SRS transmissions should cover the frequency band that is of interest for the scheduler. This can be achieved in two ways:

- By means of a sufficiently wideband SRS transmission that allows for sounding of the entire frequency band of interest with a single SRS transmission, as illustrated in the upper part of Figure 11.15.

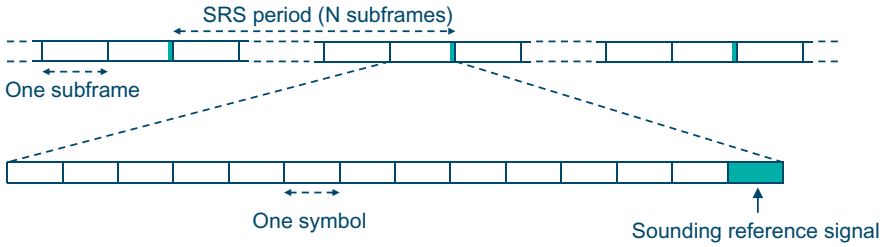


FIGURE 11.14

Transmission of SRS.

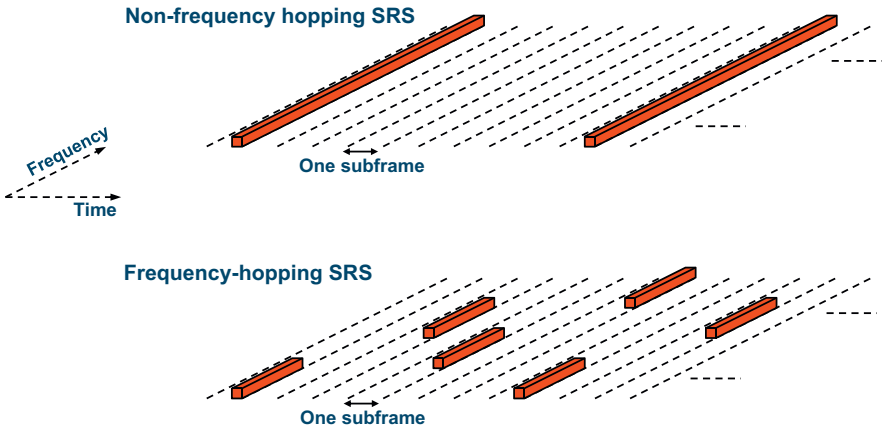


FIGURE 11.15

Non-frequency-hopping (wideband) versus frequency-hopping SRS.

- By means of more narrowband SRS transmission – that is, hopping in the frequency domain – in such a way that a sequence of SRS transmissions jointly covers the frequency band of interest, as illustrated in the lower part of Figure 11.15.

The main benefit of wideband (non-hopping) SRS transmission according to the upper part of Figure 11.15 is that the entire frequency band of interest can be sounded with a single SRS transmission – that is, within a single OFDM symbol. As described below, the entire OFDM symbol in which SRS is transmitted will be unavailable for data transmission in the cell. A single wideband SRS transmission is thus more efficient from a resource-utilization point of view as less OFDM symbols need to be used to sound a given overall bandwidth. However, in the case of a high uplink path loss, wideband SRS transmission may lead to relatively low received power density, which may degrade the channel-state estimation. In such a case it may be preferable to use a more narrowband SRS

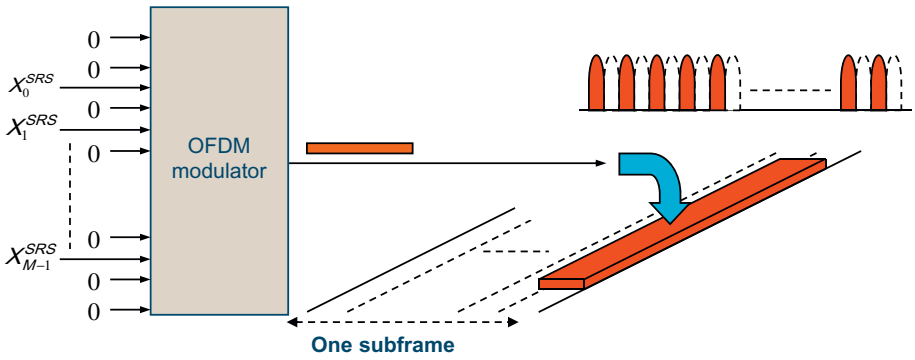


FIGURE 11.16

Generation of SRS from a frequency-domain reference-signal sequence.

transmission, thereby focusing the available transmit power in a more narrow frequency range, and then hop over the total band to be sounded.

In general, different bandwidths of the SRS transmission can be available within a cell. A narrow SRS bandwidth, corresponding to four resource blocks, is always available in all cells, regardless of the uplink cell bandwidth. Up to three additional, more wideband SRS bandwidths may also be configured within the cell. The SRS bandwidths are then always a multiple of four resource blocks. A terminal is then explicitly configured to use one of the SRS bandwidths available in the cell.

If a terminal is transmitting SRS in a certain subframe, the SRS transmission may very well overlap, in the frequency domain, with PUSCH transmissions from other terminals within the cell. To avoid collision between SRS and PUSCH transmissions from different terminals, terminals should in general avoid PUSCH transmission in the OFDM symbols in which SRS transmission may occur. To achieve this, all terminals within a cell are aware of the set of subframes within which SRS *may* be transmitted by *any* terminal within the cell. All terminals should then avoid PUSCH transmission in the last OFDM symbol of those subframes.[11] Information about the set of subframes in which SRS *may be* transmitted within a cell is provided as part of the cell system information.

On a more detailed level, the structure for sounding reference signals (SRS) is similar to that of uplink demodulation reference signals described in Section 11.2.1. More specifically, a sounding reference signal is also defined as a frequency-domain reference-signal sequence derived as a cyclic extension of prime-length Zadoff–Chu sequences. However, in the case of SRS, the reference-signal sequence is mapped to *every second subcarrier*, creating a "comb"-like spectrum, as illustrated in Figure 11.16. Taking into account that the bandwidth of the SRS transmission is always a multiple of four resource blocks, the lengths of the reference-signal sequences for SRS are thus always a multiple of 24. The reference-signal sequence to use for SRS transmission within the cell is taken from the same sequence group as the demodulation reference signals used for channel estimation for PUCCH.

[11] SRS transmission in UpPTS can obviously not collide with PUSCH transmission as there is no PUSCH transmission in UpPTS.

Similar to demodulation reference signals, different phase rotations (also, for SRS, typically referred to as "cyclic shifts") can be used to generate different SRS that are orthogonal to each other. By assigning different phase rotations to different terminals, multiple SRS can thus be transmitted in parallel in the same subframe, as illustrated by terminals #1 and #2 in the upper part of Figure 11.17. However, it is then required that the reference signals span the same frequency band.

Another way to allow for SRS to be simultaneously transmitted from different terminals is to rely on the fact that each SRS only occupies every second subcarrier. Thus, SRS transmissions from two terminals can be *frequency multiplexed* by assigning them to different frequency shifts or "combs", as illustrated by terminal #3 in the lower part of Figure 11.17. In contrast to the multiplexing of SRS transmission by means of different "cyclic shifts", frequency multiplexing of SRS transmissions does not require the transmissions to cover identical frequency bands.

To summarize, the following set of parameters defines the characteristics of an SRS transmission:

- SRS transmission bandwidth – that is, the bandwidth covered by a single SRS transmission.
- Hopping bandwidth – that is, the frequency band over which the SRS transmission is frequency hopping.
- Frequency-domain position – that is, the starting point of the SRS transmission in the frequency domain.
- Transmission comb, as illustrated in Figure 11.17.
- Phase rotation (or equivalently cyclic shift) of the reference-signal sequence.
- SRS transmission time-domain period (from 2 to 160 ms) and subframe offset.

A terminal that is to transmit SRS is configured with these parameters by means of higher layer (RRC) signaling. In addition, all terminals within a cell should be informed in what subframes SRS may be transmitted within the cell as, within these subframes, the "SRS symbol" should not be used for PUSCH transmission.

11.2.2.2 Aperiodic SRS Transmission

In contrast to periodic SRS, aperiodic SRS are *one-shot* transmissions, triggered by signaling on PDCCH as part of the scheduling grant. The frequency-domain structure of an aperiodic SRS

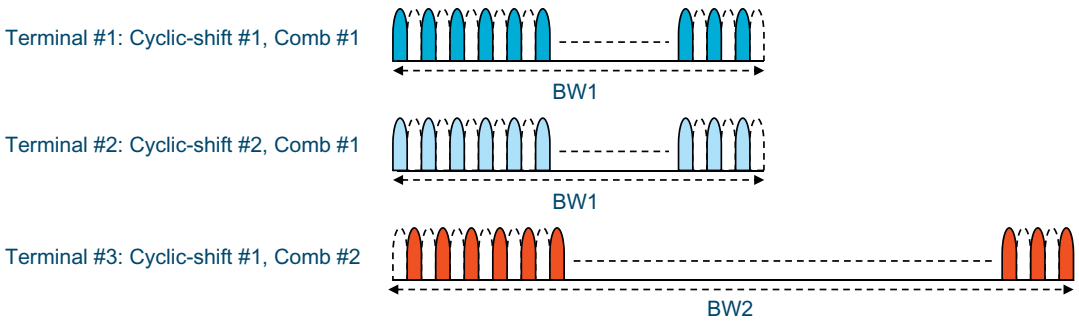


FIGURE 11.17

Multiplexing of SRS transmissions from different terminals.

transmission is identical to that of periodic SRS. Also, in the same way as for periodic SRS transmission, aperiodic SRS are transmitted within the last symbol of a subframe. Furthermore, the time instants when aperiodic SRS may be transmitted are configured per terminal using higher-layer signaling.

The frequency-domain parameters for aperiodic SRS (bandwidth, odd or even "comb", etc.) are configured by higher-layer (RRC) signaling. However, no SRS transmission will actually be carried out until the terminal is explicitly triggered to do so by an explicit *SRS trigger* on PDCCH. When such a trigger is received, a single SRS is transmitted in the next available aperiodic SRS instant configured for the terminal using the configured frequency-domain parameters. Additional SRS transmissions can then be carried out if additional triggers are received.

Three different parameter sets can be configured for aperiodic SRS, for example differing in the frequency position of the SRS transmission and/or the transmission comb. Information on what parameters to use when the SRS is actually transmitted is included in the PDCH information, which consists of two bits, three combinations of which indicate the specific SRS parameter set. The fourth combination simply indicates that no SRS should be transmitted.

11.3 UPLINK MULTI-ANTENNA TRANSMISSION

Downlink multi-antenna transmission was supported by the LTE specification from its first release (release 8). With LTE release 10, support for uplink multi-antenna transmission – that is, uplink transmission relying on multiple transmit antennas at the terminal side – was also introduced for LTE. Uplink multi-antenna transmission can be used to improve the uplink link and/or system performance in different ways:

- To improve the achievable data rates and spectral efficiency for uplink data transmission by allowing for antenna precoding supporting spatial multiplying with up to four layers for the uplink physical data channel PUSCH.
- To improve the uplink control-channel performance by allowing for transmit diversity for the uplink physical control channel PUCCH.

11.3.1 Precoder-Based Multi-Antenna Transmission for PUSCH

In the case of PUSCH transmission, multi-antenna transmission is based on antenna precoding, as illustrated in Figure 11.18. The structure of the uplink antenna precoding is very similar to that of downlink antenna precoding (Section 10.3), including the presence of precoded demodulation reference signals (one per layer) similar to downlink non-codebook-based precoding (Figure 10.19 in Section 10.3.3). Uplink antenna precoding supports transmission using up to four antenna ports, allowing for spatial multiplexing with up to four layers.

The principles for mapping of the modulation symbols to layers are also the same as for the downlink. For an initial transmission, there is one transport block in the case of a single layer and two transport blocks for more than one layer, as illustrated in Figure 11.19. Similar to the downlink, in the case of a hybrid-ARQ retransmission, a single transport block may also be transmitted on multiple layers in some cases.

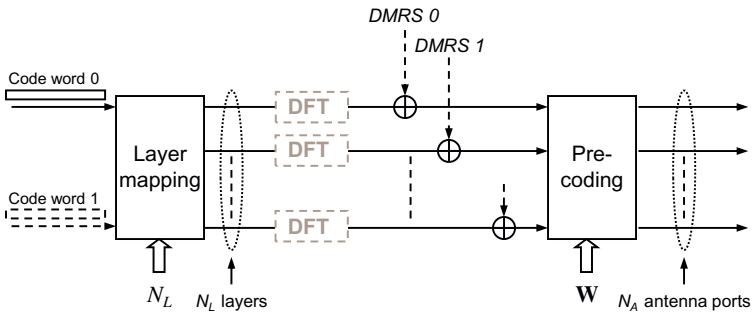


FIGURE 11.18

Precoder-based multi-antenna transmission for LTE uplink.

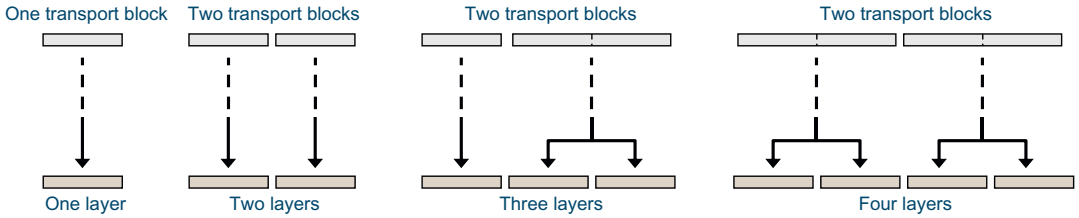


FIGURE 11.19

Uplink transport-channel-to-layer mapping (initial transmission).

As can be seen in Figure 11.18, the DFT precoding is actually taking place after layer mapping – that is, each layer is separately DFT precoded. To simplify the description this was not really visible in Figure 11.1, outlining the overall physical-layer transport-channel processing.

It can also be noted that, in contrast to Figure 10.19 in Section 10.3.3, the precoder in Figure 11.18 is not shaded. As discussed in Section 10.3.3, for downlink non-codebook-based precoding, the precoder part of the antenna mapping is not visible in the specification and the network can, in essence, apply an arbitrary precoding for the downlink transmission. Due to the use of precoded demodulation reference signals, the terminal can recover the different layers without knowledge of exactly what precoding has been applied at the transmitted side.

The same is also true for the uplink – that is, the presence of precoded demodulation reference signals would allow for the base station to demodulate the uplink multi-antenna transmission and recover the different layers without knowledge of the precoding taking place at the transmitter side. However, for LTE the uplink precoder matrix is selected by the network and conveyed to the terminal as part of the scheduling grant. The terminal should then follow the precoder matrix selected by the network. Thus, in the uplink, the precoder is visible in the specification and, in order to limit the downlink signaling, there is a limited set of precoder matrices specified for each transmission rank.

More specifically, for each combination of transmission rank N_{L} and number of antennas ports N_A, a set of precoder matrices of size $N_{\mathrm{A}} \times N_{\mathrm{L}}$ is defined, as illustrated in Tables 11.1 and 11.2 for

Table 11.1 Uplink Precoder Matrices for Two Antenna Ports

Transmission Rank	Codebook Index					
	0	**1**	**2**	**3**	**4**	**5**
1	$\begin{bmatrix}+1\\+1\end{bmatrix}$	$\begin{bmatrix}+1\\-1\end{bmatrix}$	$\begin{bmatrix}+1\\+j\end{bmatrix}$	$\begin{bmatrix}+1\\-j\end{bmatrix}$	$\begin{bmatrix}+1\\+1\end{bmatrix}$	$\begin{bmatrix}+1\\-1\end{bmatrix}$

Full-rank (2 × 2) identity matrix is not shown in the table.

Table 11.2 Subset of Uplink Precoder Matrices for Four Antenna Ports and Different Transmission Ranks

Transmission Rank	Codebook Index				
	0	**1**	**2**	**3**	…
1	$\begin{bmatrix}+1\\+1\\+1\\-1\end{bmatrix}$	$\begin{bmatrix}+1\\+1\\+j\\+j\end{bmatrix}$	$\begin{bmatrix}+1\\+1\\-1\\+1\end{bmatrix}$	$\begin{bmatrix}+1\\+1\\-j\\-j\end{bmatrix}$	…
2	$\begin{bmatrix}+1 & 0\\+1 & 0\\0 & +1\\0 & -j\end{bmatrix}$	$\begin{bmatrix}+1 & 0\\+1 & 0\\0 & +1\\0 & +j\end{bmatrix}$	$\begin{bmatrix}+1 & 0\\-j & 0\\0 & +1\\0 & +1\end{bmatrix}$	$\begin{bmatrix}+1 & 0\\-j & 0\\0 & 1\\0 & -1\end{bmatrix}$	
3	$\begin{bmatrix}+1 & 0 & 0\\+1 & 0 & 0\\0 & +1 & 0\\0 & 0 & +1\end{bmatrix}$	$\begin{bmatrix}+1 & 0 & 0\\-1 & 0 & 0\\0 & +1 & 0\\0 & 0 & +1\end{bmatrix}$	$\begin{bmatrix}+1 & 0 & 0\\0 & +1 & 0\\+1 & 0 & 0\\0 & 0 & +1\end{bmatrix}$	$\begin{bmatrix}+1 & 0 & 0\\0 & +1 & 0\\-1 & 0 & 0\\0 & 0 & +1\end{bmatrix}$	

Full-rank (4 × 4) identity matrix is not shown in the table.

two and four antenna ports respectively. For full-rank transmission – that is, when the transmission rank or number of layers equals the number of transmit antennas – only a single precoder matrix is defined, namely the identity matrix of size $N_A \times N_A$ (not shown in the tables). Note that, for the case of four antenna ports, only a subset of the defined matrices is shown. In total there are 24 rank-1 matrices, 16 rank-2 matrices, and 12 rank-3 matrices defined for four antenna ports, in addition to the single rank-4 matrix.

As can be seen, all the precoder matrices in Table 11.1 contain one and only one non-zero element in each row, and this is generally true for all precoder matrices defined for the uplink. As a consequence, the signal transmitted on a certain antenna port (corresponding to a certain row of the

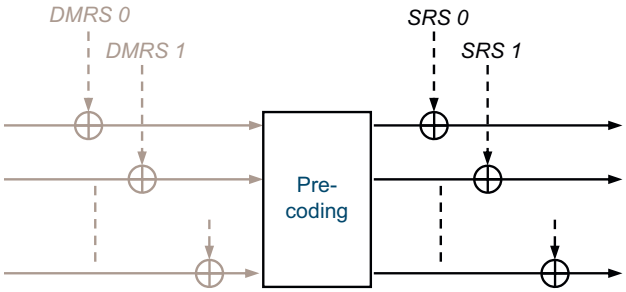


FIGURE 11.20

Illustration of SRS transmitted *after* uplink antenna precoding.

precoder matrix) always depends on one and only one specific layer (corresponding to a specific column of the precoder matrix). Expressed alternatively, the precoder matrix maps the layers to the antenna ports *with at most one layer being mapped to each antenna port*. Due to this, the good cubic-metric properties of the transmitted signal are also preserved for each antenna port when antenna precoding is applied. The precoder matrices of Tables 11.1 and 11.2 are therefore also referred to as *cubic-metric-preserving precoder matrices*.

In order to select a suitable precoder, the network needs information about the uplink channel. Such information can, for example, be based on measurements on the uplink sounding reference signals (Section 11.2.2). As indicated in Figure 11.20, sounding reference signals (SRS) are transmitted non-precoded – that is, directly on the different antenna ports. The received SRS thus reflect the channel of each antenna port, not including any precoding. Based on the received SRS, the network can thus decide on a suitable uplink transmission rank and corresponding uplink precoder matrix and provide information about the selected rank and precoder matrix as part of the scheduling grant.

The previous paragraph assumed the same number of antenna ports for PUSCH as for SRS. Clearly, this is a relevant situation and the SRS is, in this case, used to aid the selection of the precoding matrix, as discussed above. However, there are also situations when SRS and PUSCH use *different* numbers of antenna ports. One example is uplink transmission of two layers (two antenna ports), where the eNodeB would like to use SRS to probe the channel for potential four-layer transmission. In this case the SRS is transmitted on a *different* set of antenna ports than the PUSCH to aid the eNodeB in assessing the benefits, if any, of switching to four-layer transmission.

11.3.2 Uplink Multi-User MIMO

As described in Section 10.3.5, downlink multi-user MIMO (MU-MIMO) implies downlink transmission to different terminals using *the same time–frequency resource* and relying on the availability of multiple antennas, at least on the network side, to suppress interference between the transmissions. The term MU-MIMO originated from the resemblance to SU-MIMO (spatial multiplexing).

Uplink MU-MIMO is essentially the same thing but for the uplink transmission direction – that is, uplink MU-MIMO implies uplink transmissions from multiple terminals using *the same uplink time–frequency resource* and relying on the availability of multiple receive antennas at the base station

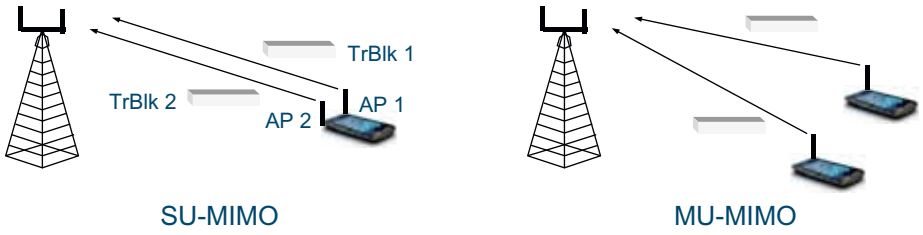


FIGURE 11.21

Relation between uplink SU-MIMO (spatial multiplexing) and MU-MIMO (SDMA).

to separate the two or more transmissions. Thus, MU-MIMO is really just another term for uplink *Space-Division Multiple Access* (SDMA).

Actually, on the uplink, the relation between MU-MIMO and SU-MIMO (spatial multiplexing) is even closer. Uplink spatial multiplexing, for example with two antenna ports and two layers, implies that the terminal transmits two transport blocks with one transport block transmitted on each layer and thus on each antenna port,[12] as illustrated in the left part of Figure 11.21. As illustrated in the right part of the figure, MU-MIMO is essentially equivalent to separating the two antennas into two different terminals and transmitting one transport block from each terminal. The base-station processing to separate the two transmissions could essentially be identical to the processing used to separate the two layers in the case of spatial multiplexing. It should be noted though that the separation of the two transmissions at the receiver side could be simplified, or at least the possible means to achieve this separation are extended, if the two terminals are well separated in space, something which is, for obvious reasons, not the case for two antennas attached to the same terminal. As an example, for sufficiently separated terminals, classical beam-forming relying on correlated receiver antennas can be used to separate the uplink transmissions. Alternatively, uncorrelated receiver antennas can be used, and the separation means are then essentially the same as for SU-MIMO.

One important benefit of uplink MU-MIMO is that one can get similar gains in *system throughput* as SU-MIMO (spatial multiplexing) without the need for multiple transmit antennas at the terminal side, allowing for less complex terminal implementation. It should be noted though that spatial multiplexing could still provide substantial gains in terms of *user throughput* and peak data rates that can be provided from a single terminal. The potential system gains of uplink MU-MIMO also rely on more than one terminal being actually available for transmission. The process of "pairing" terminals that should share the time–frequency resources is non-trivial and requires suitable radio-channel conditions.

Essentially, support for uplink MU-MIMO only requires the possibility to explicitly assign a specific orthogonal reference signal for the uplink transmission, thereby ensuring orthogonality between reference-signal transmissions from the different terminals involved in the MU-MIMO transmission. The orthogonal reference signals used for MU-MIMO are the same as for spatial multiplexing described in the previous section – that is, based on a combination of OCC (orthogonal cover codes)

[12]Note that the 2×2 precoder matrix is the identity matrix (see Table 11.1).

and different phase rotations. To support uplink MU-MIMO, each scheduling assignment includes a three-bit reference-signal indicator denoting a certain combination of OCC and phase rotation.

Also note that, similar to downlink MU-MIMO, nothing prevents the combination of spatial multiplexing and MU-MIMO – that is, multiplexing several terminals by means of MU-MIMO where one or several of the terminals are transmitting more than one layer. The eventual limitation is the number of orthogonal reference signals that can be assigned to the different users.

11.3.3 PUCCH Transmit Diversity

Precoder-based multi-layer transmission is only used for the uplink data transmission on PUSCH. However, in the case of a terminal with multiple transmit antennas, one obviously wants to use the full set of terminal antennas and corresponding terminal power amplifiers also for the L1/L2 control signaling on PUCCH in order to be able to utilize the full power resource and achieve maximum diversity. To achieve additional diversity, LTE release 10 also introduced the possibility for two-antenna *transmit diversity* for PUCCH. More specifically, the transmit diversity supported for PUCCH is referred to as Spatial Orthogonal-Resource Transmit Diversity (SORTD).

The basic principle of SORTD is simply to transmit the uplink control signaling using different resources (time, frequency, and/or code) on the different antennas. In essence, the PUCCH transmissions from the two antennas will be identical to PUCCH transmissions from two different terminals using different resources. Thus, SORTD creates additional diversity but achieves this by using twice as many PUCCH resources, compared to non-SORTD transmission.

For four physical antennas at the terminal, implementation-specific *antenna virtualization* is used. In essence, a transparent scheme is used to map the two-antenna-port signal to four physical antennas.

11.4 UPLINK L1/L2 CONTROL SIGNALING

Similar to the LTE downlink, there is also a need for uplink L1/L2 control signaling to support the transmission of downlink and uplink transport channels. Uplink L1/L2 control signaling consists of:

- hybrid-ARQ acknowledgements for received DL-SCH transport blocks;
- channel-state reports related to the downlink channel conditions, used to assist downlink scheduling; and
- scheduling requests, indicating that a terminal needs uplink resources for UL-SCH transmissions.

There is no information indicating the UL-SCH transport format signaled on the uplink. As mentioned in Chapter 8, the eNodeB is in complete control of the uplink UL-SCH transmissions and the terminal always follows the scheduling grants received from the network, including the UL-SCH transport format specified in those grants. Thus, the network knows the transport format used for the UL-SCH transmission in advance and there is no need for any explicit transport-format signaling on the uplink.

Uplink L1/L2 control signaling needs to be transmitted on the uplink regardless of whether or not the terminal has any uplink transport-channel (UL-SCH) data to transmit and thus regardless of whether or not the terminal has been assigned any uplink resources for UL-SCH transmission. Hence, two different methods are supported for the transmission of the uplink L1/L2 control signaling,

depending on whether or not the terminal has been assigned an uplink resource for UL-SCH transmission:

- *No simultaneous transmission of UL-SCH and L1/L2 control*. If the terminal does not have a valid scheduling grant – that is, no resources have been assigned for the UL-SCH in the current subframe – a separate physical channel, the *Physical Uplink Control Channel* (PUCCH), is used for transmission of uplink L1/L2 control signaling. In the case of uplink carrier aggregation, the PUCCH can be transmitted on the primary component carrier only. A consequence of this is that transmissions on multiple component carriers in the downlink may need to be acknowledged on a single uplink component carrier.
- *Simultaneous transmission of UL-SCH and L1/L2 control*. If the terminal has a valid scheduling grant – that is, resources have been assigned for the UL-SCH in the current subframe – the uplink L1/L2 control signaling is time multiplexed with the coded UL-SCH on to the PUSCH prior to DFT precoding and OFDM modulation. Obviously, as the terminal has been assigned UL-SCH resources, there is no need to support transmission of the scheduling request in this case. Instead, scheduling information can be included in the MAC headers, as described in Chapter 12. In the case of carrier aggregation, all control signaling is transmitted on one of the uplink component carriers – that is, uplink control signaling cannot be spread across multiple UL-SCHs.

The reason to differentiate between the two cases above is to minimize the cubic metric for the uplink power amplifier in order to maximize coverage. However, in situations when there is sufficient power available in the terminal, simultaneous transmission of PUSCH and PUCCH can be used with no impact on the coverage. The possibility for simultaneous PUSCH and PUCCH transmission was therefore introduced in release 10 as one part of several features[13] adding flexibility at the cost of a somewhat higher cubic metric. In situations where this cost is not acceptable, simultaneous PUSCH and PUCCH can always be avoided by using the basic mechanism introduced in the first version of LTE.

These two cases, control on PUCCH and PUSCH respectively, are described in more detail in the following.

11.4.1 Uplink L1/L2 Control Signaling on PUCCH

If the terminal has not been assigned an uplink resource for UL-SCH transmission, the L1/L2 control information (channel-state reports, hybrid-ARQ acknowledgements, and scheduling requests) is transmitted on uplink resources (resource blocks) specifically assigned for uplink L1/L2 control on PUCCH. As mentioned in the previous section, the PUCCH can be transmitted on the primary component carrier only. However, as the primary component carrier is specified on a per-terminal basis, there may, from a network perspective, be PUCCH resources used on multiple component carriers.

Figure 11.22 illustrates the location of the PUCCH resources on one component carrier at the edges of the bandwidth allocated to that component carrier. Each such resource consists of 12 subcarriers (one resource block) within each of the two slots of an uplink subframe. To provide frequency diversity, the frequency resource is frequency hopping on the slot boundary – that is, one "frequency resource" consists of 12 subcarriers at the upper part of the spectrum within the first slot of a subframe

[13] Other examples of such features are simultaneous transmission on multiple uplink component carriers and uplink multi-cluster transmission.

Petitioners' Exhibit 1003, p. 586
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

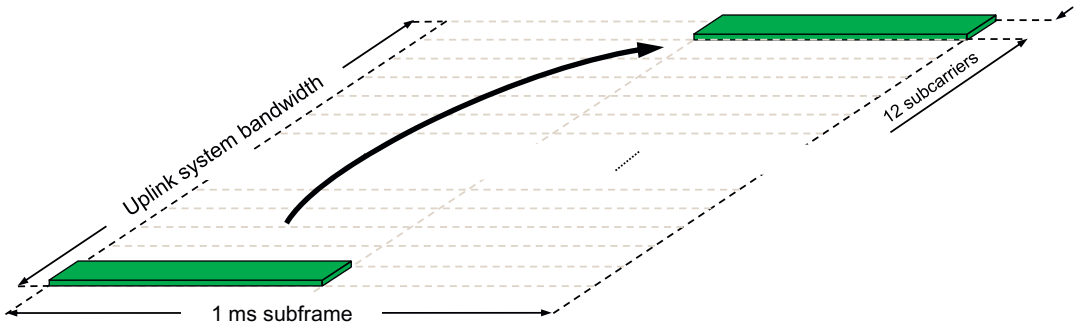


FIGURE 11.22

Uplink L1/L2 control signaling transmission on PUCCH.

and an equally sized resource at the lower part of the spectrum during the second slot of the subframe or vice versa. If more resources are needed for the uplink L1/L2 control signaling, for example in the case of very large overall transmission bandwidth supporting a large number of users, then additional resource blocks can be assigned next to the previously assigned resource blocks.

The reasons for locating the PUCCH resources at the edges of the overall available spectrum are twofold:

- Together with the frequency hopping described above, this maximizes the frequency diversity experienced by the control signaling.
- Assigning uplink resources for the PUCCH at other positions within the spectrum – that is, not at the edges – would have fragmented the uplink spectrum, making it impossible to assign very wide transmission bandwidths to a single terminal and still preserve the low-cubic-metric properties of the uplink transmission.

The bandwidth of one resource block during one subframe is too large for the control signaling needs of a single terminal. Therefore, to efficiently exploit the resources set aside for control signaling, multiple terminals can share the same resource block. This is done by assigning the different terminals to different orthogonal phase rotations of a cell-specific length-12 frequency-domain sequence, where the sequence is identical to a length-12 reference-signal sequence. Furthermore, as described in conjunction with the reference signals in Section 11.2, a linear phase rotation in the frequency domain is equivalent to applying a cyclic shift in the time domain. Thus, although the term "phase rotation" is used herein, the term cyclic shift is sometimes used with an implicit reference to the time domain.

The resource used by a PUCCH is therefore not only specified in the time–frequency domain by the resource-block pair, but also by the phase rotation applied. Similarly to the case of reference signals, there are up to 12 different phase rotations specified, providing up to 12 different orthogonal sequences from each cell-specific sequence. However, in the case of frequency-selective channels, not all the 12 phase rotations can be used if orthogonality is to be retained. Typically, up to six rotations are considered usable in a cell from a radio-propagation perspective, although inter-cell interference may result in a smaller number being useful from an overall system perspective. Higher-layer signaling is used to configure the number of rotations that is used in a cell.

As mentioned earlier, uplink L1/L2 control signaling includes hybrid-ARQ acknowledgements, channel-state reports, and scheduling requests. Different combinations of these types of messages are possible as described later, but to explain the structure for these cases it is beneficial to discuss separate transmission of each of the types first, starting with the hybrid-ARQ acknowledgement and the scheduling request. There are three formats defined for PUCCH, formats 1, 2, and 3, each capable of carrying a different number of bits.

11.4.1.1 PUCCH Format 1

Hybrid-ARQ acknowledgements are used to acknowledge the reception of one (or two in the case of spatial multiplexing) transport blocks on the DL-SCH. The hybrid-ARQ acknowledgement is only transmitted when the terminal correctly received control signaling related to DL-SCH transmission intended for this terminal on one of the PDCCHs. In the case of downlink carrier aggregation, there can be multiple simultaneous DL-SCHs for a single terminal, one per downlink component carrier and, consequently, multiple acknowledgement bits need to be conveyed in the uplink. This is described further below once the non-carrier-aggregated case has been treated.

If no valid DL-SCH-related control signaling is detected, then nothing is transmitted on the PUCCH (i.e. DTX). Apart from not unnecessarily occupying PUCCH resources that can be used for other purposes, this allows the eNodeB to perform three-state detection, ACK, NAK, or DTX, on the PUCCH received. Three-state detection is useful as NAK and DTX may need to be treated differently. In the case of NAK, retransmission of additional parity bits is useful for incremental redundancy, while for DTX the terminal has most likely missed the initial transmission of systematic bits and a better alternative than transmitting additional parity bits is to retransmit the systematic bits.

Scheduling requests are used to request resources for uplink data transmission. Obviously, a scheduling request should only be transmitted when the terminal is requesting resources, otherwise the terminal should be silent to save battery resources and not create unnecessary interference. Hence, unlike hybrid-ARQ acknowledgements, no explicit information bit is transmitted by the scheduling request; instead the information is conveyed by the presence (or absence) of energy on the corresponding PUCCH. However, the scheduling request, although used for a completely different purpose, shares the same PUCCH format as the hybrid-ARQ acknowledgement. This format is referred to as *PUCCH format 1* in the specifications.[14]

PUCCH format 1 uses the same structure in the two slots of a subframe, as illustrated in Figure 11.23. For transmission of a hybrid-ARQ acknowledgement, the single hybrid-ARQ acknowledgement bit related to one downlink component carrier is used to generate a BPSK symbol (in the case of downlink spatial multiplexing the two acknowledgement bits are used to generate a QPSK symbol). For a scheduling request, the same constellation point as for a negative acknowledgement is used. The modulation symbol is then used to generate the signal to be transmitted in each of the two PUCCH slots.

There are seven OFDM symbols per slot for a normal cyclic prefix (six in the case of an extended cyclic prefix). In each of those seven OFDM symbols, a length-12 sequence, obtained by phase rotation of the cell-specific sequence as described earlier, is transmitted. Three of the symbols are used

[14]There are actually three variants in the LTE specifications, formats 1, 1A, and 1B, used for transmission of scheduling requests and one or two hybrid-ARQ acknowledgements respectively. However, for simplicity, they are all referred to as format 1 herein.

Petitioners' Exhibit 1003, p. 588
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

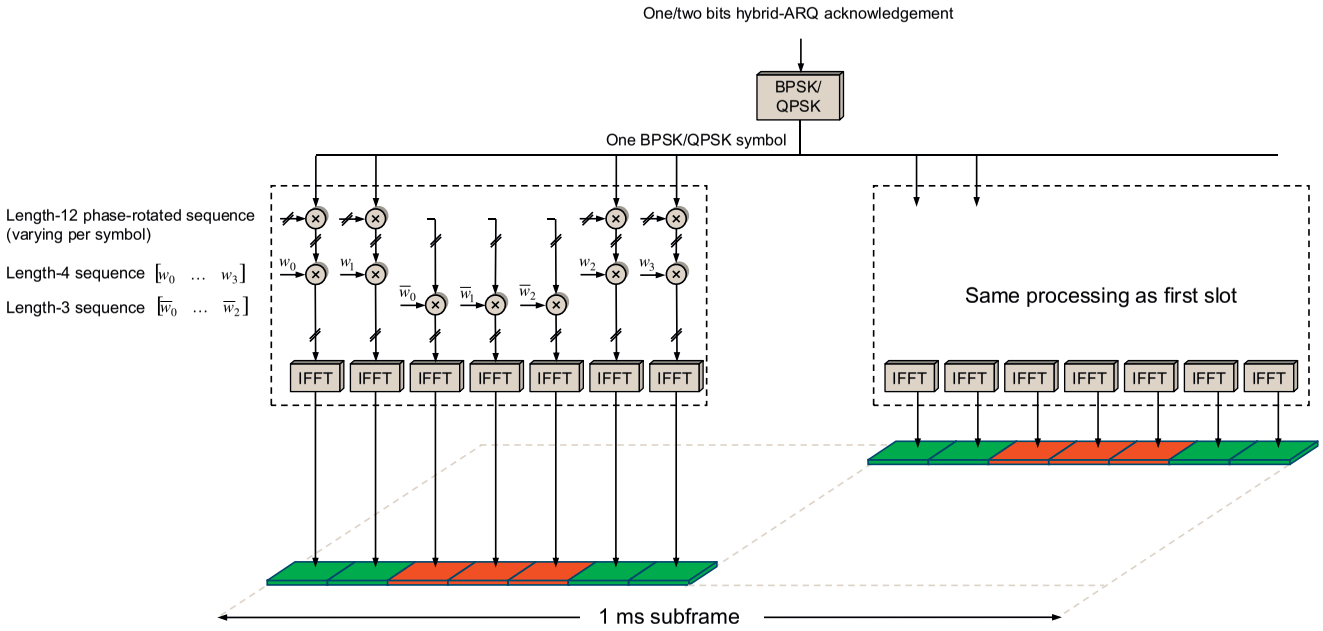


FIGURE 11.23

PUCCH format 1 (normal cyclic prefix).

as reference signals to enable channel estimation by the eNodeB and the remaining four[15] are modulated by the BPSK/QPSK symbols described earlier. In principle, the BPSK/QPSK modulation symbol could directly modulate the rotated length-12 sequence used to differentiate terminals transmitting on the same time–frequency resource. However, this would result in unnecessarily low capacity on the PUCCH. Therefore, the BPSK/QPSK symbol is multiplied by a length-4 orthogonal cover sequence.[16] Multiple terminals may transmit on the same time–frequency resource using the same phase-rotated sequence and be separated through different orthogonal covers. To be able to estimate the channels for the respective terminals, the reference signals also employ an orthogonal cover sequence, with the only difference being the length of the sequence – three for the case of a normal cyclic prefix. Thus, since each cell-specific sequence can be used for up to $3 \cdot 12 = 36$ different terminals (assuming all 12 rotations are available; typically at most six of them are used), there is a threefold improvement in the PUCCH capacity compared to the case of no cover sequence. The cover sequences are three Walsh sequences of length 4 for the data part and three DFT sequences of length 3 for the reference signals (for an extended cyclic prefix, the reference-signal cover sequence is of length 2).

A PUCCH format 1 resource, used for either a hybrid-ARQ acknowledgement or a scheduling request, is represented by a single scalar resource index. From the index, the phase rotation and the orthogonal cover sequence are derived.

The use of a phase rotation of a cell-specific sequence together with orthogonal sequences as described earlier provides orthogonality between different terminals in the same cell transmitting PUCCH on the same set of resource blocks. Hence, in the ideal case, there will be no intra-cell interference, which helps improve the performance. However, there will typically be inter-cell interference for the PUCCH as the different sequences used in neighboring cells are non-orthogonal. To randomize the inter-cell interference, the phase rotation of the sequence used in a cell varies on a symbol-by-symbol basis in a slot according to a hopping pattern derived from the physical-layer cell identity. On top of this, slot-level hopping is applied to the orthogonal cover and phase rotation to further randomize the interference. This is exemplified in Figure 11.24 assuming normal cyclic prefix and six of 12 rotations used for each cover sequence. To the phase rotation given by the cell-specific hopping a slot-specific offset is added. In cell A, a terminal is transmitting on PUCCH resource number 3, which in this example corresponds to using the (phase rotation, cover sequence) combination (6, 0) in the first slot and (11, 1) in the second slot of this particular subframe. PUCCH resource number 11, used by another terminal in cell A transmitting in the same subframe, corresponds to (11, 1) and (8, 2) in the first and second slots respectively of the subframe. In another cell the PUCCH resource numbers are mapped to different sets (rotation, cover sequence) in the slots. This helps to randomize the inter-cell interference.

For an extended cyclic prefix, the same structure as in Figure 11.23 is used, with the difference being the number of reference symbols in each slot. In this case, the six OFDM symbols in each slot are divided such that the two middle symbols are used for reference signals and the remaining four symbols used for the information. Thus, the length of the orthogonal sequence used to spread the

[15] The number of symbols used for reference signals and the acknowledgement is a trade-off between channel-estimation accuracy and energy in the information part; three symbols for reference symbols and four symbols for the acknowledgement have been found to be a good compromise.

[16] In the case of simultaneous SRS and PUCCH transmissions in the same subframe, a length-3 sequence is used, thereby making the last OFDM symbol in the subframe available for the sounding reference signal.

Petitioners' Exhibit 1003, p. 590
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Phase rotation [multiples of 2π/12]	Number of cover sequence					
	Even-numbered slot			Odd-numbered slot		
	0	1	2	0	1	2
0	0		12	12		16
1		6			14	
2	1		13	6		10
3		7			8	
4	2		14	0		4
5		8			2	
6	3		15	13		17
7		9			15	
8	4		16	7		11
9		10			9	
10	5		17	1		5
11		11			3	

Cell A

Phase rotation [multiples of 2π/12]	Number of cover sequence					
	Even-numbered slot			Odd-numbered slot		
	0	1	2	0	1	2
0		11			3	
1	0		12	12		16
2		6			14	
3	1		13	6		10
4		7			8	
5	2		14	0		4
6		8			2	
7	3		15	13		17
8		9			15	
9	4		16	7		11
10		10			9	
11	5		17	1		5

Cell B

FIGURE 11.24

Example of phase rotation and cover hopping for two PUCCH resource indices in two different cells.

reference symbols is reduced from 3 to 2 and the multiplexing capacity is lower. However, the general principles described above still apply.

As mentioned earlier, a PUCCH resource can be represented by an index. For a hybrid-ARQ acknowledgement, the resource index to use is given as a function of the first CCE in the PDCCH used to schedule the downlink transmission to the terminal. In this way, there is no need to explicitly include information about the PUCCH resources in the downlink scheduling assignment, which of course reduces overhead. Furthermore, as described in Chapter 12, hybrid-ARQ acknowledgements are transmitted a fixed time after the reception of a DL-SCH transport block and when to expect a hybrid ARQ on the PUCCH is therefore known to the eNodeB.

In addition to dynamic scheduling by using the PDCCH, there is also, as described in Chapter 13, the possibility to semi-persistently schedule a terminal according to a specific pattern. In this case there is no PDCCH to derive the PUCCH resource index from. Instead, the configuration of the semi-persistent scheduling pattern includes information on the PUCCH index to use for the hybrid-ARQ acknowledgement. In either of these two cases, a terminal is using PUCCH resources only when it has been scheduled in the downlink. Thus, the amount of PUCCH resources required for hybrid-ARQ acknowledgements does not necessarily increase with an increasing number of terminals in the cell, but, for dynamic scheduling, is rather related to the number of CCEs in the downlink control signaling.

The description above was mainly concerned with the case of downlink carrier aggregation not being used. For downlink carrier aggregation, there can be multiple simultaneous DL-SCHs scheduled for a single terminal, one per downlink component carrier and, consequently, multiple acknowledgement bits need to be conveyed in the uplink (one, or two in the case of spatial multiplexing, per

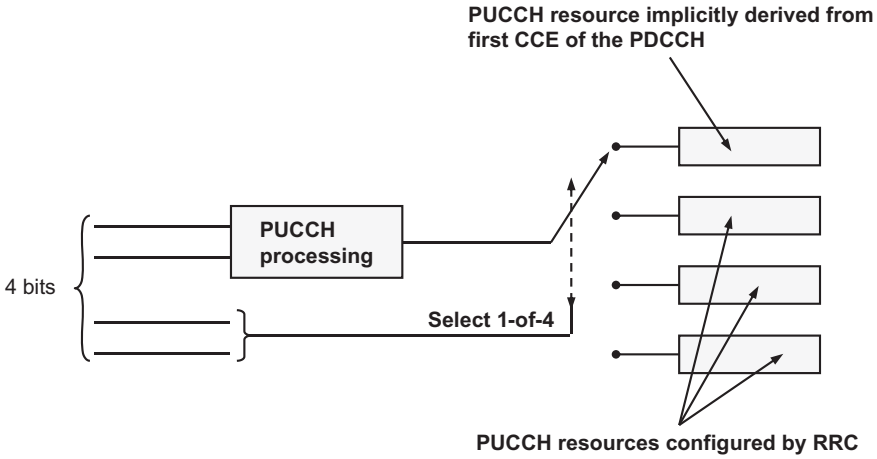


FIGURE 11.25

Resource selection for carrier aggregation.

downlink component carrier). PUCCH format 1 can be used to support more than two bits in the uplink by using resource selection. Assume four bits are to be transmitted in the uplink. With resource selection, two bits indicate which PUCCH resource to use while the remaining two bits are transmitted using the normal PUCCH structure but on the resource pointed to by the first two bits. This is illustrated in Figure 11.25. In total, four PUCCH resources are needed. One resource is derived from the first CCE using the same rule as in the absence of carrier aggregation (assuming that the scheduling assignment is transmitted on, and relating to, the primary component carrier). The remaining resources are semi-statically configured by RRC signaling.

For more than four bits, resource selection is less efficient and PUCCH format 3, described in a subsequent section, was therefore introduced in LTE release 10 in conjunction with carrier aggregation.

Unlike the hybrid-ARQ acknowledgements, whose occurrence is known to the eNodeB from the downlink scheduling decisions, the need for uplink resources for a certain terminal is in principle unpredictable by the eNodeB. One way to handle this would be to have a contention-based mechanism for requesting uplink resources. The random-access mechanism is based on this principle and can, to some extent, also be used for scheduling requests, as discussed in Chapter 13. Contention-based mechanisms typically work well for low intensities, but for higher scheduling-request intensities, the collision rate between different terminals simultaneously requesting resources becomes too large. Therefore, LTE provides a contention-free scheduling-request mechanism on the PUCCH, where each terminal in the cell is given a reserved resource on which it can transmit a request for uplink resources. The contention-free resource is represented by a PUCCH resource index as described earlier, occurring at every *n*th subframe. The more frequently these time instants occur, the lower the scheduling-request delay at the cost of higher PUCCH resource consumption. As the eNodeB configures all the terminals in the cell, when and on which resources a terminal can request resources is known to the eNodeB. A single scheduling request resource is also sufficient for the case

Petitioners' Exhibit 1003, p. 592
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

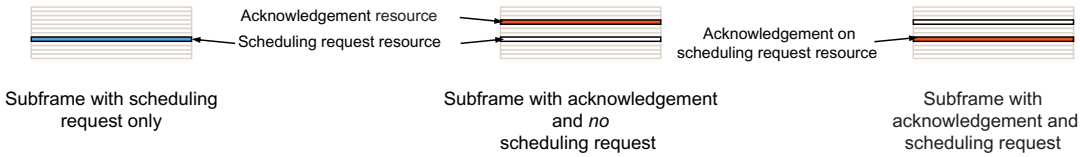


FIGURE 11.26

Multiplexing of scheduling request and hybrid-ARQ acknowledgement from a single terminal.

of carrier aggregation, as it only represents a request for uplink resources, which is independent of whether carrier aggregation is used or not.

The discussion earlier has considered transmission of *either* a hybrid-ARQ acknowledgement *or* a scheduling request. However, there are situations when the terminal needs to transmit *both* of them. In such a situation, the hybrid-ARQ acknowledgement is transmitted on the scheduling-request resource (see Figure 11.26). This is possible as the same PUCCH structure is used for both of them and the scheduling request carries no explicit information. By comparing the amount of energy detected on the acknowledgement resource and the scheduling-request resource for a specific terminal, the eNodeB can determine whether the terminal is requesting resources or not. Once the resource used for transmission of the acknowledgement is detected, the hybrid-ARQ acknowledgement can be decoded. Other, more advanced methods jointly decoding hybrid ARQ and scheduling request can also be envisioned.

11.4.1.2 PUCCH Format 2

Channel-state reports, the contents of which are discussed in Chapter 13, are used to provide the eNodeB with an estimate of the channel properties as seen from the terminal to aid channel-dependent scheduling. A channel-state report consists of multiple bits transmitted in one subframe. PUCCH format 1, which is capable of at most two bits of information per subframe, obviously cannot be used for this purpose. Transmission of channel-state reports on the PUCCH is instead handled by PUCCH format 2, which is capable of multiple information bits per subframe.[17]

PUCCH format 2, illustrated for a normal cyclic prefix in Figure 11.27, is based on a phase rotation of the same cell-specific sequence as format 1. After block coding using a punctured Reed–Müller code and QPSK modulation of the channel-state information, there are 10 QPSK symbols to transmit in the subframe: the first five symbols are transmitted in the first slot and the remaining five in the last slot.

Assuming a normal cyclic prefix, there are seven OFDM symbols per slot. Of the seven OFDM symbols in each slot, two[18] are used for reference-signal transmission to allow coherent demodulation at the eNodeB. In the remaining five, the respective QPSK symbol to be transmitted is multiplied

[17] There are actually three variants in the LTE specifications, formats 2, 2A, and 2B, where the last two formats are used for simultaneous transmission of channel-state reports and hybrid-ARQ acknowledgements, as discussed later in this section. However, for simplicity, they are all referred to as format 2 herein.

[18] Similarly to format 1, the number of symbols used for reference signals and the coded channel-quality information is a trade-off between channel-estimation accuracy and energy in the information part. Two symbols for reference symbols and five symbols for the coded information part in each slot were found to be the best compromise.

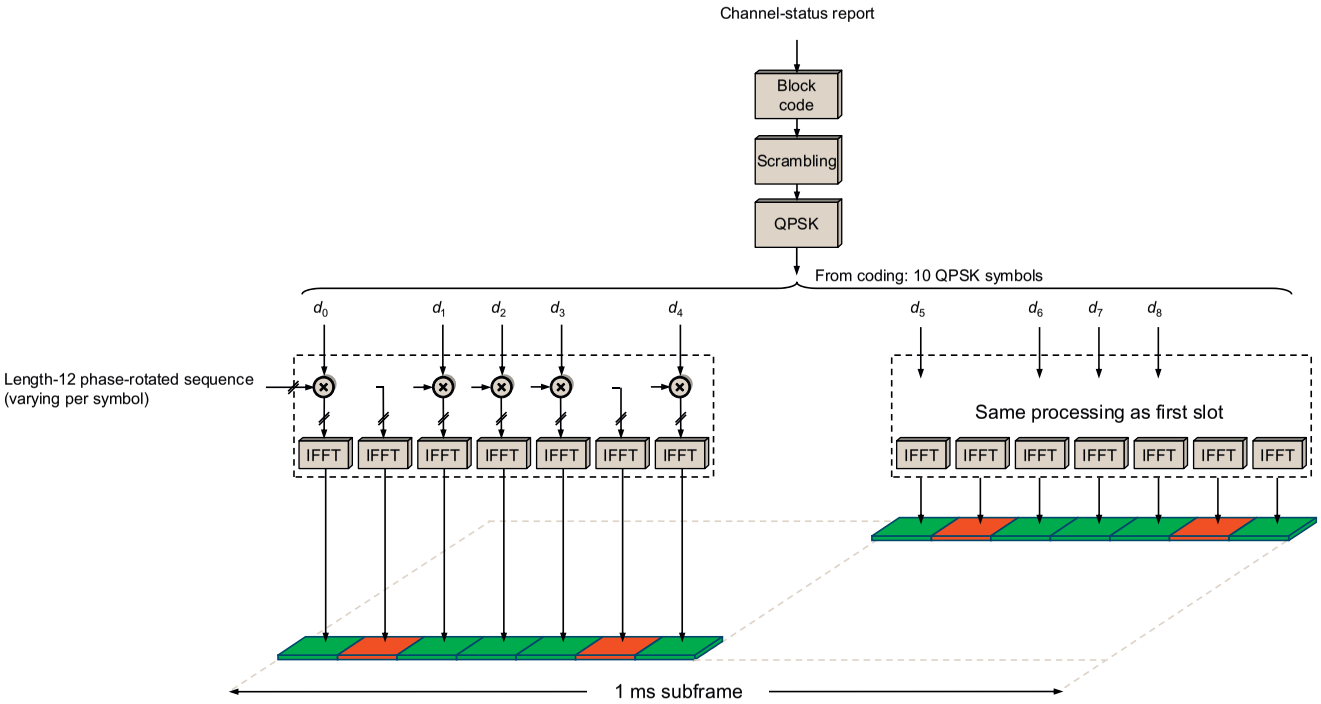


FIGURE 11.27

PUCCH format 2 (normal cyclic prefix).

by a phase-rotated length-12 cell-specific sequence and the result is transmitted in the corresponding OFDM symbol. For an extended cyclic prefix, where there are six OFDM symbols per slot, the same structure is used but with one reference-signal symbol per slot instead of two.

Basing the format 2 structure on phase rotations of the same cell-specific sequence as format 1 is beneficial as it allows the two formats to be transmitted in the same resource block. As phase-rotated sequences are orthogonal, one rotated sequence in the cell can be used either for one PUCCH instance using format 2 or three PUCCH instances using format 1. Thus, the "resource consumption" of one channel-state report is equivalent to three hybrid-ARQ acknowledgements (assuming normal cyclic prefix). Note that no orthogonal cover sequences are used for format 2.

The rotation angles to use in the different symbols for PUCCH format 2 are hopping in a similar way as for format 1, motivated by interference randomization. Resources for PUCCH format 2 can, similar to format 1, be represented by a scalar index, which can be seen as a "channel number" and higher-layer signaling is used to configure each terminal with a resource to transmit its channel-state report on, as well as when those reports should be transmitted. Hence, the eNodeB has full knowledge of when and on which resources each of the terminals will transmit channel-state reports on PUCCH. The channel-state reports on PUCCH are also known as *periodic* reports; as will be discussed later, there are also *aperiodic* reports but those reports can only be transmitted on PUSCH.

Periodic CSI reports in combination with carrier aggregation are provided for by transmitting multiple periodic reports, one per component carrier, offset in time such that reports for two different component carriers do not collide.

11.4.1.3 PUCCH Format 3

For downlink carrier aggregation, multiple hybrid-ARQ acknowledgement bits need to be fed back in the case of simultaneous transmission on multiple component carriers. As discussed above, PUCCH format 1 in combination with resource selection can be used, but for more than four bits this is not an efficient solution from a performance perspective. To enable the possibility of transmitting more than four bits in an efficient way, PUCCH format 3 can be used. A terminal capable of more than two downlink component carriers – that is, capable of more than fours bits for hybrid-ARQ acknowledgements – needs to support PUCCH format 3. For such a terminal, PUCCH format 3 can also be used for less than four bits of feedback relating to simultaneous transmission on multiple component carriers if configured by higher-layer signaling not to use PUCCH format 1 with resource selection.

The basis for PUCCH format 3, illustrated in Figure 11.28, is DFT-precoded OFDM – that is, the same transmission scheme as used for UL-SCH. The acknowledgement bits, one or two per downlink component carrier depending on the transmission mode configured for that particular component carrier, are concatenated with a scheduling request bit (if present) into a sequence of bits where bits corresponding to unscheduled transport blocks are set to zero. Block coding is applied,[19] followed by scrambling using a cell-specific scrambling sequence to randomize inter-cell interference. The resulting 48 bits are QPSK-modulated and divided into two groups, one per slot, of 12 QPSK symbols each.

Assuming a normal cyclic prefix, there are seven OFDM symbols per slot. Similarly to PUCCH format 2, two OFDM symbols (one in the case of an extended cyclic prefix) in each slot are used for reference signal transmission, leaving five symbols for data transmission. In each slot, the block of 12 DFT-precoded QPSK symbols is transmitted in the five available DFTS-OFDM symbols. To further

[19] A (32, k) Reed–Müller code is used, but for 12 or more bits in TDD two Reed–Müller codes are used in combination.

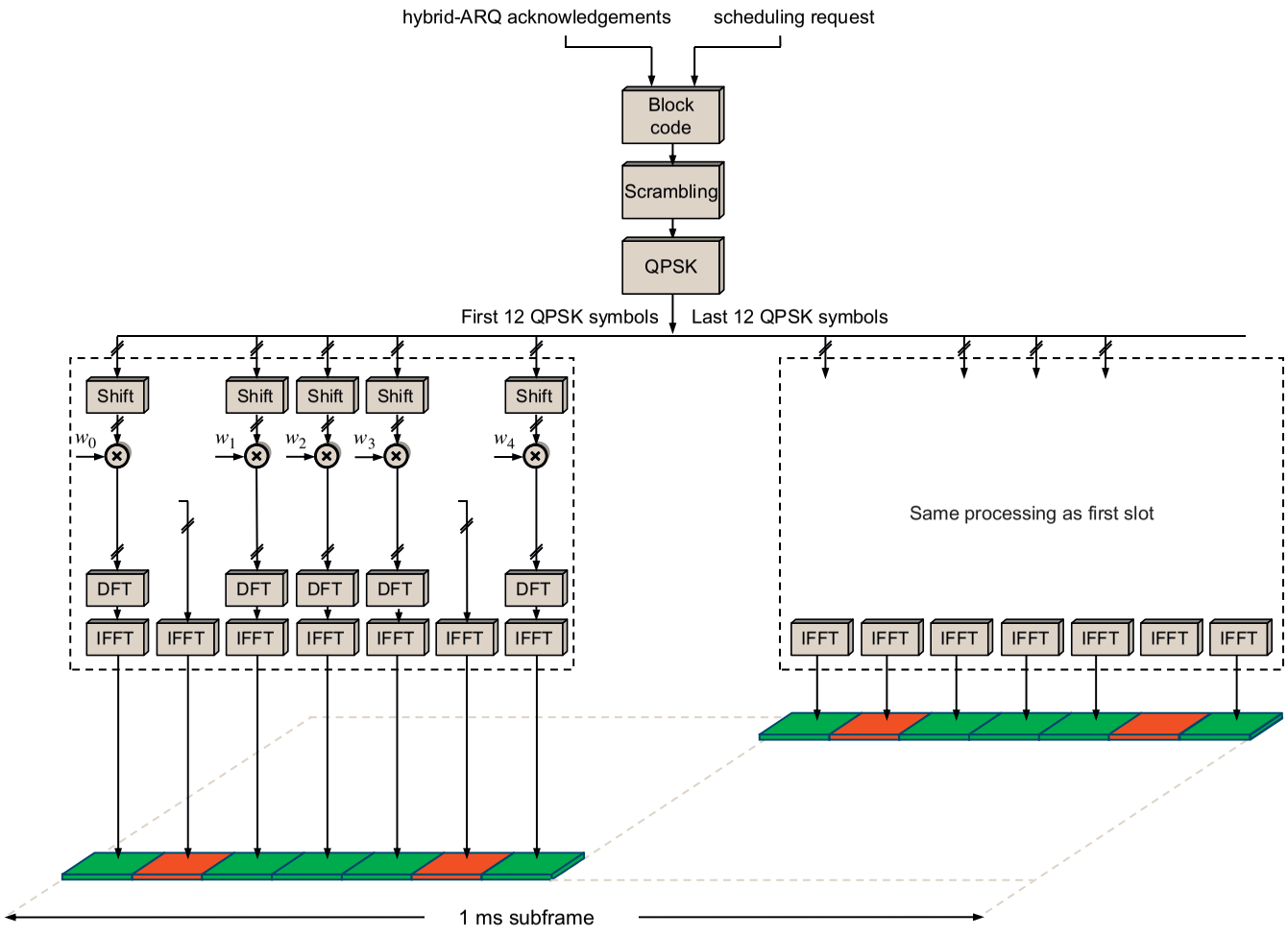


FIGURE 11.28

PUCCH format 3 (normal cyclic prefix).

Petitioners' Exhibit 1003, p. 596
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

randomize the inter-cell interference, a cyclic shift of the 12 inputs to the DFT, varying between OFDM symbols in a cell-specific manner, is applied to the block of 12 QPSK symbols prior to DFT precoding.

To increase the multiplexing capacity, a length-5 orthogonal sequence is used with each of the five OFDM symbol carrying data in a slot being multiplied by one element of the sequence. Thus, up to five terminals may share the same resource-block pair for PUCCH format 3. Different length-5 sequences are used in the two slots to improve the performance in high-Doppler scenarios. To facilitate channel estimation for the different transmissions sharing the same resource block, different reference-signal sequences are used.

The length-5 orthogonal cover sequences are obtained as five DFT sequences. There is also the possibility to use a length-4 Walsh sequence for the second slot in order to leave the last OFDM symbol unused for the case when sounding is configured in the subframe.

In the same manner as for the other two PUCCH formats, a resource can be represented by a single index from which the orthogonal sequence and the resource-block number can be derived. A terminal can be configured with four different resources for PUCCH format 3. In the scheduling grant for a secondary carrier, two bits[20] inform the terminal which of the four resources to use. In this was, the scheduler can avoid PUCCH collisions between different terminals by assigning them to different resources.

Note that, due to the differences in the underlying structure of PUCCH format 3 compared to the other two formats, resource blocks cannot be shared between format 3 and the other two formats.

11.4.1.4 Simultaneous Transmission of Multiple Feedback Reports

The above description has focused on transmission of hybrid-ARQ acknowledgements or channel-state reports alone. However, there is also a need to handle the case when hybrid ARQ or scheduling requests need to be transmitted in the same subframe. Transmitting multiple PUCCHs simultaneously from the same terminal would increase the cubic metric. Therefore, a single PUCCH structure supporting simultaneous transmission of multiple feedback signals is used.

In principle, the following four situations requiring simultaneous transmission of multiple feedback signals from a single terminal can be envisioned:

1. *Hybrid-ARQ acknowledgement and scheduling request*. For PUCCH format 1, this is supported by transmitting the hybrid-ARQ acknowledgement on the scheduling-request resource as described earlier. For PUCCH format 3, the transmission structure supports inclusion of a scheduling-request bit.
2. *Scheduling request and channel-state report*. The eNodeB is in control of when a terminal may transmit a scheduling request and when the terminal should report the channel state. Hence, this situation can be avoided by proper configuration, but if this is not done the terminal drops the channel-state report and transmits the scheduling request only. Missing a channel-state report is not detrimental and only incurs some degradation in the scheduling and rate-adaptation accuracy, whereas the scheduling request is critical for uplink transmissions.

[20]The power control bits in an assignment relating to a secondary component carrier are reinterpreted as an *acknowledgement resource indicator* (ARI) – see Chapter 10.

3. *Scheduling request, hybrid-ARQ acknowledgement, and channel-state report*. This is similar to the previous situation; the channel-state report is dropped and multiplexing of hybrid ARQ and scheduling request is handled as described in point 1 above.
4. *Hybrid-ARQ acknowledgement and channel-state report*. Simultaneous transmission of acknowledgement and channel-state report from the same terminal is possible, as described below. There is also the possibility to configure the terminal to drop the channel-state report and only transmit the acknowledgement. In the case of carrier aggregation, the channel-state report is always dropped if it happens to collide with PUCCH format 3.

Transmission of data in the downlink implies transmission of hybrid-ARQ acknowledgements in the uplink. At the same time, since data is transmitted in the downlink, up-to-date channel-state reports are beneficial to optimize the downlink transmissions. Hence, simultaneous transmission of hybrid-ARQ acknowledgements and channel-state reports is supported by LTE. The basis is PUCCH format 2 as described earlier for both normal and extended cyclic prefixes, although the detailed solution differs between the two.

For a normal cyclic prefix, each slot in PUCCH format 2 has two OFDM symbols used for reference signals. When transmitting a hybrid-ARQ acknowledgement at the same time as a channel-state report, the second reference signal in each slot is modulated by the acknowledgement, as illustrated in Figure 11.29a. Either BPSK or QPSK is used, depending on whether one or two acknowledgement bits are to be fed back. The fact that the acknowledgement is superimposed on the reference signal needs to be accounted for at the eNodeB. One possibility is to decode the acknowledgement bit(s) modulated on to the second reference symbol using the first reference symbol for channel estimation. Once the acknowledgement bit(s) have been decoded, the modulation imposed on the second reference symbol can be removed and channel estimation and decoding of the channel-state report can be handled in the same way as in the absence of simultaneous hybrid-ARQ acknowledgement. This two-step approach works well for low to medium Doppler frequencies; for higher Doppler frequencies the acknowledgement and channel-state reports are preferably decoded jointly.

For an extended cyclic prefix, there is only a single reference symbol per slot. Hence, it is not possible to overlay the hybrid-ARQ acknowledgement on the reference symbol. Instead, the acknowledgement bit(s) are jointly coded with the channel-state report prior to transmission using PUCCH format 2, as illustrated in Figure 11.29b.

The time instances when to expect channel-state reports and hybrid-ARQ acknowledgements are known to the eNodeB, which therefore knows whether to expect a hybrid-ARQ acknowledgement along with the channel-state report or not. If the PDCCH assignment is missed by the terminal, then only the channel-state report will be transmitted as the terminal is not aware that it has been scheduled. In the absence of a simultaneous channel-state report, the eNodeB can employ DTX detection to discriminate between a missed assignment and a failed decoding of downlink data. However, one consequence of the structures above is that DTX detection is cumbersome, if not impossible. This implies that incremental redundancy needs to be operated with some care if the eNodeB has scheduled data such that the acknowledgement occurs at the same time as a channel-state report. As the terminal may have missed the original transmission attempt in the downlink, it may be preferable for the eNodeB to select the redundancy version of the retransmission such that systematic bits are also included in the retransmission.

Petitioners' Exhibit 1003, p. 598
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

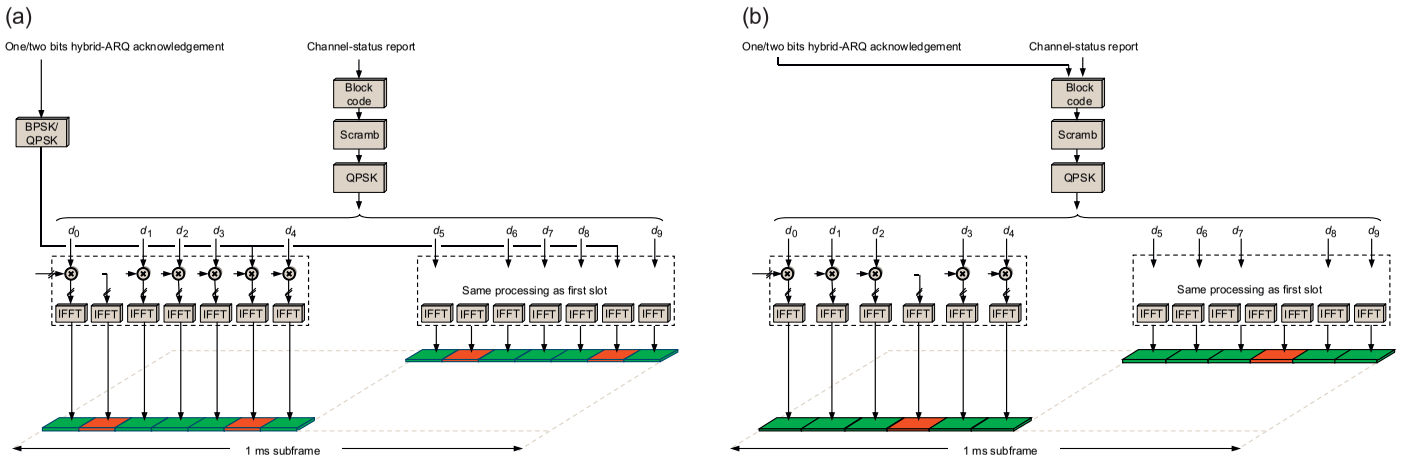


FIGURE 11.29

Simultaneous transmission of channel-state reports and hybrid-ARQ acknowledgements. (a) Normal cyclic prefix. (b) Extended cyclic prefix.

One possibility to circumvent this is to configure the terminal to drop the channel-state report in the case of simultaneous transmission of a hybrid-ARQ acknowledgement. In this case, the eNodeB can detect DTX as the acknowledgement can be transmitted using PUCCH format 1, as described earlier. Obviously, there will be no channel-state report sent in this case, which needs to be taken into account in the scheduling process. Dropping the channel-state report can also be useful for handling coverage-limited situations when the available transmission power is insufficient for a channel-state report in addition to the acknowledgement.

11.4.1.5 Resource-Block Mapping for PUCCH

The signals described above for all three of the PUCCH formats are, as already explained, transmitted on a resource-block pair with one resource block in each slot. The resource-block pair to use is determined from the PUCCH resource index. Multiple resource-block pairs can be used to increase the control-signaling capacity; when one resource-block pair is full, the next PUCCH resource index is mapped to the next resource-block pair in sequence. The mapping is in principle done such that PUCCH format 2 (channel-state reports) is transmitted closest to the edges of the uplink cell bandwidth with PUCCH format 1 (hybrid-ARQ acknowledgements, scheduling requests) next, as illustrated in Figure 11.30. The location of PUCCH format 3 is configurable and it can, for example, be located between formats 1 and 2. A semi-static parameter, provided as part of the system information, controls on which resource-block pair the mapping of PUCCH format 1 starts. Furthermore, the semi-statically configured scheduling requests are located at the outermost parts of the format 1 resources. As the amount of resources necessary for hybrid-ARQ acknowledgements varies dynamically, this maximizes the amount of contiguous spectrum available for PUSCH.

In many scenarios, the configuration of the PUCCH resources can be done such that the three PUCCH formats are transmitted on separate sets of resource blocks. However, for the smallest cell bandwidths, this would result in too high an overhead. Therefore, it is possible to mix the first two PUCCH formats in one of the resource-block pairs – for example, in Figure 11.30 this is the case for the resource with index 2. Although this mixture is primarily motivated by the smaller cell bandwidths, it can equally well be used for the larger cell bandwidths. In the resource-block pair where PUCCH formats 1 and 2 are mixed, the rotation angles are divided between the two formats. Furthermore,

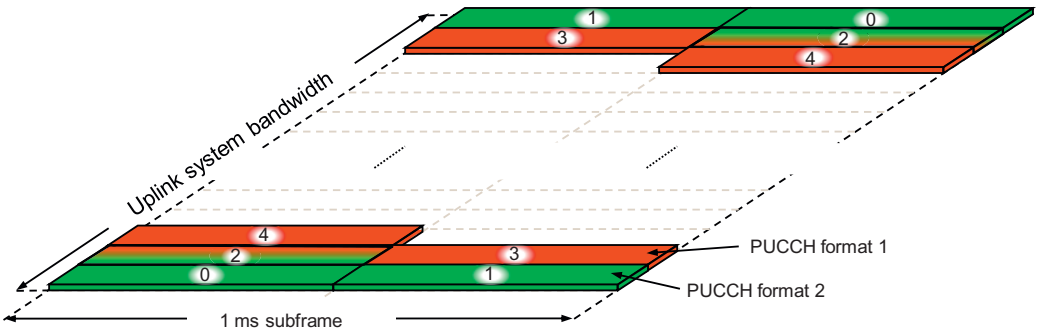


FIGURE 11.30

Allocation of resource blocks for PUCCH.

some of the phase rotations are reserved as "guard"; hence the efficiency of such a mixed resource-block pair is slightly lower than a resource-block pair carrying only one of the first two PUCCH formats.

11.4.2 Uplink L1/L2 Control Signaling on PUSCH

If the terminal is transmitting data on PUSCH – that is, has a valid scheduling grant in the subframe – control signaling is time multiplexed[21] with data on the PUSCH instead of using the PUCCH (in release 10, simultaneous PUSCH and PUCCH can be used). Only hybrid-ARQ acknowledgements and channel-state reports are transmitted on the PUSCH. Obviously there is no need to request a scheduling grant when the terminal is already scheduled; instead, in-band buffer-status reports are sent as part of the MAC headers, as described in Chapter 12.

Time multiplexing of channel-state reports and hybrid-ARQ acknowledgements is illustrated in Figure 11.31. However, although they both use time multiplexing there are some differences in the details for the two types of uplink L1/L2 control signaling motivated by their different properties.

The hybrid-ARQ acknowledgement is important for proper operation of the downlink. For one and two acknowledgements, robust QPSK modulation is used, regardless of the modulation scheme used for the data, while for a larger number of bits the same modulation scheme as for the data is used. Furthermore, the hybrid-ARQ acknowledgement is transmitted near to the reference symbols as the channel estimates are of better quality close to the reference symbols. This is especially important at high Doppler frequencies, where the channel may vary during a slot. Unlike the data part, the hybrid-ARQ acknowledgement cannot rely on retransmissions and strong channel coding to handle these variations.

In principle, the eNodeB knows when to expect a hybrid-ARQ acknowledgement from the terminal and can therefore perform the appropriate demultiplexing of the acknowledgement and the data part. However, there is a certain probability that the terminal has missed the scheduling assignment on the PDCCH, in which case the eNodeB will expect a hybrid-ARQ acknowledgement while the terminal will not transmit one. If the rate-matching pattern were to depend on whether an acknowledgement is transmitted or not, all the coded bits transmitted in the data part could be affected by a missed PDCCH assignment, which is likely to cause the UL-SCH decoding to fail. To avoid this error, the hybrid-ARQ acknowledgements are therefore punctured into the coded UL-SCH bit stream. Thus, the non-punctured bits are not affected by the presence/absence of hybrid-ARQ acknowledgements and the problem of a mismatch between the rate matching in the terminal and the eNodeB is avoided.

The contents of the channel-state reports is described in Chapter 12; at this stage it suffices to note that a channel-state report consists of *Channel-Quality Indicator* (CQI), *Precoding Matrix Indicator* (PMI), and *Rank Indicator* (RI). The CQI and PMI are time multiplexed with the coded data bits from PUSCH and transmitted using the same modulation as the data part. Channel-state reports are mainly useful for low-to-medium Doppler frequencies for which the radio channel is relatively constant, hence the need for special mapping is less pronounced. The RI, however, is mapped differently than the CQI and PMI; as illustrated in Figure 11.31, the RI is located near to the reference symbols using a similar mapping as the hybrid-ARQ acknowledgements. The more robust mapping of

[21] In the case of spatial multiplexing, the CQI/PMI is time multiplexed with one of the codewords, implying that it is spatially multiplexed with the other codeword.

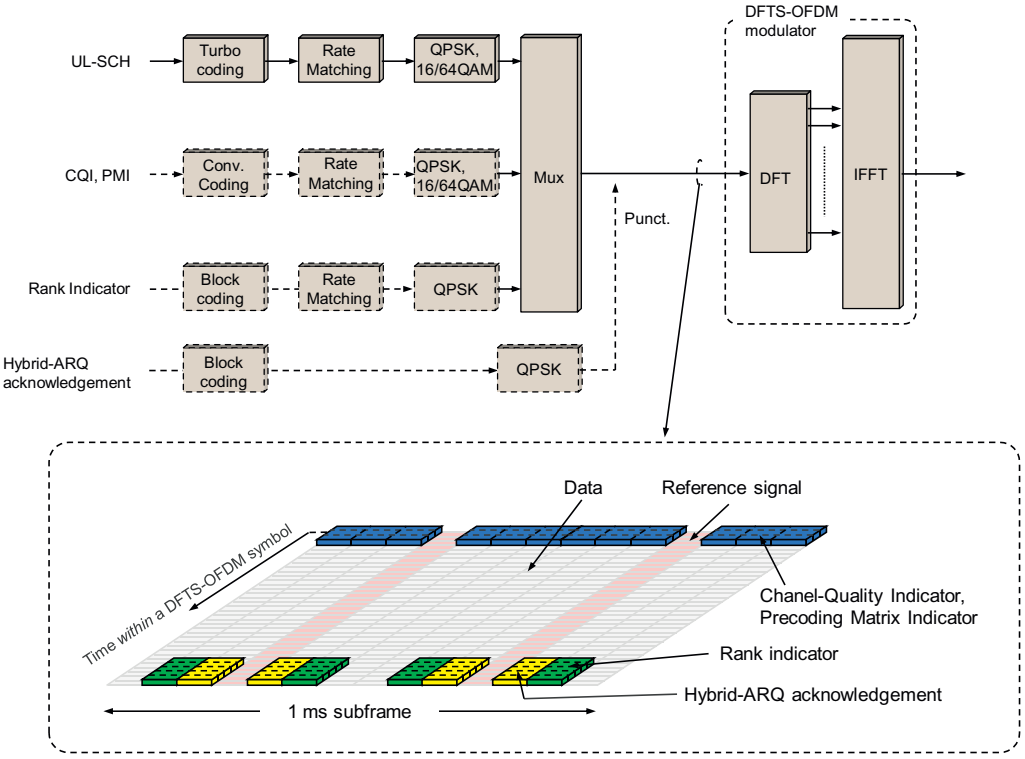


FIGURE 11.31

Multiplexing of control and data on to PUSCH. Note that there are *two* time dimensions and no frequency dimension in the "grid" at the bottom, the reason being that the signal prior to DFT precoding is illustrated. The acknowledgement (and the RI) will thus be located near but not as close as possible to the reference signal as possible as the "grid" is read column by column.

the RI is motivated by the fact that the RI is required in order to correctly interpret the CQI/PMI. The CQI/PMI, on the other hand, is simply mapped across the full subframe duration. Modulation-wise, the RI is handled in the same way as the hybrid-ARQ acknowledgements.

For uplink spatial multiplexing, in which case two transport blocks are transmitted simultaneously on the PUSCH, the CQI and PMI are multiplexed with the coded transport block using the highest modulation-and-coding scheme, followed by applying the multiplexing scheme described above per layer (Figure 11.32). The intention behind this approach is to transmit the CQI and PMI on the (one or two) layers with the best quality.[22]

The hybrid-ARQ acknowledgements and the rank indicator are replicated across all transmission layers and multiplexed with the coded data in each layer in the same way as the single layer case

[22]Assuming the MCS follows the channel quality, this holds for one, two, and four layers but not necessarily for three layers.

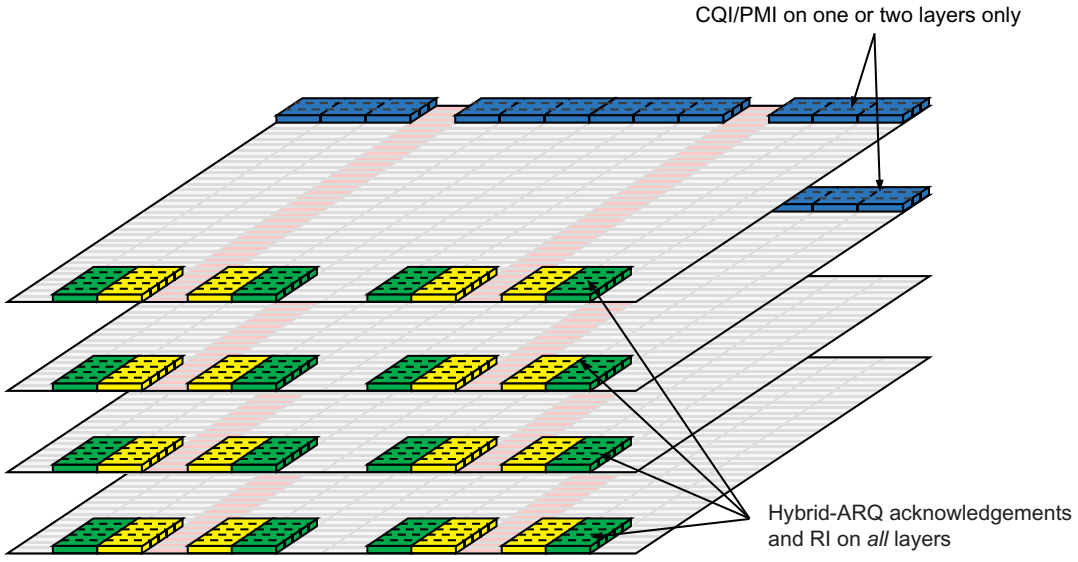


FIGURE 11.32

Multiplexing of CQI/PMI, RI, and hybrid-ARQ acknowledgements in the case of uplink spatial multiplexing.

described above. The bits may, though, have been scrambled differently on the different layers. In essence, as the same information is transmitted on multiple layers with different scrambling, this provides diversity.

The basis for channel-state reports on the PUSCH is *aperiodic reports*, where the eNodeB requests a channel-state report from the terminal by setting the CSI request bit in the scheduling grant, as mentioned in Chapter 10. UL-SCH rate matching takes the presence of the channel-state reports into account; by using a higher code rate a suitable number of resource elements is made available for transmission of the channel-state report. Since the reports are explicitly requested by the eNodeB, their presence is known and the appropriate rate de-matching can be done at the receiver. If one of the configured transmission instances for a periodic report coincides with the terminal being scheduled on the PUSCH, the periodic report is "rerouted" and transmitted on the PUSCH resources. Also, in this case there is no risk of mismatch in rate matching; the transmission instants for periodic reports are configured by robust RRC signaling and the eNodeB knows in which subframes such reports will be transmitted.

The channel coding of the channel-state reports depends on the report size. For the smaller sizes such as a periodic report that otherwise would have been transmitted on the PUCCH, the same block coding as used for the PUCCH reports is used. For the larger reports, a tail-biting convolutional code is used for CQI/PMI, whereas the RI uses a (3, 2) block code for a single component carrier.

Unlike the data part, which relies on rate adaptation to handle different radio conditions, this cannot be used for the L1/L2 control-signaling part. Power control could, in principle, be used as an alternative, but this would imply rapid power variations in the time domain, which negatively impact

the RF properties. Therefore, the transmission power is kept constant over the subframe and the amount of resource elements allocated to L1/L2 control signaling – that is, the code rate of the control signaling – is varied according to the scheduling decision for the data of the data part. High data rates are typically scheduled when the radio conditions are advantageous and hence a smaller amount of resource needs to be used by the L1/L2 control signaling compared to the case of poor radio conditions. To account for different hybrid-ARQ operating points, an offset between the code rate for the control-signaling part and the modulation-and-coding scheme used for the data part can be configured via higher-layer signaling.

For carrier aggregation, control signaling is time multiplexed on one uplink component carrier only – that is, uplink control information cannot be split across multiple uplink component carriers. Apart from the aperiodic CSI reports, which are transmitted upon the component carrier that triggered the report, the primary component carrier is used for uplink control signaling if scheduled in the same subframe, otherwise one of the secondary component carriers is used.

11.5 UPLINK TIMING ALIGNMENT

The LTE uplink allows for uplink intra-cell orthogonality, implying that uplink transmissions received from different terminals within a cell do not cause interference to each other. A requirement for this *uplink orthogonality* to hold is that the signals transmitted from different terminals within the same subframe but within different frequency resources (different resource blocks) arrive approximately time aligned at the base station. More specifically, any timing misalignment between received signals received should fall within the cyclic prefix. To ensure such receiver-side time alignment, LTE includes a mechanism for *transmit-timing advance*.

In essence, timing advance is a negative offset, at the terminal, between the start of a received downlink subframe and a transmitted uplink subframe. By controlling the offset appropriately for each terminal, the network can control the timing of the signals received at the base station from the terminals. Terminals far from the base station encounter a larger propagation delay and therefore need to start their uplink transmissions somewhat in advance, compared to terminals closer to the base station, as illustrated in Figure 11.33. In this specific example, the first terminal is located close to the base station and experiences a small propagation delay, $T_{P,1}$. Thus, for this terminal, a small value of the timing advance offset $T_{A,1}$ is sufficient to compensate for the propagation delay and to ensure the correct timing at the base station. However, a larger value of the timing advance is required for the second terminal, which is located at a larger distance from the base station and thus experiences a larger propagation delay.

The timing-advance value for each terminal is determined by the network based on measurements on the respective uplink transmissions. Hence, as long as a terminal carries out uplink data transmission, this can be used by the receiving base station to estimate the uplink receive timing and thus be a source for the timing-advance commands. Sounding reference signals can be used as a regular signal to measure upon, but in principle the base station can use any signal transmitted from the terminals.

Based on the uplink measurements, the network determines the required timing correction for each terminal. If the timing of a specific terminal needs correction, the network issues a timing-advance command for this specific terminal, instructing it to retard or advance its timing relative

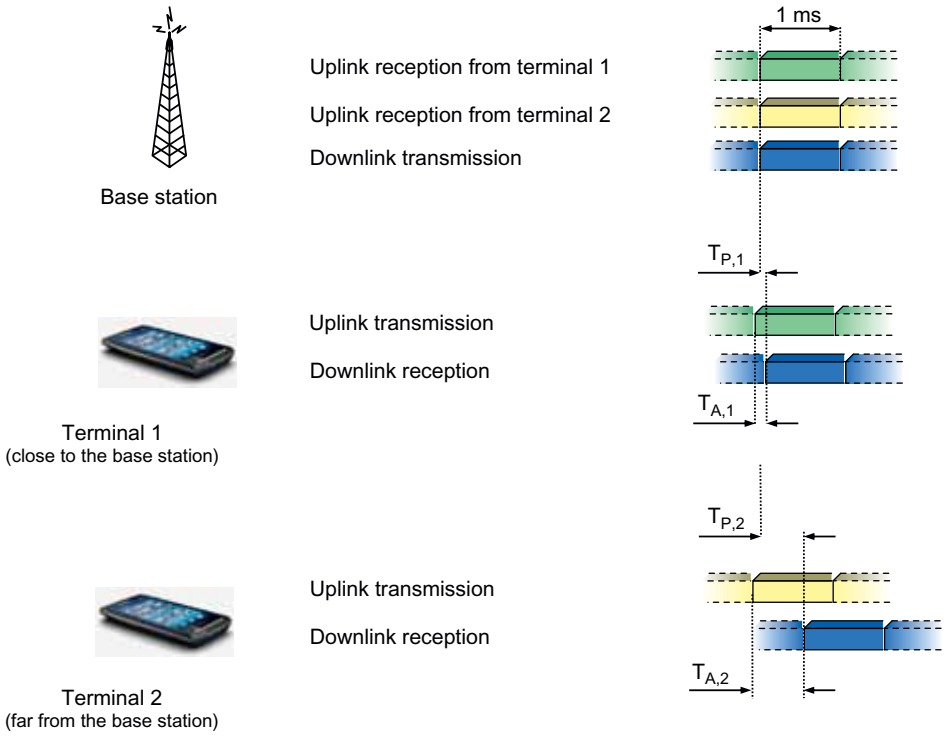


FIGURE 11.33

Uplink timing advance.

to the current uplink timing. The user-specific timing-advance command is transmitted as a MAC control element (see Chapter 8 for a description of MAC control elements) on the DL-SCH. The maximum value possible for timing advance is 0.67 ms, corresponding to a terminal-to-base-station distance of slightly more than 100 km. This is also the value assumed when determining the processing time for decoding, as discussed in Section 12.1. Typically, timing-advance commands to a terminal are transmitted relatively infrequently – for example, one or a few times per second.

If the terminal has not received a timing-advance command during a (configurable) period, the terminal assumes it has lost the uplink synchronization. In this case, the terminal must re-establish uplink timing using the random-access procedure prior to any PUSCH or PUCCH transmission in the uplink.

For carrier aggregation, there may be multiple component carriers transmitted from a single terminal. In principle, different timing advance commands for different component carriers could be envisioned. One motivation for this could be inter-band carrier aggregation, where the different component carriers are received at different geographical locations, for example by using remote radio heads for some of the bands but not others. However, such deployments are not common and in the interest of simplicity LTE is using a single timing-advance command valid for all uplink component carriers.

CHAPTER

Retransmission Protocols 12

The LTE downlink and uplink transmission schemes have been described from a physical layer perspective in Chapters 10 and 11 respectively. In this chapter, the operation of the two mechanisms responsible for retransmission handling in LTE, the MAC and RLC sublayers, will be described.

Retransmissions of missing or erroneous data units are handled primarily by the hybrid-ARQ mechanism in the MAC layer, complemented by the retransmission functionality of the RLC protocol. The reasons for having a two-level retransmission structure can be found in the trade-off between fast and reliable feedback of the status reports. The hybrid-ARQ mechanism targets very fast retransmissions and, consequently, feedback on success or failure of the decoding attempt is provided to the transmitter after each received transport block. Although it is in principle possible to attain an arbitrarily low error probability of the hybrid-ARQ feedback, it comes at a cost in transmission power. Keeping the cost reasonable typically results in a feedback error rate of around 1%, which results in a hybrid-ARQ residual error rate of a similar order. Such an error rate is in many cases far too high; high data rates with TCP may require virtually error-free delivery of packets to the TCP protocol layer. As an example, for sustainable data rates exceeding 100 Mbit/s, a packet-loss probability less than 10^{-5} is required [72]. The reason is that TCP assumes packet errors to be due to congestion in the network. Any packet error therefore triggers the TCP congestion-avoidance mechanism with a corresponding decrease in data rate.

Compared to the hybrid-ARQ acknowledgements, the RLC status reports are transmitted relatively infrequently and thus the cost of obtaining a reliability of 10^{-5} or lower is relatively small. Hence, the combination of hybrid-ARQ and RLC attains a good combination of small round-trip time and a modest feedback overhead where the two components complement each other – fast retransmissions due to the hybrid-ARQ mechanism and reliable packet delivery due to the RLC. As the MAC and RLC protocol layers are located in the same network node, a tight interaction between the two protocols is possible. Hence, to some extent, the combination of the two can be viewed as *one* retransmission mechanism with *two* feedback channels. However, note that, as discussed in Chapter 8 and illustrated in Figure 12.1, the RLC operates per logical channel, while the hybrid-ARQ operates per transport channel (that is, per component carrier). One hybrid-ARQ entity may therefore retransmit data belonging to multiple logical channels. Similarly, one RLC entity may handle data transmitted across multiple component carriers in the presence of carrier aggregation. Finally, for carrier aggregation, hybrid-ARQ retransmissions must occur on the same component carrier as the original transmission, as each component carrier has its own independent hybrid-ARQ entity. RLC retransmissions, on the other hand, are not tied to a specific component carrier as, in essence, carrier aggregation is invisible above the MAC layer.

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 606
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

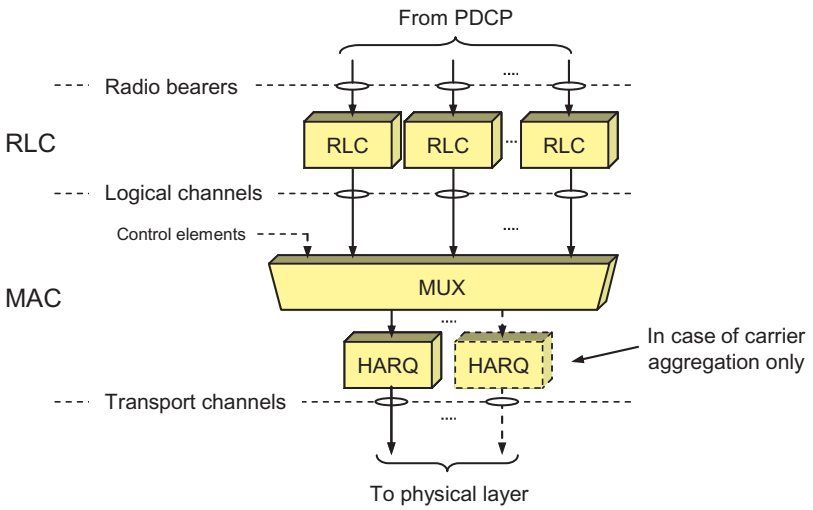


FIGURE 12.1

RLC and hybrid-ARQ retransmission mechanisms in LTE.

In the following section, the principles behind the hybrid-ARQ and RLC protocols will be discussed in more detail.

12.1 HYBRID ARQ WITH SOFT COMBINING

The hybrid-ARQ functionality spans both the physical layer and the MAC layer; generation of different redundancy versions at the transmitter as well as the soft combining at the receiver are handled by the physical layer, while the hybrid-ARQ protocol is part of the MAC layer. In the presence of carrier aggregation, there is, as already stated, one independent hybrid-ARQ entity per component carrier and terminal. Unless otherwise noted, the description below holds for one component carrier – that is, the description is on a per-component carrier basis.

The basis for the LTE hybrid-ARQ mechanism is a structure with multiple stop-and-wait protocols, each operating on a single transport block. In a stop-and-wait protocol, the transmitter stops and waits for an acknowledgement after each transmitted transport block. This is a simple scheme; the only feedback required is a single bit indicating positive or negative acknowledgement of the transport block. However, since the transmitter stops after each transmission, the throughput is also low. LTE therefore applies *multiple* stop-and-wait processes operating in parallel such that, while waiting for acknowledgement from one process, the transmitter can transmit data to another hybrid-ARQ process. This is illustrated in Figure 12.2; while processing the data received in the first hybrid-ARQ process the receiver can continue to receive using the second process and so on. This structure, multiple hybrid-ARQ processes operating in parallel to form one hybrid-ARQ entity, combines the simplicity of a stop-and-wait protocol while still allowing continuous transmission of data.

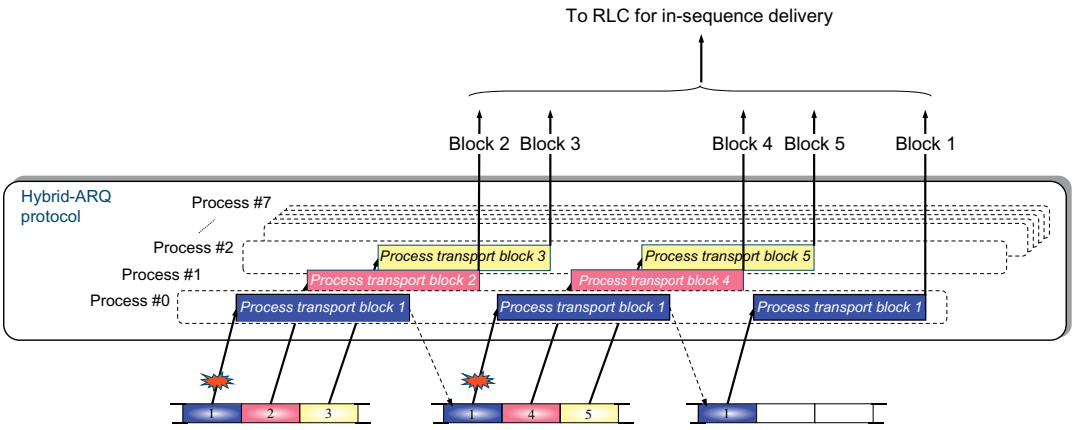


FIGURE 12.2

Multiple parallel hybrid-ARQ processes forming one hybrid-ARQ entity.

There is one hybrid-ARQ entity per terminal (and per component carrier in the case of carrier aggregation; see Figure 12.1). Spatial multiplexing, where two transport blocks can be transmitted in parallel on the same transport channel as described in Chapter 10, is supported by one hybrid-ARQ entity having two sets of hybrid-ARQ processes with independent hybrid-ARQ acknowledgements. The details for the physical-layer transmission of the downlink and uplink hybrid-ARQ acknowledgements were described in Chapters 10 and 11.

Upon receiving a transport block for a certain hybrid-ARQ process, the receiver makes an attempt to decode the transport block and informs the transmitter about the outcome through a hybrid-ARQ acknowledgement, indicating whether the transport block was correctly decoded or not. The time from reception of data until transmission of the hybrid-ARQ acknowledgement is fixed, hence the transmitter knows from the timing relation which hybrid-ARQ process a received acknowledgement relates to. This is beneficial from an overhead perspective as there is no need to signal the process number along with the acknowledgement.

An important part of the hybrid-ARQ mechanism is the use of *soft combining*, which implies that the receiver combines the received signal from multiple transmission attempts. The principles of hybrid-ARQ with soft combining were outlined in Chapter 6, with incremental redundancy being the basic scheme in LTE. Clearly, the receiver needs to know when to perform soft combining prior to decoding and when to clear the soft buffer – that is, the receiver needs to differentiate between the reception of an initial transmission (prior to which the soft buffer should be cleared) and the reception of a retransmission. Similarly, the transmitter must know whether to retransmit erroneously received data or to transmit new data. Therefore, an explicit *new-data indicator* is included for each of the one or two scheduled transport blocks along with other downlink scheduling information on the PDCCH. The new-data indicator is present in both downlink assignments and uplink grants, although the meaning is slightly different for the two.

For downlink data transmission, the new-data indicator is toggled for a new transport block – that is, it is essentially a single-bit sequence number. Upon reception of a downlink scheduling assignment, the terminal checks the new-data indicator to determine whether the current transmission

Petitioners' Exhibit 1003, p. 608
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

should be soft combined with the received data currently in the soft buffer for the hybrid-ARQ process in question, or if the soft buffer should be cleared.

For uplink data transmission, there is also a new-data indicator transmitted on the downlink PDCCH. In this case, toggling the new-data indicator requests transmission of a new transport block, otherwise the previous transport block for this hybrid-ARQ process should be retransmitted (in which case the eNodeB should perform soft combining).

The use of multiple parallel hybrid-ARQ processes operating in parallel can result in data being delivered from the hybrid-ARQ mechanism out of sequence. For example, transport block 5 in Figure 12.2 was successfully decoded before transport block 1, which required two retransmissions. Out-of-sequence delivery can also occur in the case of carrier aggregation, where transmission of a transport block on one component carrier could be successful while a retransmission is required on another component carrier. To handle out-of-sequence delivery from the hybrid-ARQ protocol, the RLC protocol includes an in-sequence-delivery mechanism, as described in Section 12.2.

Hybrid-ARQ protocols can be characterized as synchronous vs. asynchronous, related to the flexibility in the time domain, as well as adaptive vs. non-adaptive, related to the flexibility in the frequency domain:

- An *asynchronous* hybrid-ARQ protocol implies that retransmissions can occur at any time, whereas a *synchronous* protocol implies that retransmissions occur at a fixed time after the previous transmission (see Figure 12.3). The benefit of a synchronous protocol is that there is no need to explicitly signal the hybrid-ARQ process number as this information can be derived from the subframe number. On the other hand, an asynchronous protocol allows for more flexibility in the scheduling of retransmissions.
- An *adaptive* hybrid-ARQ protocol implies that the frequency location and possibly also the more detailed transmission format can be changed between retransmissions. A *non-adaptive protocol*,

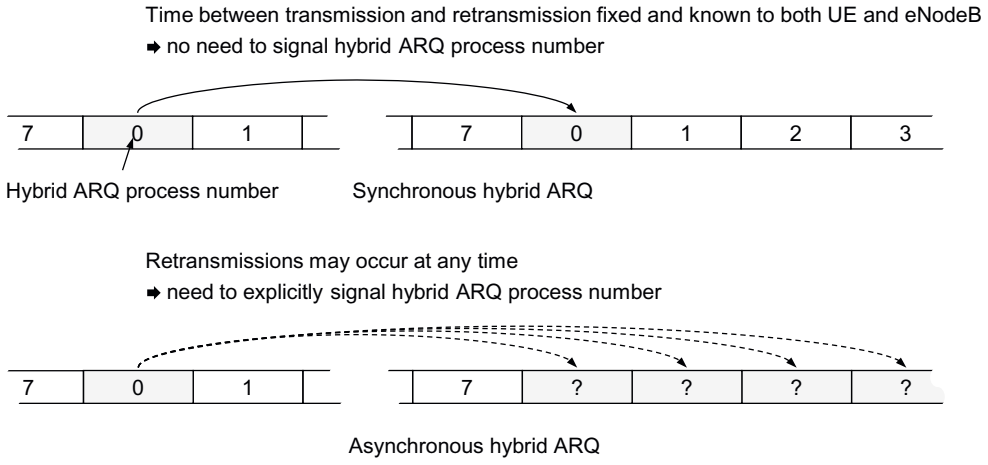


FIGURE 12.3

Synchronous and asynchronous hybrid ARQ.

in contrast, implies that the retransmission must occur at the same frequency resources and with the same transmission format as the initial transmission.

In the case of LTE, asynchronous adaptive hybrid ARQ is used for the downlink. For the uplink, synchronous hybrid ARQ is used. Typically, the retransmissions are non-adaptive, but there is also the possibility to use adaptive retransmissions as a complement.

12.1.1 Downlink Hybrid ARQ

In the downlink, retransmissions are scheduled in the same way as new data – that is, they may occur at any time and at an arbitrary frequency location within the downlink cell bandwidth. Hence, the downlink hybrid-ARQ protocol is *asynchronous* and *adaptive*. The support for asynchronous and adaptive hybrid ARQ for the LTE downlink is motivated by the need to avoid collisions with, for example, transmission of system information and MBSFN subframes. Instead of dropping a retransmission that otherwise would collide with MBSFN subframes or transmission of system information, the eNodeB can move the retransmission in time and/or frequency to avoid the overlap in resources.

Support for soft combining is, as described in the introduction, provided through an explicit new-data indicator, toggled for each new transport block. In addition to the new-data indicator, hybrid-ARQ-related downlink control signaling consists of the hybrid-ARQ process number (three bits for FDD, four bits for TDD) and the redundancy version (two bits), both explicitly signaled in the scheduling assignment for each downlink transmission.

Downlink spatial multiplexing implies, as already mentioned, transmission of two transport blocks in parallel on a component carrier. To provide the possibility to retransmit only one of the transport blocks, which is beneficial as error events for the two transport blocks can be fairly uncorrelated, each transport block has its own separate new-data indicator and redundancy-version indication. However, there is no need to signal the process number separately as each process consists of two subprocesses in the case of spatial multiplexing or, expressed differently, once the process number for the first transport block is known, the process number for the second transport block is given implicitly.

Transmissions on downlink component carriers are acknowledged independently. On each component carrier, transport blocks are acknowledged by transmitting one or two bits on the uplink, as described in Chapter 11. In the absence of spatial multiplexing, there is only a single transport block within a TTI and consequently only a single acknowledgement bit is required in response. However, if the downlink transmission used spatial multiplexing, there are two transport blocks per TTI, each requiring its own hybrid-ARQ acknowledgement bit. The total number of bits required for hybrid-ARQ acknowledgements thus depends on the number of component carriers and the transmission mode for each of the component carriers. As each downlink component carrier is scheduled separately from its own PDCCH, the hybrid-ARQ process numbers are signaled independently for each component carrier.

Obviously, the terminal should not transmit a hybrid-ARQ acknowledgement in response to reception of system information, paging messages and other broadcast traffic. Hence, hybrid-ARQ acknowledgements are only sent in the uplink for "normal" unicast transmission.

12.1.2 Uplink Hybrid ARQ

Shifting the focus to the uplink, a difference compared to the downlink case is the use of synchronous, non-adaptive operation as the basic principle of the hybrid-ARQ protocol, motivated by the

Petitioners' Exhibit 1003, p. 610
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

lower overhead compared to an asynchronous, adaptive structure. Hence, uplink retransmissions always occur at an *a priori* known subframe; in the case of FDD operation uplink retransmissions occur eight subframes after the prior transmission attempt for the same hybrid-ARQ process. The set of resource blocks used for the retransmission on a component carrier is identical to the initial transmission. Thus, the only control signaling required in the downlink for a retransmission is a hybrid-ARQ acknowledgement, transmitted on the PHICH as described in Chapter 10. In the case of a negative acknowledgement on the PHICH, the data is retransmitted.

Spatial multiplexing is handled in the same way as in the downlink – two transport blocks transmitted in parallel on the uplink, each with its own modulation-and-coding scheme and new-data indicator but sharing the same hybrid-ARQ process number. The two transport blocks are individually acknowledged and hence two bits of information are needed in the downlink to acknowledge an uplink transmission using spatial multiplexing. Uplink carrier aggregation is another example of a situation where multiple acknowledgements are needed – one or two acknowledgement bits per uplink component carrier. TDD is a third example, as will be discussed further below, where uplink transmissions in different subframes may need to be acknowledged in the same downlink subframe. Thus, multiple PHICHs may be needed as each PHICH is capable of transmitting a single bit only. Each of the PHICHs is transmitted on the same downlink component carrier that was used to schedule the initial uplink transmission.

Despite the fact that the basic mode of operation for the uplink is synchronous, non-adaptive hybrid ARQ, there is also the possibility to operate the uplink hybrid ARQ in a synchronous, *adaptive* manner, where the resource-block set and modulation-and-coding scheme for the retransmissions is changed. Although non-adaptive retransmissions are typically used due to the very low overhead in terms of downlink control signaling, adaptive retransmissions are sometimes useful to avoid fragmenting the uplink frequency resource or to avoid collisions with random-access resources. This is illustrated in Figure 12.4. A terminal is scheduled for an initial transmission in subframe n; a transmission that is not correctly received and consequently a retransmission is required in subframe $n + 8$ (assuming FDD; for TDD the timing obviously depends on the downlink–uplink allocation, as discussed further below). With non-adaptive hybrid ARQ, the retransmissions occupy the same part of the uplink spectrum as the initial transmission. Hence, in this example the spectrum is fragmented, which limits the bandwidth available to another terminal (unless the other terminal is capable of multi-cluster transmission). In subframe $n + 16$, an example of an adaptive retransmission is found; to make room for another terminal to be granted a large part of the uplink spectrum, the retransmission is moved in the frequency domain. It should be noted that the uplink hybrid-ARQ protocol is still synchronous – that is, a retransmission should always occur eight subframes after the previous transmission.

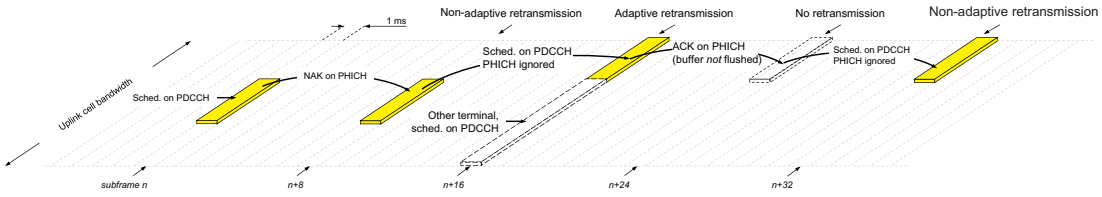


FIGURE 12.4

Non-adaptive and adaptive hybrid-ARQ operation.

Petitioners' Exhibit 1003, p. 611
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The support for both adaptive and non-adaptive hybrid ARQ is realized by *not* flushing the transmission buffer when receiving a positive hybrid-ARQ acknowledgement on PHICH for a given hybrid-ARQ process. Instead, the actual control of whether data should be retransmitted or not is done by the new-data indicator included in the uplink scheduling grant sent on the PDCCH. The new-data indicator is toggled for each new transport block. If the new-data indicator is toggled, the terminal flushes the transmission buffer and transmits a new data packet. However, if the new-data indicator does not request transmission of a new transport block, the previous transport block is retransmitted. Hence, clearing of the transmission buffer is not handled by the PHICH but by the PDCCH as part of the uplink grant. The negative hybrid-ARQ acknowledgement on the PHICH could instead be seen as a single-bit scheduling grant for retransmissions where the set of bits to transmit and all the resource information are known from the previous transmission attempt. In Figure 12.4 an example of postponing a transmission is seen in subframe $n + 24$. The terminal has received a positive acknowledgement and therefore does *not* retransmit the data. However, the transmission buffer is not flushed, which later is exploited by an uplink grant requesting retransmission in subframe $n + 32$.

A consequence of the above method of supporting both adaptive and non-adaptive hybrid ARQ is that the PHICH and PDCCH related to the same uplink subframe have the same timing. If this were not the case, the complexity would increase as the terminal would not know whether to obey the PHICH or wait for a PDCCH overriding the PHICH.

As explained earlier, the new-data indicator is explicitly transmitted in the uplink grant. However, unlike the downlink case, the redundancy version is *not* explicitly signaled for each retransmission. With a single-bit acknowledgement on the PHICH, this is not possible. Instead, as the uplink hybrid-ARQ protocol is synchronous, the redundancy version follows a predefined pattern, starting with zero when the initial transmission is scheduled by the PDCCH. Whenever a retransmission is requested by a negative acknowledgement on the PHICH, the next redundancy version in the sequence is used. However, if a retransmission is explicitly scheduled by the PDCCH overriding the PHICH, there is the potential to affect the redundancy version to use. Grants for retransmissions use the same format as ordinary grants (for initial transmissions). One of the information fields in an uplink grant is, as described in Chapter 10, the modulation-and-coding scheme. Of the 32 different combinations this five-bit field can take, three of them are reserved. Those three combinations represent different redundancy versions; hence, if one of these combinations is signaled as part of an uplink grant indicating a retransmission, the corresponding redundancy version is used for the transmission. The transport-block size is already known from the initial transmission as it, by definition, cannot change between retransmission attempts. In Figure 12.4, the initial transmission in subframe n uses the first redundancy version in sequence as the transport-block size must be indicated for the initial transmission. The retransmission in subframe $n + 8$ uses the next redundancy version in the sequence, while the explicitly scheduled retransmission in subframe $n + 16$ can use any redundancy scheme as indicated on the PDCCH.

Whether to exploit the possibility to signal an arbitrary redundancy version in a retransmission scheduled by the PDCCH is a trade-off between incremental-redundancy gain and robustness. From an incremental-redundancy perspective, changing the redundancy value between retransmissions is typically beneficial to fully exploit the gain from incremental redundancy. However, as the modulation-and-coding scheme is normally not indicated for uplink retransmissions, as either the single-bit PHICH is used or the modulation-and-coding field is used to explicitly indicate a new redundancy version, it is implicitly assumed that the terminal did not miss the initial scheduling grant. If this is

Petitioners' Exhibit 1003, p. 612
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

the case, it is necessary to explicitly indicate the modulation-and-coding scheme, which also implies that the first redundancy version in the sequence is used.

In order to minimize the overhead and not introduce any additional signaling in the uplink grants, the PHICH that the terminal will expect the hybrid-ARQ acknowledgement upon is derived from the number of the first resource block upon which the corresponding uplink PUSCH transmission occurred. This principle is also compatible with semi-persistently scheduled transmission (see Chapter 13) as well as retransmissions. In addition, the resources used for a particular PHICH further depend on the reference-signal phase rotation signaled as part of the uplink grant. In this way, multiple terminals scheduled on the same set of resources using multi-user MIMO will use different PHICH resources as their reference signals are assigned different phase rotations through the corresponding field in the uplink grant. For spatial multiplexing, where two PHICH resources are needed, the second PHICH uses the same principle as the first, but to ensure that different PHICHs are used for the two transport blocks, the resource for the second PHICH is derived not from the first but from the second resource block upon which the PUSCH was transmitted.[1]

The above association is also used in the case of carrier aggregation. For the case when no cross-carrier scheduling is used and each uplink component carrier is scheduled on its corresponding downlink component carrier, this is straightforward and there is no risk of multiple uplink component carriers being associated with the same PHICH resource. With cross-carrier scheduling, on the other hand, transmissions on multiple uplink component carriers may need to be acknowledged on a single downlink component carrier, as illustrated in Figure 12.5. Avoiding PHICH collisions in this case is up to the scheduler by ensuring that different reference-signal phase rotations or different resource-block starting positions are used for the different uplink component carriers. For semi-persistent scheduling the reference-signal phase rotation is always set to zero, but since semi-persistent scheduling is supported on the primary component carrier only, there is no risk of collisions between component carriers.

In the case of multiple component carriers being used for the uplink data transmission in a subframe, there are one (in the absence of spatial multiplexing) or two (in the presence of spatial multiplexing)

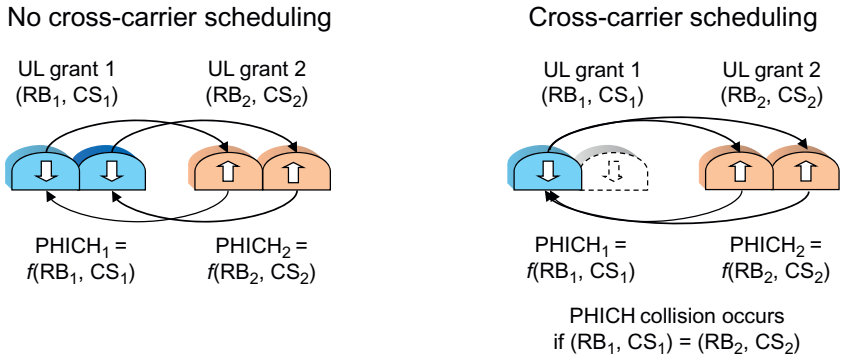


FIGURE 12.5

PHICH association.

[1] In essence, this implies that uplink spatial multiplexing must use at least two resource blocks in the frequency domain.

PHICHs transmitted per uplink component carrier. As a general principle, LTE transmits the PHICH on the same component carrier that was used for the grant scheduling the corresponding uplink data transmission. Not only is this principle general in the sense that it can handle symmetric as well as asymmetric carrier aggregation scenarios, it is also beneficial from a terminal power consumption perspective as the terminal only need to monitor the component carriers it monitors for uplink scheduling grants (especially as the PDCCH may override the PHICH to support adaptive retransmissions as discussed above).

12.1.3 Hybrid-ARQ Timing

Clearly, the receiver must know to which hybrid-ARQ process a received acknowledgement is associated. This is handled by the timing of the hybrid-ARQ acknowledgement being used to associate the acknowledgement with a certain hybrid-ARQ process; the timing relation between the reception of data in the downlink and transmission of the hybrid-ARQ acknowledgement in the uplink (and vice versa) is fixed. From a latency perspective, the time between the reception of downlink data at the terminal and transmission of the hybrid-ARQ acknowledgement in the uplink should be as short as possible. At the same time, an unnecessarily short time would increase the demand on the terminal processing capacity and a trade-off between latency and implementation complexity is required. The situation is similar for uplink data transmissions. For LTE, this trade-off led to the decision to have eight hybrid-ARQ processes in both uplink and downlink for FDD. For TDD, the number of processes depends on the downlink–uplink allocation, as discussed below.

Starting with the FDD case, transmission of acknowledgements in the uplink in response to downlink data transmission is illustrated in Figure 12.6. Downlink data on the DL-SCH is transmitted to the terminal in subframe n and received by the terminal, after the propagation delay T_p, in subframe n. The terminal attempts to decode the received signal, possibly after soft combining with a previous transmission attempt, and transmits the hybrid-ARQ acknowledgement in uplink subframe $n + 4$ (note that the start of an uplink subframe at the terminal is offset by T_{TA} relative to the start of the corresponding downlink subframe at the terminal as a result of the timing-advance procedure described

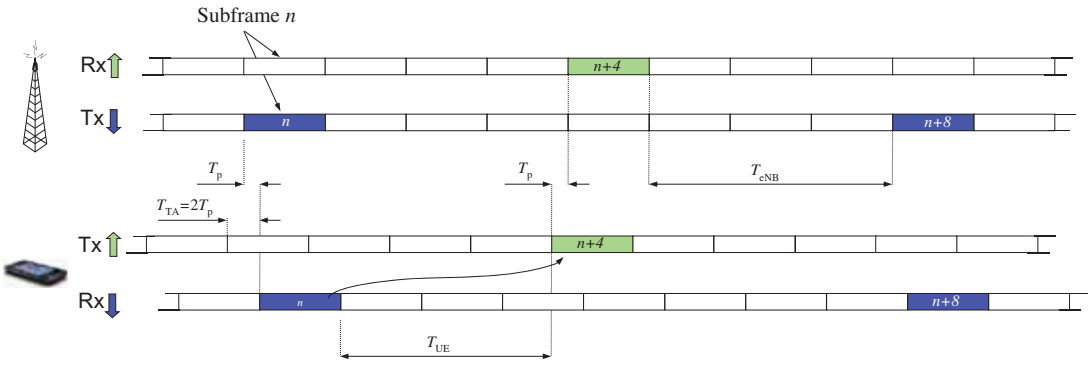


FIGURE 12.6

Timing relation between downlink data in subframe n and uplink hybrid-ARQ acknowledgement in subframe $n + 4$ for FDD.

in Section 11.5). Upon reception of the hybrid-ARQ acknowledgement, the eNodeB can, if needed, retransmit the downlink data in subframe $n + 8$. Thus, eight hybrid-ARQ processes are used – that is, the hybrid-ARQ round-trip time is 8 ms.

The description in the previous paragraph, as well as the illustration in Figure 12.6, describe the timing for downlink data transmission – that is, data on DL-SCH and acknowledgements on PUCCH (or PUSCH). However, the timing of uplink data transmission – that is, data on PUSCH and acknowledgements on PHICH – is identical, namely uplink data transmission in subframe n results in a PHICH transmission in subframe $n + 4$. This is also the same timing relation as for uplink scheduling grants in general (as described in Section 13.2.2) and allows a scheduling grant on the PDCCH to override the PHICH, as shown in Figure 12.4.

In Figure 12.6 it is seen that the processing time available to the terminal, T_{UE}, depends on the value of the timing advance or, equivalently, on the terminal-to-base-station distance. As a terminal must operate at any distance up to the maximum size supported by the specifications, the terminal must be designed such that it can handle the worst-case scenario. LTE is designed to handle at least 100 km, corresponding to a maximum timing advance of 0.67 ms. Hence, there is approximately 2.3 ms left for the terminal processing, which is considered a reasonable trade-off between the processing requirements imposed on a terminal and the associated delays.

For the eNodeB, the processing time available, denoted as T_{eNB}, is 3 ms and thus of the same order as for the terminal. In the case of downlink data transmission, the eNodeB performs scheduling of any retransmissions during this time and, for uplink data transmission, the time is used for decoding of the received signal. The timing budget is thus similar for the terminal and the eNodeB, which is motivated by the fact that, although the eNodeB typically has more processing power than a terminal, it also has to serve multiple terminals and to perform the scheduling operation.

Having the same number of hybrid-ARQ processes in uplink and downlink is beneficial for half-duplex FDD operation, discussed in Chapter 13. By proper scheduling, the uplink hybrid-ARQ transmission from the terminal will coincide with transmission of uplink data and the acknowledgements related to the reception of uplink data will be transmitted in the same subframe as the downlink data. Thus, using the same number of hybrid-ARQ processes in uplink and downlink results in a 50:50 split between transmission and reception for a half-duplex terminal.

Shifting to TDD operation, the time relation between the reception of data in a certain hybrid-ARQ process and the transmission of the hybrid-ARQ acknowledgement depends on the downlink–uplink allocation. Obviously, an uplink hybrid-ARQ acknowledgement can only be transmitted in an uplink subframe and a downlink acknowledgement only in a downlink subframe. The amount of processing time required in the terminal and the eNodeB remains the same though, as the same turbo decoders are used and the scheduling decisions are similar. Therefore, for TDD the acknowledgement of a transport block in subframe n is transmitted in subframe $n + k$, where $k \geq 4$ and is selected such that $n + k$ is an uplink subframe when the acknowledgement is to be transmitted from the terminal (on PUCCH or PUSCH) and a downlink subframe when the acknowledgement is transmitted from the eNodeB (on PHICH). The value of k depends on the downlink–uplink configuration, as shown in Table 12.1 for both downlink and uplink transmissions. From the table it is seen that, as a consequence of the downlink–uplink configuration, the value of k is sometimes larger than the FDD value $k = 4$. For example, assuming configuration 2, an uplink transmission on PUSCH received in subframe 2 should be acknowledged on PHICH in subframe $2 + 6 = 8$. Similarly, for the same configuration, downlink transmission on PDSCH in subframe 0 should be acknowledged on PUCCH (or PUSCH) in subframe $0 + 7 = 7$.

Petitioners' Exhibit 1003, p. 615
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 12.1 Number of Hybrid-ARQ Processes and Acknowledgement Timing *k* for Different TDD Configurations

Configuration (DL:UL)	Downlink											Uplink									
	Proc.	PDSCH reception in subframe *n*										Proc.	PUSCH reception in subframe *n*								
		0	1	2	3	4	5	6	7	8	9		0	1	2	3	4	5	6	7	8	9
0 (2:3)	4	4	6	–	–	–	4	6	–	–	–	6	–	–	4	7	6	–	–	4	7	6
1 (3:2)	7	7	6	–	–	4	7	6	–	–	4	4	–	–	4	6	–	–	–	4	6	–
2 (4:1)	10	**7**	6	–	**4**	8	7	6	–	4	8	2	–	–	6	–	–	–	–	6	–	–
3 (7:3)	9	4	11	–	–	–	7	6	6	5	5	3	–	–	6	6	6	–	–	–	–	–
4 (8:2)	12	12	11	–	–	8	7	7	6	5	4	2	–	–	6	6	–	–	–	–	–	–
5 (9:1)	15	12	11	–	9	8	7	6	5	4	13	1	–	–	6	–	–	–	–	–	–	–
6 (5:5)	6	7	7	–	–	–	7	7	–	–	5	6	–	–	4	6	6	–	–	4	7	–

Petitioners' Exhibit 1003, p. 616
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

From the table it is also seen that the number of hybrid-ARQ processes used for TDD depends on the downlink–uplink configuration, implying that the hybrid-ARQ round-trip time is configuration dependent for TDD (actually, it may even vary between subframes, as seen in Figure 12.7). For the downlink-heavy configurations 2, 3, 4, and 5, the number of downlink hybrid-ARQ processes is larger than for FDD. The reason is the limited number of uplink subframes available, resulting in *k*-values well beyond 4 for some subframes (Table 12.1).

The PHICH timing in TDD is identical to the timing when receiving an uplink grant, as described in Section 13.2.2. The reason is the same as in FDD, namely to allow a PDCCH uplink grant to override the PHICH in order to implement adaptive retransmissions, as illustrated in Figure 12.4.

The downlink–uplink allocation for TDD has implications on the number of transport blocks to acknowledge in a single subframe. For FDD, in the absence of carrier aggregation, there is always a one-to-one relation between uplink and downlink subframes. Hence, a subframe only needs to carry acknowledgements for one subframe in the other direction. For TDD, in contrast, there is not necessarily a one-to-one relation between uplink and downlink subframes. This can be seen in the possible downlink–uplink allocations described in Chapter 9.

For uplink transmissions using UL-SCH, each uplink transport block is acknowledged individually by using the PHICH. Hence, in uplink-heavy asymmetries (downlink–uplink configuration 0), the terminal may need to receive two hybrid-ARQ acknowledgements in downlink subframes 0 and 5 in the absence of uplink spatial multiplexing; for spatial multiplexing up to four acknowledgements per component carrier are needed. There are also some subframes where no PHICH will be transmitted and therefore the amount of PHICH groups may vary between subframes for TDD.

For downlink transmissions, there are some configurations where DL-SCH receipt in multiple downlink subframes needs to be acknowledged in a single uplink subframe, as illustrated in Figure 12.7 (the illustration corresponds to the two entries shown in bold in Table 12.1). Two different mechanisms to handle this are provided in TDD: multiplexing and bundling.

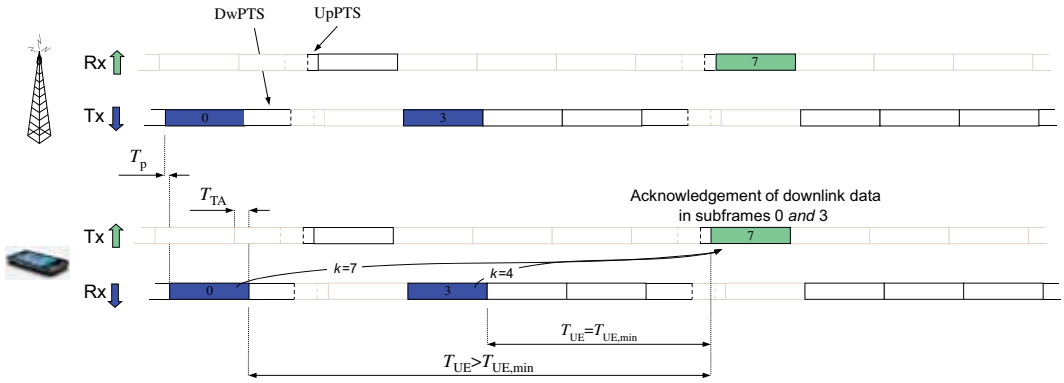


FIGURE 12.7

Example of timing relation between downlink data and uplink hybrid-ARQ acknowledgement for TDD (configuration 2).

Multiplexing implies that independent acknowledgements for each of the received transport blocks are fed back to the eNodeB. This allows independent retransmission of erroneous transport blocks. However, it also implies that multiple bits need to be transmitted from the terminal, which may limit the uplink coverage. This is the motivation for the bundling mechanism.

Bundling of acknowledgements implies that the outcome of the decoding of downlink transport blocks from multiple downlink subframes can be combined into a single hybrid-ARQ acknowledgement transmitted in the uplink. Only if both of the downlink transmissions in subframes 0 and 3 in the example in Figure 12.7 are correctly decoded will a positive acknowledgement be transmitted in uplink subframe 7.

Combining acknowledgements related to multiple downlink transmissions into a single uplink message assumes that the terminal has not missed any of the scheduling assignments upon which the acknowledgement is based. Assume, as an example, that the eNodeB scheduled the terminal in two (subsequent) subframes, but the terminal missed the PDCCH transmission in the first of the two subframes and successfully decoded the data transmitted in the second subframe. Obviously, without any additional mechanism, the terminal will transmit an acknowledgement based on the assumption that it was scheduled in the second subframe only, while the eNodeB will interpret acknowledgement as the terminal successfully received both transmissions. To avoid such errors, the *downlink assignment index* (see Section 10.4.4) in the scheduling assignment on the PDCCH is used. The downlink assignment index in essence informs the terminal about the number of transmissions it should base the combined acknowledgement upon. If there is a mismatch between the assignment index and the number of transmissions the terminal received, the terminal concludes at least one assignment was missed and transmits no hybrid-ARQ acknowledgement, thereby avoiding acknowledging transmissions not received.

TDD is not the only example when transmissions in multiple downlink subframes must be acknowledged in a single uplink subframe. Carrier aggregation in FDD with different numbers of uplink and downlink component carriers[2] in essence leads to the same problem. In LTE, there is at most one PUCCH and it is always transmitted on the primary component carrier. Hence, even for a symmetric carrier aggregation configuration, the possibility to transmit more than two hybrid-ARQ acknowledgement bits in the uplink must be supported. As discussed in Chapter 10, this is handled either by resource selection or by using PUCCH format 3. Acknowledgements in response to UL-SCH reception are transmitted using multiple PHICHs, where the PHICH is transmitted on the same downlink component carrier as the uplink scheduling grant initiating the uplink transmission.

12.2 RADIO-LINK CONTROL

The *radio-link control* (RLC) protocol takes data in the form of RLC SDUs from PDCP and delivers them to the corresponding RLC entity in the receiver by using functionality in MAC and physical layers. The relation between RLC and MAC, including multiplexing of multiple logical channels into a single transport channel, is illustrated in Figure 12.8. Multiplexing of several logical channels into a single transport channel is mainly used for priority handling, as described in Section 13.2 in conjunction with downlink and uplink scheduling.

[2]In LTE release 10, the number of downlink component carriers is always at least as large as the number of uplink component carriers (see Chapter 9).

Petitioners' Exhibit 1003, p. 618
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

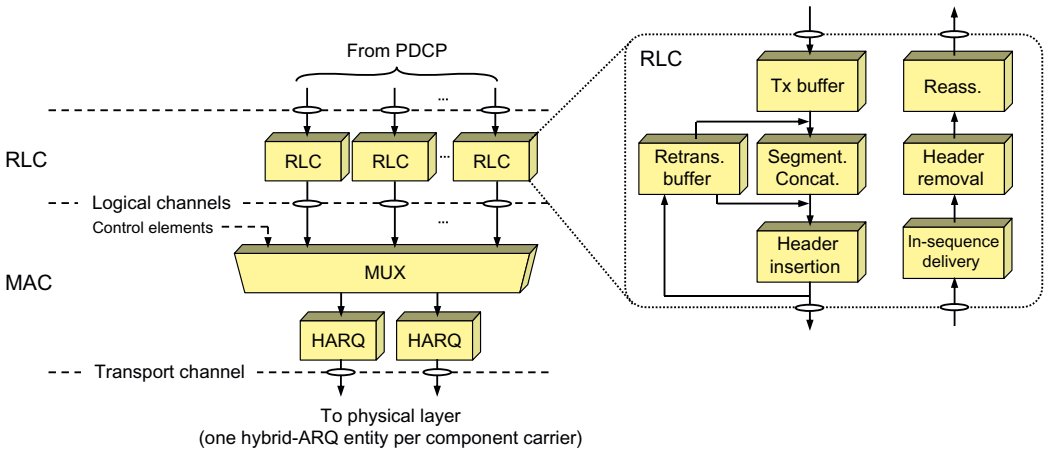


FIGURE 12.8

MAC and RLC structure (single-terminal view).

There is one RLC entity per logical channel configured for a terminal, where each RLC entity is responsible for:

- segmentation, concatenation, and reassembly of RLC SDUs;
- RLC retransmission; and
- in-sequence delivery and duplicate detection for the corresponding logical channel.

Other noteworthy features of the RLC are: (1) the handling of varying PDU sizes; and (2) the possibility for close interaction between the hybrid-ARQ and RLC protocols. Finally, the fact that there is one RLC entity per logical channel and one hybrid-ARQ entity per component carrier implies that one RLC entity may interact with multiple hybrid-ARQ entities in the case of carrier aggregation.

12.2.1 Segmentation, Concatenation, and Reassembly of RLC SDUs

The purpose of the segmentation and concatenation mechanism is to generate RLC PDUs of appropriate size from the incoming RLC SDUs. One possibility would be to define a fixed PDU size, a size that would result in a compromise. If the size were too large, it would not be possible to support the lowest data rates. Also, excessive padding would be required in some scenarios. A single small PDU size, however, would result in a high overhead from the header included with each PDU. To avoid these drawbacks, which is especially important given the very large dynamic range of data rates supported by LTE, the RLC PDU size varies dynamically.

Segmentation and concatenation of RLC SDUs into RLC PDUs are illustrated in Figure 12.9. The header includes, among other fields, a sequence number, which is used by the reordering and retransmission mechanisms. The reassembly function at the receiver side performs the reverse operation to reassemble the SDUs from the received PDUs.

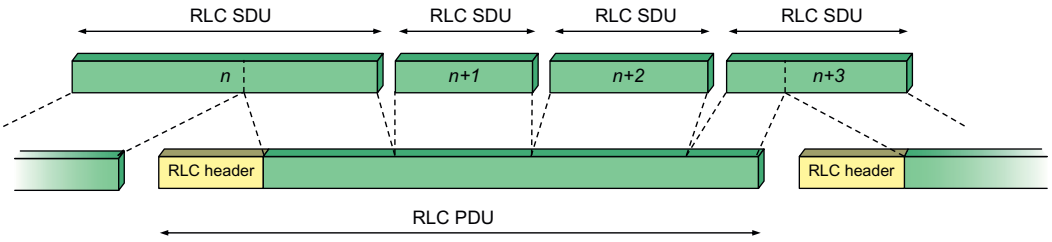


FIGURE 12.9

Generation of RLC PDUs from RLC SDUs.

12.2.2 RLC Retransmission

Retransmission of missing PDUs is one of the main functionalities of the RLC. Although most of the errors can be handled by the hybrid-ARQ protocol, there are, as discussed at the beginning of the chapter, benefits of having a second-level retransmission mechanism as a complement. By inspecting the sequence numbers of the received PDUs, missing PDUs can be detected and a retransmission requested from the transmitting side.

Different services have different requirements; for some services (for example, transfer of a large file), error-free delivery of data is important, whereas for other applications (for example, streaming services), a small amount of missing packets is not a problem. The RLC can therefore operate in three different modes, depending on the requirements from the application:

- *Transparent mode* (TM), where the RLC is completely transparent and is essentially bypassed. No retransmissions, no segmentation/reassembly, and no in-sequence delivery take place. This configuration is used for control-plane broadcast channels such as BCCH, CCCH, and PCCH, where the information should reach multiple users. The size of these messages are selected such that all intended terminals are reached with a high probability and hence there is neither need for segmentation to handle varying channel conditions, nor retransmissions to provide error-free data transmission. Furthermore, retransmissions are not possible for these channels as there is no possibility for the terminal to feed back status reports as no uplink has been established.
- *Unacknowledged mode* (UM) supports segmentation/reassembly and in-sequence delivery, but not retransmissions. This mode is used when error-free delivery is not required, for example voice-over IP, or when retransmissions cannot be requested, for example broadcast transmissions on MTCH and MCCH using MBSFN.
- *Acknowledged mode* (AM) is the main mode of operation for TCP/IP packet data transmission on the DL-SCH. Segmentation/reassembly, in-sequence delivery, and retransmissions of erroneous data are all supported.

In the following, the acknowledged mode is described. The unacknowledged mode is similar, with the exception that no retransmissions are done and that each RLC entity is unidirectional.

In acknowledged mode, the RLC entity is bidirectional – that is, data may flow in both directions between the two peer entities. This is obviously needed as the reception of PDUs needs to be acknowledged back to the entity that transmitted those PDUs. Information about missing PDUs is

provided by the receiving end to the transmitting end in the form of so-called *status reports*. Status reports can either be transmitted autonomously by the receiver or requested by the transmitter. To keep track of the PDUs in transit, the transmitter attaches an RLC header to each PDU, including, among other fields, a sequence number.

Both RLC entities maintain two windows, the transmission and reception windows respectively. Only PDUs in the transmission window are eligible for transmission; PDUs with sequence number below the start of the window have already been acknowledged by the receiving RLC. Similarly, the receiver only accepts PDUs with sequence numbers within the reception window. The receiver also discards any duplicate PDUs as each PDU should be assembled into an SDU only once.

12.2.3 In-Sequence Delivery

In-sequence delivery implies that data blocks are delivered by the receiver in the same order as they were transmitted. This is an essential part of RLC; the hybrid-ARQ processes operate independently and transport blocks may therefore be delivered out of sequence, as seen in Figure 12.2. In-sequence delivery implies that SDU n should be delivered prior to SDU $n + 1$. This is an important aspect as several applications require the data to be received in the same order as it was transmitted. TCP can, to some extent, handle IP packets arriving out of sequence, although with some performance impact, while for some streaming applications in-sequence delivery is essential. The basic idea behind in-sequence delivery is to store the received PDUs in a buffer until all PDUs with lower sequence number have been delivered. Only when all PDUs with lower sequence number have been used for assembling SDUs is the next PDU used. RLC retransmission, provided when operating in acknowledged mode only, operates on the same buffer as the in-sequence delivery mechanism.

12.2.4 RLC Operation

The operation of the RLC with respect to retransmissions and in-sequence delivery is perhaps best understood by the simple example in Figure 12.10, where two RLC entities are illustrated, one in the transmitting node and one in the receiving node. When operating in acknowledged mode, as assumed below, each RLC entity has both transmitter and receiver functionality, but in this example only one

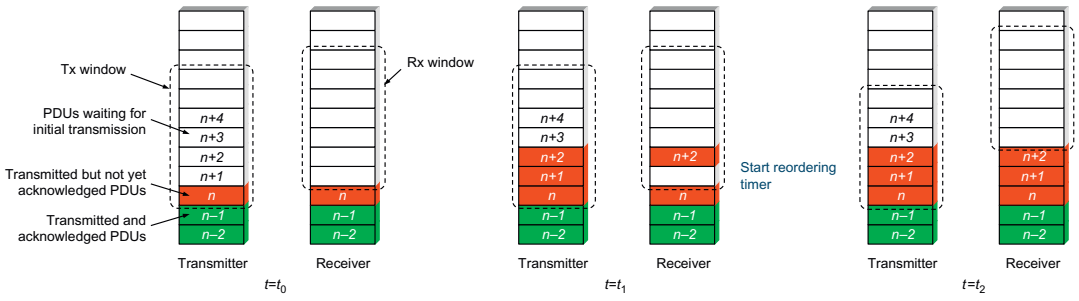


FIGURE 12.10

In-sequence delivery.

of the directions is discussed as the other direction is identical. In the example, PDUs numbered from n to $n + 4$ are awaiting transmission in the transmission buffer. At time t_0, PDUs with sequence number up to and including n have been transmitted and correctly received, but only PDUs up to and including $n - 1$ have been acknowledged by the receiver. As seen in the figure, the transmission window starts from n, the first not-yet-acknowledged PDU, while the reception window starts from $n + 1$, the next PDU expected to be received. Upon reception of PDU n, the PDU is forwarded to the SDU reassembly functionality for further processing.

The transmission of PDUs continues and, at time t_1, PDUs $n + 1$ and $n + 2$ have been transmitted but, at the receiving end, only PDU $n + 2$ has arrived. One reason for this could be that the missing PDU, $n + 1$, is being retransmitted by the hybrid-ARQ protocol and therefore has not yet been delivered from the hybrid ARQ to the RLC. The transmission window remains unchanged compared to the previous figure, as none of the PDUs n and higher have been acknowledged by the receiver. Hence, any of these PDUs may need to be retransmitted as the transmitter is not aware of whether they have been received correctly or not. The reception window is not updated when PDU $n + 2$ arrives. The reason is that PDU $n + 2$ cannot be forwarded to SDU assembly as PDU $n + 1$ is missing. Instead, the receiver waits for the missing PDU $n + 1$. Clearly, waiting for the missing PDU for an infinite time would stall the queue. Hence, the receiver starts a timer, the *reordering timer*, for the missing PDU. If the PDU is not received before the timer expires, a retransmission is requested. Fortunately, in this example, the missing PDU arrives from the hybrid-ARQ protocol at time t_2, before the timer expires. The reception window is advanced and the reordering timer is stopped as the missing PDU has arrived. PDUs $n + 1$ and $n + 2$ are delivered for reassembly into SDUs.

Duplicate detection is also the responsibility of the RLC, using the same sequence number as used for reordering. If PDU $n + 2$ arrives again (and is within the reception window), despite it having already been received, it is discarded.

The example above illustrates the basic principle behind in-sequence delivery, which is supported by both acknowledged and unacknowledged modes. However, the acknowledged mode of operation also provides retransmission functionality. To illustrate the principles behind this, consider Figure 12.11, which is a continuation of the example above. At time t_3, PDUs up to $n + 5$ have been transmitted. Only PDU $n + 5$ has arrived and PDUs $n + 3$ and $n + 4$ are missing. Similar to the case

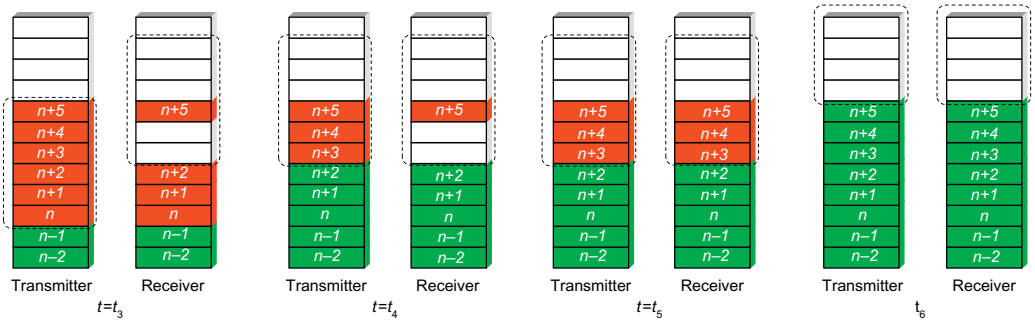


FIGURE 12.11

Retransmission of missing PDUs.

above, this causes the reordering timer to start. However, in this example no PDUs arrive prior to the expiration of the timer. The expiration of the timer at time t_4 triggers the receiver to send a control PDU containing a status report, indicating the missing PDUs, to its peer entity. Control PDUs have higher priority than data PDUs to avoid the status reports being unnecessarily delayed and negatively impact the retransmission delay. Upon reception of the status report at time t_5, the transmitter knows that PDUs up to $n + 2$ have been received correctly and the transmission window is advanced. The missing PDUs $n + 3$ and $n + 4$ are retransmitted and, this time, correctly received.

The retransmission was triggered by the reception of a status report in this example. However, as the hybrid-ARQ and RLC protocols are located in the same node, tight interaction between the two is possible. The hybrid-ARQ protocol at the transmitting end could therefore inform the RLC at the transmitting end in case the transport block(s) containing PDUs $n + 3$ and $n + 4$ have failed. The RLC can use this to trigger retransmission of missing PDUs without waiting for an explicit RLC status report, thereby reducing the delays associated with RLC retransmissions.

Finally, at time t_6, all PDUs, including the retransmissions, have been delivered by the transmitter and successfully received. As $n + 5$ was the last PDU in the transmission buffer, the transmitter requests a status report from the receiver by setting a flag in the header of the last RLC data PDU. Upon reception of the PDU with the flag set, the receiver will respond by transmitting the requested status report, acknowledging all PDUs up to and including $n + 5$. Reception of the status report by the transmitter causes all the PDUs to be declared as correctly received and the transmission window is advanced.

Status reports can, as mentioned earlier, be triggered for multiple reasons. However, to control the amount of status reports and to avoid flooding the return link with an excessive number of status reports, it is possible to use a status prohibit timer. With such a timer, status reports cannot be transmitted more often than once per time interval as determined by the timer.

For the initial transmission, it is relatively straightforward to rely on a dynamic PDU size as a means to handle the varying data rates. However, the channel conditions and the amount of resources may also change between RLC retransmissions. To handle these variations, already transmitted PDUs can be (re)segmented for retransmissions. The reordering and retransmission mechanisms described above still apply; a PDU is assumed to be received when all the segments have been received. Status reports and retransmissions operate on individual segments; only the missing segment of a PDU needs to be retransmitted.

Petitioners' Exhibit 1003, p. 623
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CHAPTER

Power Control, Scheduling, and Interference Handling

13

This chapter deals with some radio-resource-management issues, including uplink power control, downlink and uplink scheduling, and different means for inter-cell interference coordination to handle/avoid severe interference between different cells including cells of different layers in so-called *heterogeneous network deployments*.

13.1 UPLINK POWER CONTROL

Uplink power control for LTE is the set of algorithms and tools by which the transmit power for different uplink physical channels and signals are controlled to ensure that they, if possible, are received at the cell site with appropriate power. This means that the transmission should be received with sufficient power to allow for proper demodulation of the corresponding information. At the same time, the transmit power should not be unnecessarily high as that would cause unnecessary interference to other cells.[1] The transmit power will thus depend on the channel properties, including the channel attenuation and the noise and interference level at the receiver side. Furthermore, in the case of DL-SCH transmission on PDSCH, if the received power is too low one can either increase the transmit power or reduce the data rate by use of rate control. Thus, in this case there is an intimate relation between power control and rate control.

How to set the transmit power for random access will be discussed in Chapter 14. Here we will mainly discuss the power-control mechanism for the PUCCH and PUSCH physical channels. We will also briefly discuss the power setting for sounding reference signals. Uplink *demodulation* reference signals are always transmitted together and time-multiplexed with PUSCH or PUCCH. The demodulation reference signals are then transmitted with the same power as the corresponding physical channel. This is also true in the case of uplink spatial multiplexing if the reference signal power is defined as the total power of all demodulation reference signals transmitted by the terminal. Expressed differently, the power of a single demodulation reference signal is equal to the corresponding *per-layer* PDSCH power.

Fundamentally, LTE uplink power control is a combination of an *open-loop* mechanism, implying that the terminal transmit power depends on estimates of the downlink path loss, and a *closed-loop* mechanism, implying that the network can, in addition, directly adjust the terminal transmit power by means of explicit *power-control commands* transmitted on the downlink. In practice, these power-control commands are determined based on prior network measurements of the received uplink power, thus the term "*closed loop*".

[1] In the case of uplink MU-MIMO there may also be interference to the cell itself.

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 624
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

13.1.1 Uplink Power Control – Some Basic Rules

Before going into the details of the power control algorithms for PUSCH and PUCCH, some basic rules for the power assignment to different physical channels will be discussed. These rules mainly deal with the presence of different transmit-power limitations and how these limitations impact the transmit-power setting for different physical channels. This is especially of interest in the case of the simultaneous transmission of multiple physical channels from the same terminal, a situation that may occur for LTE release 10 and beyond:

- With LTE release 10 there is the possibility for *carrier aggregation*, implying that multiple PUSCH may be transmitted in parallel on different component carriers.
- With LTE release 10 there is also the possibility for *simultaneous PUSCH/PUCCH transmission* on the same or different component carriers.

In principle, each physical channel is separately and independently power controlled. However, in the case of multiple physical channels to be transmitted in parallel from the same terminal, the total power to be transmitted for all physical channels may, in some cases, exceed the maximum terminal output power P_{TMAX} corresponding to the terminal power class. As will be seen below, the basic strategy is then to first ensure that transmission of any L1/L2 control signaling is assigned the power assumed to be needed for reliable transmission. The remaining available power is then assigned to the remaining physical channels.

For each uplink component carrier configured for a terminal there is also an associated and explicitly configured *maximum per-carrier transmit power* $P_{\mathrm{CMAX},c}$, which may be different for different component carriers (indicated by the index c). Furthermore, although it obviously does not make sense for $P_{\mathrm{CMAX},c}$ to exceed the maximum terminal output power P_{TMAX}, the sum of $P_{\mathrm{CMAX},c}$ for all configured component carriers may very well, and typically will, exceed P_{TMAX}. The reason is that, in many cases, the terminal will not be scheduled for uplink transmission on all its configured component carriers and the terminal should also in that case be able to transmit with its maximum output power.

As will be seen in the next sections, the power control of each physical channel explicitly ensures that the total transmit power for a given component carrier does not exceed $P_{\mathrm{CMAX},c}$ for that carrier. However, the separate power-control algorithms do not ensure that the total transmit power for all component carriers to be transmitted by the terminal does not exceed the maximum terminal output power P_{TMAX}. Rather, this is ensured by a subsequent *power scaling* applied to the physical channels to be transmitted. This power scaling is carried out in such a way that any L1/L2 control signaling has higher priority, compared to data (UL-SCH) transmission.

If PUCCH is to be transmitted in the subframe it is first assigned the power determined by its corresponding power-control algorithm, before any power is assigned to any PUSCH to be transmitted in parallel PUCCH. This ensures that L1/L2 control signaling on PUCCH is assigned the power assumed to be needed for reliable transmission before any power is assigned for data transmission.

If PUCCH is not transmitted in the subframe but L1/L2 control signaling is multiplexed on to PUSCH, the PUSCH carrying the L1/L2 control signaling is first assigned the power determined by its corresponding power-control algorithm, before any power is assigned to any other PUSCH to be transmitted in parallel. Once again, this ensures that L1/L2 control signaling is assigned the power assumed to be needed before any power is assigned for other PUSCH transmissions only carrying UL-SCH. Note that, in the case of transmission of multiple PUSCH in parallel (carrier aggregation),

at most one PUSCH may include L1/L2 control signaling. Also, there cannot be PUCCH transmission and L1/L2 control signaling multiplexed on to PUSCH in the same subframe. Thus, there will never be any conflict between the above rules.

If the remaining available transmit power is not sufficient to fulfill the power requirements of any remaining PUSCH to be transmitted, the powers of these remaining physical channels, which only carry UL-SCH, are scaled so that the total power for all physical channels to be transmitted does not exceed the maximum terminal output power.

Overall, the PUSCH power scaling, including the priority for PUSCH with L1/L2 control signaling, can thus be expressed as:

$$\sum_i w_c \cdot P_{\mathrm{PUSCH},c} \leq P_{\mathrm{TMAX}} - P_{\mathrm{PUCCH}}, \tag{13.1}$$

where $P_{\mathrm{PUSCH},c}$ is the transmit power for PUSCH on carrier c as determined by the power-control algorithm (before power scaling but including the per-carrier limitation $P_{\mathrm{CMAX},c}$), P_{PUCCH} is the transmit power for PUCCH (which is zero if there is no PUCCH transmission in the subframe), and w_c is the power-scaling factor for PUSCH on carrier c ($w_c \leq 1$). For any PUSCH carrying L1/L2 control signaling the scaling factor w_c should be set to 1. For the remaining PUSCH, some scaling factors may be set to zero by decision of the terminal, in practice implying that the PUSCH, as well as the corresponding UL-SCH mapped to the PUSCH, are not transmitted. For the remaining PUSCH the scaling factors w_c are set to the same value less than or equal to 1 to ensure that the above inequality is fulfilled. Thus, all PUSCH that are actually transmitted are power scaled by the same factor.

After this overview of some general rules for the power setting of different terminals, especially for the case of multiple physical channels transmitted in parallel from the same terminal, the power control carried out separately for each physical channel will be described in more detail.

13.1.2 Power Control for PUCCH

For PUCCH, the appropriate received power is simply the power needed to achieve a desired – that is, a sufficiently low – error rate in the decoding of the L1/L2 control information transmitted on the PUCCH. However, it is then important to bear the following in mind:

- In general, decoding performance is not determined by the *received signal strength* but rather by the *received signal-to-interference-plus-noise ratio* (SINR). What is an appropriate received power thus depends on the interference level at the receiver side, an interference level that may differ between different deployments and which may also vary in time as, for example, the load of the network varies.
- As described in Chapter 11, there are different PUCCH formats which are used to carry different types of uplink L1/L2 control information (hybrid-ARQ acknowledgements, scheduling requests, channel-state reports, or combinations thereof). The different PUCCH formats thus carry different numbers of information bits per subframe and the information they carry may also have different error-rate requirements. The required received SINR may therefore differ between the different PUCCH formats, something that needs to be taken into account when setting the PUCCH transmit power in a given subframe.

Petitioners' Exhibit 1003, p. 626
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Overall, power-control for PUCCH can be described by the following expression:

$$P_{\text{PUCCH}} = \min\left\{P_{\text{CMAX},c}, P_{0,\text{PUCCH}} + PL_{\text{DL}} + \Delta_{\text{Format}} + \delta\right\}. \quad (13.2)$$

In the expression above, P_{PUCCH} is the PUCCH transmit power to use in a given subframe and PL_{DL} is the downlink path loss as estimated by the terminal. The "min $\{P_{\text{CMAX},c}, \ldots\}$" term ensures that the PUCCH transmit power as determined by the power control will not exceed the per-carrier maximum power $P_{\text{CMAX},c}$.

The parameter $P_{0,\text{PUCCH}}$ in expression (13.2) is a cell-specific parameter that is broadcast as part of the cell system information. Considering only the part $P_{0,\text{PUCCH}} + PL_{\text{DL}}$ in the PUCCH power-control expression and assuming that the (estimated) downlink path loss accurately reflects the true uplink path loss, it is obvious that $P_{0,\text{PUCCH}}$ can be seen as the *desired* or *target* received power. As discussed earlier, the required received power will depend on the uplink noise/interference level. From this point of view, the value of $P_{0,\text{PUCCH}}$ should take the interference level into account and thus vary in time as the interference level varies. However, in practice it is not feasible to have $P_{0,\text{PUCCH}}$ varying with the instantaneous interference level. One simple reason is that the terminal does not read the system information continuously and thus the terminal would anyway not have access to a fully up-to-date $P_{0,\text{PUCCH}}$ value. Another reason is that the uplink path-loss estimates derived from downlink measurements will anyway not be fully accurate, for example due to differences between the instantaneous downlink and uplink path loss, as well as due to measurement inaccuracies.

Thus, in practice, $P_{0,\text{PUCCH}}$ may reflect the average interference level, or perhaps only the relatively constant noise level. More rapid interference variations can then be taken care of by closed-loop power control, see below.

For the transmit power to reflect the typically different SINR requirements for different PUCCH formats, the PUCCH power-control expression includes the term Δ_{Format}, which adds a format-dependent power offset to the transmit power. The power offsets are defined such that a baseline PUCCH format, more exactly the format corresponding to the transmission of a single hybrid-ARQ acknowledgement (format 1 with BPSK modulation, as described in Section 11.4.1.1), has an offset equal to 0 dB, while the offsets for the remaining formats can be explicitly configured by the network. For example, PUCCH format 1 with QPSK modulation, carrying two simultaneous acknowledgements and used in the case of downlink spatial multiplexing, should have a power offset of roughly 3 dB, reflecting the fact that twice as much power is needed to communicate two acknowledgements instead of just a single acknowledgement.

Finally, it is possible for the network to directly adjust the PUCCH transmit power by providing the terminal with explicit power-control commands that adjust the term δ in the power-control expression above. These power-control commands are *accumulative* – that is, each received power-control command increases or decreases the term δ by a certain amount. The power-control commands for PUCCH can be provided to the terminal by two different means:

- As mentioned in Section 10.4, a power-control command is included in each downlink scheduling assignment – that is, the terminal receives a power-control command every time it is explicitly scheduled on the downlink. One reason for uplink PUCCH transmissions is the transmission of hybrid-ARQ acknowledgements as a response to downlink DL-SCH transmissions. Such downlink transmissions are typically associated with downlink scheduling assignments on PDCCH and

the corresponding power-control commands could thus be used to adjust the PUCCH transmit power prior to the transmission of the hybrid-ARQ acknowledgements.

- Power-control commands can also be provided on a special PDCCH that simultaneously provides power-control commands to multiple terminals (PDCCH using DCI format 3/3A; see Section 10.4.7). In practice, such power-control commands are then typically transmitted on a regular basis and can be used to adjust the PUCCH transmit power, for example prior to (periodic) uplink channel-state reports. They can also be used in the case of semi-persistent scheduling (see Section 13.2.3), in which case there may be uplink transmission of both PUSCH (UL-SCH) and PUCCH (L1/L2 control) without any explicit scheduling assignments/grants.

The power-control command carried within the uplink scheduling grant consists of two bits, corresponding to the four different update steps −1, 0, +1, or +3 dB. The same is true for the power-control command carried on the special PDCCH assigned for power control when this is configured to DCI format 3A. On the other hand, when the PDCCH is configured to use DCI format 3, each power-control command consists of a single bit, corresponding to the update steps −1 and +1 dB. In the latter case, twice as many terminals can be power controlled by a single PDCCH. One reason for including the possibility for 0 dB (no change of power) as one power-control step is that a power-control command is included in *every* downlink scheduling assignment and it is desirable not to have to update the PUCCH transmit power for each assignment.

13.1.3 Power Control for PUSCH

Power-control for PUSCH transmission can be described by the following expression:

$$P_{\text{PUSCH},c} = \min\left\{P_{\text{CMAX},c} - P_{\text{PUCCH}}, P_{0,\text{PUSCH}} + \alpha \cdot PL_{\text{DL}} + 10 \cdot \log_{10}(M) + \Delta_{\text{MCS}} + \delta\right\}, \qquad (13.3)$$

where M indicates the instantaneous PUSCH bandwidth measured in number of resource blocks and the term Δ_{MCS} is similar to the term Δ_{Format} in the expression for PUCCH power control – that is, it reflects the fact that different SINR is required for different modulation schemes and coding rates used for the PUSCH transmission.

The above expression is clearly similar to the power-control expression for PUCCH transmission, with some key differences:

- The use of "$P_{\text{CMAX},c} - P_{\text{PUCCH}}$" reflects the fact that the transmit power available for PUSCH on a carrier is the maximum allowed per-carrier transmit power *after power has been assigned to any PUCCH transmission* on that carrier. This ensures priority of L1/L2 signaling on PUCCH over data transmission on PUSCH in the power assignment, as described in Section 13.1.1.
- The term $10 \cdot \log_{10}(M)$ reflects the fact that what is fundamentally controlled by the parameter $P_{0,\text{PUSCH}}$ is the power *per resource block*. For a larger resource assignment, a correspondingly higher received power and thus a correspondingly higher transmit power is needed.[2]

[2]One could also have included a corresponding term in the expression for PUCCH power control. However, as the PUCCH bandwidth always corresponds to one resource block, the term would always equal zero.

- The parameter α, which can take a value smaller than or equal to 1, allows for so-called *partial path-loss compensation*, as described below.

In general, the parameters $P_{0,\text{PUSCH}}$, α, and Δ_{MCS} can be different for the different component carriers configured for a terminal.

In the case of PUSCH transmission, the explicit power-control commands controlling the term δ above are included in the uplink scheduling grants, rather than in the downlink scheduling assignments. This makes sense as PUSCH transmissions are preceded by an uplink scheduling grant except for the case of semi-persistent scheduling. Similar to the power-control commands for PUCCH in the downlink scheduling assignment, the power-control commands for PUSCH are multi-level. Furthermore, also in the same way as for PUCCH power control, explicit power-control commands for PUSCH can be provided on the special PDCCH that simultaneously provides power-control commands to multiple terminals. These power-control commands can, for example, be used for the case of PUSCH transmission using semi-persistent scheduling.

Assuming α equal to 1, also referred to as *full path-loss compensation*, the PUSCH power-control expression becomes very similar to the corresponding expression for PUCCH. Thus, the network can select a modulation-and-coding scheme (MCS) and the power-control mechanism, including the term Δ_{MCS}, will ensure that the received SINR will match the SINR required for that modulation-and-coding scheme, *assuming that the terminal transmit power does not reach its maximum value*.

In the case of PUSCH transmission, it is also possible to "turn off" the Δ_{MCS} function by setting all Δ_{MCS} values to zero. In that case, the PUSCH received power will be matched to a certain MCS given by the selected value of $P_{0,\text{PUSCH}}$.

With the parameter α less than 1, the PUSCH power control operates with so-called *partial path-loss compensation* – that is, an increased path loss is not fully compensated for by a corresponding increase in the uplink transmit power. In that case, the received power, and thus the received SINR per resource block, will vary with the path loss and, consequently, the scheduled modulation-and-coding scheme should vary accordingly. Clearly, in the case of fractional path-loss compensation, the Δ_{MCS} function should be disabled. Otherwise, the terminal transmit power would be further reduced when the modulation-and-coding scheme is reduced to match the partial path-loss compensation.

Figure 13.1 illustrates the differences between full path-loss compensation ($\alpha = 1$) and partial path-loss compensation ($\alpha < 1$). As can be seen, with partial path-loss compensation, the terminal transmit power increases more slowly than the increase in path loss (left-hand figure) and, consequently, the received power, and thus also the received SINR, is reduced as the path loss increases (right-hand figure). To compensate for this, the modulation-and-coding scheme – that is, the PUSCH data rate – should be reduced as the path loss increases.

The potential benefit of partial path-loss compensation is a relatively lower transmit power for terminals closer to the cell border, implying less interference to other cells. At the same time, this also leads to a reduced data rate for these terminals. It should also be noted that a similar effect can be achieved with full path-loss compensation by having the scheduled modulation-and-coding scheme depend on the estimated downlink path loss, which can be derived from the power headroom report, and rely on Δ_{MCS} to reduce the relative terminal transmit power for terminals with higher path loss. However, an even better approach would then be to not only base the modulation-and-coding scheme selection on the path loss to the current cell, but also on the path loss to the neighboring interfered cells.

Petitioners' Exhibit 1003, p. 629
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

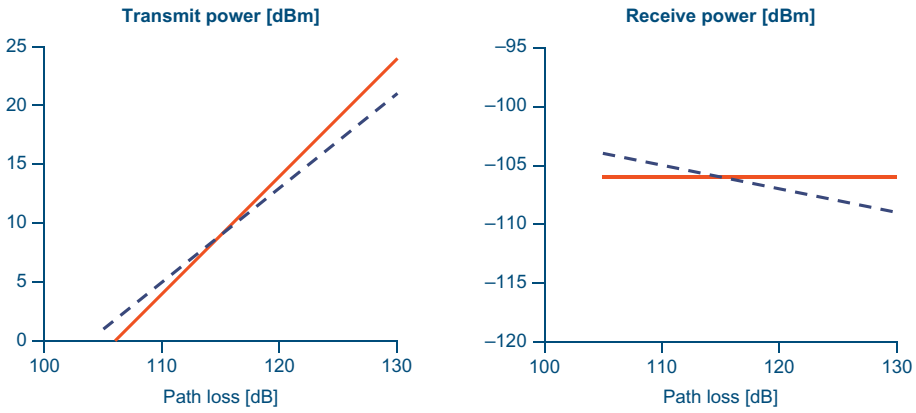


FIGURE 13.1

Full vs. partial path-loss compensation. Solid curve: full compensation ($\alpha = 1$). Dashed curve: partial compensation ($\alpha = 0.8$ in this example).

13.1.4 Power Control for SRS

The SRS transmit power basically follows that of the PUSCH, compensating for the exact bandwidth of the SRS transmission and with an additional power offset. Thus, the power control for SRS transmission can be described according to:

$$P_{\text{SRS}} = \min\left\{P_{\text{CMAX},c}, P_{0,\text{PUSCH}} + \alpha \cdot PL_{\text{DL}} + 10 \cdot \log_{10}\left(M_{\text{SRS}}\right) + \delta + P_{\text{SRS}}\right\}, \quad (13.4)$$

where the parameters $P_{0,\text{PUSCH}}$, α, and δ are the same as for PUSCH power control, as discussed in Section 13.1.3. Furthermore, M_{SRS} is the bandwidth, expressed as number of resource blocks, of the SRS transmission and P_{SRS} is a configurable offset.

13.1.5 Power Headroom

To assist the scheduler in the selection of a combination of modulation-and-coding scheme and resource size M that does not lead to the terminal being power limited, the terminal can be configured to provide regular *power headroom* reports on its power usage (see also Section 13.2.2.2). According to Section 13.1.1 there is a separate transmit-power limitation for each component carrier. Thus, power headroom should be measured and reported separately for each component carrier.

There are two different types of power-headroom reports defined for LTE release 10, *Type 1* and *Type 2*. Type 1 reporting reflects the power headroom assuming PUSCH-only transmission on the carrier, while the Type-2 report assumes combined PUSCH and PUCCH transmission.

The Type-1 power headroom valid for a certain subframe, assuming that the terminal was really scheduled for PUSCH transmission in that subframe, is given by the following expression:

$$\text{Power Headroom} = P_{\text{CMAX},c} - \left(P_{0,\text{PUSCH}} + \alpha \cdot PL_{\text{DL}} + 10 \cdot \log_{10}\left(M\right) + \Delta_{\text{MCS}} + \delta\right), \quad (13.5)$$

Petitioners' Exhibit 1003, p. 630
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

where the values for M and Δ_{MCS} correspond to the resource assignment and modulation-and-coding scheme used in the subframe to which the power-headroom report corresponds. It can be noted that the power headroom is not a measure of the difference between the maximum per-carrier transmit power and the actual carrier transmit power. Rather, comparing with expression (13.3) it can be seen that the power headroom is a measure of the difference between $P_{\text{CMAX},c}$ and the transmit power that would have been used *assuming that there would have been no upper limit on the transmit power.* Thus, the power headroom can very well be negative. More exactly, a negative power headroom indicates that the per-carrier transmit power was limited by $P_{\text{CMAX,c}}$ at the time of the power headroom reporting. As the network knows what modulation-and-coding scheme and resource size the terminal used for transmission in the subframe to which the power-headroom report corresponds, it can determine what are the valid combinations of modulation-and-coding scheme and resource size M, assuming that the downlink path loss PL_{DL} and the term δ have not changed substantially.

Type-1 power headroom can also be reported for subframes where there is no actual PUSCH transmission. In such cases, $10 \bullet \log_{10}(M)$ and Δ_{MCS} in the expression above are set to zero:

$$\text{Power Headroom} = P_{\text{CMAX},c} - \left(P_{0,\text{PUSCH}} + \alpha \cdot PL_{\text{DL}} + \delta\right). \tag{13.6}$$

This can be seen as the power headroom assuming a default transmission configuration corresponding to the minimum possible resource assignment ($M = 1$) and the modulation-and-coding scheme associated with $\Delta_{\text{MCS}} = 0\,\text{dB}$.

Similarly, Type-2 power headroom reporting is defined as the difference between the maximum per-carrier transmit power and the sum of the PUSCH and PUCCH transmit power given by their corresponding power-control expressions (13.2) and (13.1) respectively, once again not taking into account any maximum per-carrier power when calculating the PUSCH and PUCCH transmit power.

Similar to Type-1 power headroom reporting, the Type-2 power headroom can also be reported for subframes in which no PUSCH and/or PUCCH is transmitted. In that case a virtual PUSCH and or PUCCH transmit power is calculated, assuming the smallest possible resource assignment ($M = 1$) and $\Delta_{\text{MCS}} = 0\,\text{dB}$ for PUSCH and $\Delta_{\text{Format}} = 0$ for PUCCH.

13.2 SCHEDULING AND RATE ADAPTATION

The purpose of the scheduler is to determine to/from which terminal(s) to transmit data and on which set of resource blocks. The scheduler is a key element and to a large degree determines the overall behavior of the system. The basic operation is so-called *dynamic* scheduling, where the eNodeB in each 1 ms TTI transmits scheduling information to the selected set of terminals, controlling the uplink and downlink transmission activity. The scheduling decisions are transmitted on the PDCCHs as described in Chapter 10. To reduce the control signaling overhead, there is also the possibility of *semi-persistent scheduling*. Semi-persistent scheduling will be described further in Section 13.2.3.

For carrier aggregation, each component carrier is independently scheduled with individual scheduling assignments/grants and one DL-SCH/UL-SCH per scheduled component carrier. Semi-persistent scheduling is only supported on the primary component carriers, motivated by the fact that the main usage is for small payloads not requiring multiple component carriers.

The *downlink scheduler* is responsible for dynamically controlling the terminal(s) to transmit to and, for each of these terminals, the set of resource blocks upon which the terminal's DL-SCH (or

Petitioners' Exhibit 1003, p. 631
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

DL-SCHs in the case of carrier aggregation) is transmitted. Transport-format selection (selection of transport-bock size, modulation-and-coding scheme, resource-block allocation, and antenna mapping) for each component carrier and logical channel multiplexing for downlink transmissions are controlled by the eNodeB, as illustrated in the left part of Figure 13.2.

The *uplink scheduler* serves a similar purpose, namely to dynamically control which terminals are to transmit on their UL-SCH (or UL-SCHs in the case of carrier aggregation) and on which uplink resources. The uplink scheduler is in complete control of the transport format the terminal will use, whereas the logical-channel multiplexing is controlled by the terminal according to a set of rules. Thus, uplink scheduling is *per terminal* and not per radio bearer. This is illustrated in the right part of Figure 13.2, where the scheduler controls the transport format and the terminal controls the logical-channel multiplexing.

In the following, dynamic downlink and uplink scheduling will be described, as well as related functionality such as uplink priority handling, scheduling request and buffer status reporting, semi-persistent scheduling, half-duplex FDD operation, channel-state reporting, and DRX functionality.

13.2.1 Downlink Scheduling

The task of the downlink scheduler is to dynamically determine the terminal(s) to transmit to and, for each of these terminals, the set of resource blocks upon which the terminal's DL-SCH should be transmitted. In most cases, a single terminal cannot use the full capacity of the cell, for example due to lack of data. Also, as the channel properties may vary in the frequency domain, it is useful to be able to transmit to different terminals on different parts of the spectrum. Therefore, multiple terminals can be scheduled in parallel in a subframe, in which case there is one DL-SCH per scheduled terminal and component carrier, each dynamically mapped to a (unique) set of frequency resources.

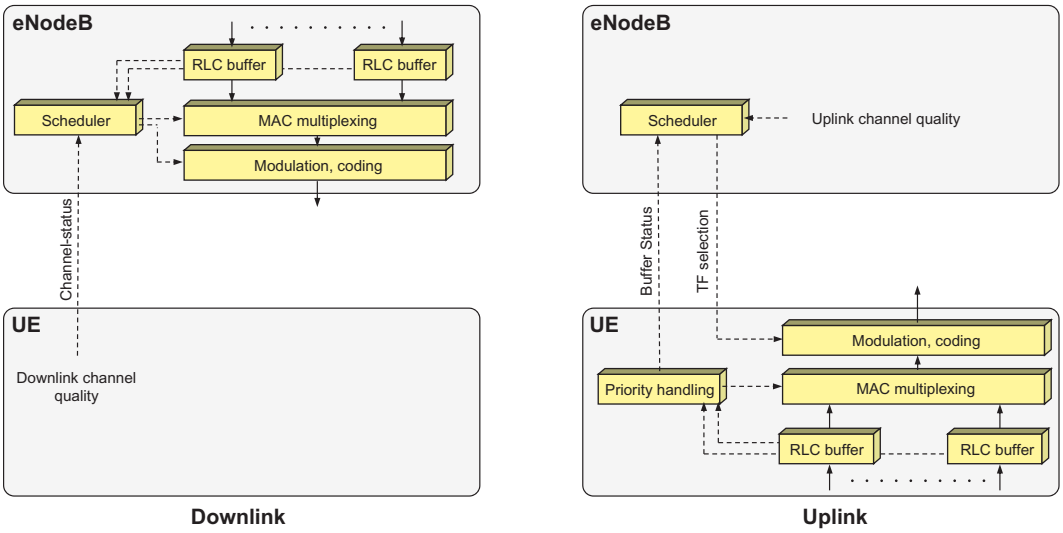


FIGURE 13.2

Transport-format selection in downlink (left) and uplink (right).

Petitioners' Exhibit 1003, p. 632
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The scheduler is in control of the instantaneous data rate used, and the RLC segmentation and MAC multiplexing will therefore be affected by the scheduling decision. Although formally part of the MAC layer but to some extent better viewed as a separate entity, the scheduler is thus controlling most of the functions in the eNodeB associated with downlink data transmission:

- *RLC*. Segmentation/concatenation of RLC SDUs is directly related to the instantaneous data rate. For low data rates, it may only be possible to deliver a part of an RLC SDU in a TTI, in which case segmentation is needed. Similarly, for high data rates, multiple RLC SDUs may need to be concatenated to form a sufficiently large transport block.
- *MAC*. Multiplexing of logical channels depends on the priorities between different streams. For example, radio resource control signaling, such as handover commands, typically has a higher priority than streaming data, which in turn has higher priority than a background file transfer. Thus, depending on the data rate and the amount of traffic of different priorities, the multiplexing of different logical channels is affected. Hybrid-ARQ retransmissions also need to be accounted for.
- *L1*. Coding, modulation and, if applicable, the number of transmission layers and the associated precoding matrix are obviously affected by the scheduling decision. The choices of these parameters are mainly determined by the radio conditions and the selected data rate – that is, the transport block size.

The scheduling decision is communicated to each of the scheduled terminals through the downlink L1/L2 control signaling as described in Chapter 10, using one PDCCH per downlink assignment.

Each terminal monitors a set of PDCCHs as described in Chapter 10 for downlink scheduling assignments. A scheduling assignment is transmitted in the same subframe as the data. If a valid assignment matching the identity of the terminal is found, then the terminal receives and processes the transmitted signal as indicated in the assignment. Once the transport block is successfully decoded, the terminal will demultiplex the received data into the appropriate logical channels.

In the case of carrier aggregation, there is one PDCCH per component carrier. Furthermore, if cross-carrier scheduling is configured (see Chapter 10), the downlink assignment does not have to be transmitted on the same component carrier as the associated data, as information about the component carrier containing the associated data is included in the scheduling assignment in this case.

The scheduling strategy is implementation specific and not part of the 3GPP specifications. In principle, any of the schedulers described in Chapter 6 can be applied. However, the overall goal of most schedulers is to take advantage of the channel variations between terminals and preferably to schedule transmissions to a terminal when the channel conditions are advantageous. Most scheduling strategies therefore need information about:

- channel conditions at the terminal;
- buffer status and priorities of the different data flows;
- the interference situation in neighboring cells (if some form of interference coordination is implemented).

Information about the channel conditions at the terminal can be obtained in several ways. In principle, the eNodeB can use any information available, but typically the channel-state reports from the terminal, further described in Section 13.2.5, are used. However, additional sources of channel knowledge, for example exploiting channel reciprocity to estimate the downlink quality from uplink channel estimates in the case of TDD, can also be exploited by a particular scheduler implementation.

Petitioners' Exhibit 1003, p. 633
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

In addition to the channel-state information, the scheduler should take buffer status and priority levels into account. Obviously it does not make sense to schedule a terminal with empty transmission buffers. Priorities of the different types of traffic may also vary; RRC signaling may be prioritized over user data. Furthermore, RLC and hybrid-ARQ retransmissions, which are in no way different from other types of data from a scheduler perspective, are typically also given priority over initial transmissions.

Downlink inter-cell interference coordination is also part of the implementation-specific scheduler strategy. A cell may signal to its neighboring cells the intention to transmit with a lower transmission power in the downlink on a set of resource blocks. This information can then be exploited by neighboring cells as a region of low interference where it is advantageous to schedule terminals at the cell edge, terminals that otherwise could not attain high data rates due to the interference level. Inter-cell interference handling is further discussed in Section 13.3.

13.2.2 Uplink Scheduling

The basic function of the *uplink scheduler* is similar to its downlink counterpart, namely to dynamically determine, for each 1 ms interval, which terminals are to transmit and on which uplink resources. As discussed before, the LTE uplink is primarily based on maintaining orthogonality between different uplink transmissions and the shared resource controlled by the eNodeB scheduler is time–frequency resource units. In addition to assigning the time–frequency resources to the terminal, the eNodeB scheduler is also responsible for controlling the transport format the terminal will use for each of the uplink component carriers. As the scheduler knows the transport format the terminal will use when it is transmitting, there is no need for outband control signaling from the terminal to the eNodeB. This is beneficial from a coverage perspective, taking into account that the cost per bit of transmitting outband control information can be significantly higher than the cost of data transmission, as the control signaling needs to be received with higher reliability. It also allows the scheduler to tightly control the uplink activity to maximize the resource usage compared to schemes where the terminal autonomously selects the data rate, as autonomous schemes typically require some margin in the scheduling decisions. A consequence of the scheduler being responsible for selection of the transport format is that accurate and detailed knowledge about the terminal situation with respect to buffer status and power availability is more accentuated in LTE compared to systems where the terminal autonomously controls the transmission parameters.

The basis for uplink scheduling is *scheduling grants*, containing the scheduling decision and providing the terminal information about the resources and the associated transport format to use for transmission of the UL-SCH on one component carrier. Only if the terminal has a valid grant is it allowed to transmit on the corresponding UL-SCH; autonomous transmissions are not possible without a corresponding grant. Dynamic grants are valid for one subframe – that is, for each subframe in which the terminal is to transmit on the UL-SCH, the scheduler issues a new grant. Uplink component carriers are scheduled independently; if the terminal is to transmit simultaneously on multiple component carriers, multiple scheduling grants are needed.

The terminal monitors a set of PDCCHs as described in Chapter 10 for uplink scheduling grants. Upon detection of a valid uplink grant, the terminal will transmit its UL-SCH according to the information in the grant. Obviously, the grant cannot relate to the same subframe it was received in as the uplink subframe has already started when the terminal has decoded the grant. The terminal also needs

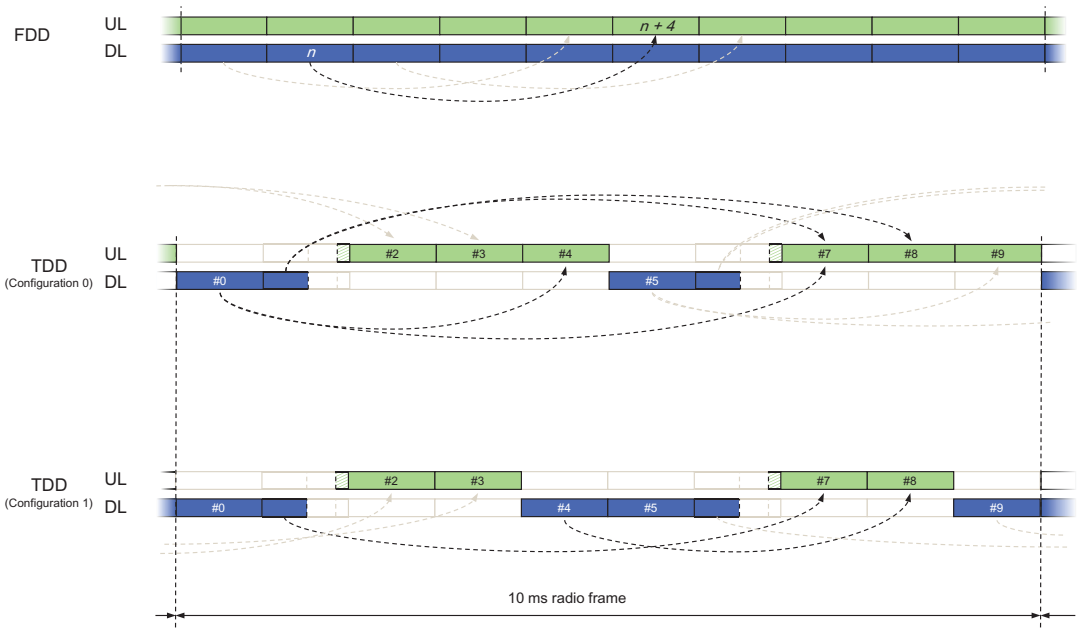


FIGURE 13.3

Timing relation for uplink grants in FDD and TDD configurations 0 and 1.

some time to prepare the data to transmit. Therefore, a grant received in subframe n affects the uplink transmission in a later subframe.

For FDD, the grant timing is straightforward. An uplink grant received in a subframe n triggers an uplink transmission in subframe $n + 4$, as illustrated in Figure 13.3. This is the same timing relation as used for uplink retransmission triggered by the PHICH, motivated by the possibility to override the PHICH by a dynamic scheduling grant, as described in Chapter 12.

For TDD, the situation is slightly more complicated as subframe $n + 4$ may not be an uplink subframe. Hence, for TDD configurations 1–6 the timing relation is modified such that the uplink transmission occurs in subframe $n + k$, where k is the smallest value larger than or equal to 4 such that subframe $n + k$ is an uplink subframe. This provides at least the same processing time for the terminal as in the FDD case while minimizing the delay from receipt of the uplink grant to the actual transmission. Note that this implies that the time between grant receipt and uplink transmission may differ between different subframes. Furthermore, for the downlink-heavy configurations 1–5, another property is that uplink scheduling grants can only be received in some of the downlink subframes.

For TDD configuration 0 there are more uplink subframes than downlink subframes, which calls for the possibility to schedule transmissions in multiple uplink subframes from a single downlink subframe. The same timing relation as for the other TDD configurations is used but with slight modifications. Recall from Chapter 10 that the grant transmitted in the downlink contains an uplink index consisting of two bits. For downlink–uplink configuration 0, the index field specifies which uplink subframe(s) a grant received in a downlink subframe applies to. For example, as illustrated in Figure 13.3, an uplink

scheduling grant received in downlink subframe 0 applies to one or both of the uplink subframes 4 and 7, depending on which of the bits in the uplink index are set.

Similarly to the downlink case, the uplink scheduler can exploit information about channel conditions, buffer status, and priorities of the different data flows, and, if some form of interference coordination is employed, the interference situation in neighboring cells. Channel-dependent scheduling, which typically is used for the downlink, can be used for the uplink as well. In the uplink, estimates of the channel quality can be obtained from the use of uplink channel sounding, as described in Chapter 11. For scenarios where the overhead from channel sounding is too costly, or when the variations in the channel are too rapid to be tracked, for example at high terminal speeds, uplink diversity can be used instead. The use of frequency hopping as discussed in Chapter 11 is one example of obtaining diversity in the uplink.

Inter-cell interference coordination can be used in the uplink for similar reasons as in the downlink by exchanging information between neighboring cells, as discussed in Section 13.3.

13.2.2.1 Uplink Priority Handling

Multiple logical channels of different priorities can be multiplexed into the same transport block using the same MAC multiplexing functionality as in the downlink (described in Chapter 8). However, unlike the downlink case, where the prioritization is under control of the scheduler and up to the implementation, the uplink multiplexing is done according to a set of well-defined rules in the terminal as a scheduling grant applies to a specific uplink carrier of a *terminal*, not to a specific radio bearer within the terminal. Using radio-bearer-specific scheduling grants would increase the control signaling overhead in the downlink and hence per-terminal scheduling is used in LTE.

The simplest multiplexing rule would be to serve logical channels in strict priority order. However, this may result in starvation of lower-priority channels; all resources would be given to the high-priority channel until its transmission buffer is empty. Typically, an operator would instead like to provide at least some throughput for low-priority services as well. Therefore, for each logical channel in an LTE terminal, a *prioritized data rate* is configured in addition to the priority value. The logical channels are then served in decreasing priority order up to their prioritized data rate, which avoids starvation as long as the scheduled data rate is at least as large as the sum of the prioritized data rates. Beyond the prioritized data rates, channels are served in strict priority order until the grant is fully exploited or the buffer is empty. This is illustrated in Figure 13.4.

13.2.2.2 Scheduling Requests and Buffer Status Reports

The scheduler needs knowledge about the amount of data awaiting transmission from the terminals to assign the proper amount of uplink resources. Obviously, there is no need to provide uplink resources to a terminal with no data to transmit as this would only result in the terminal performing padding to

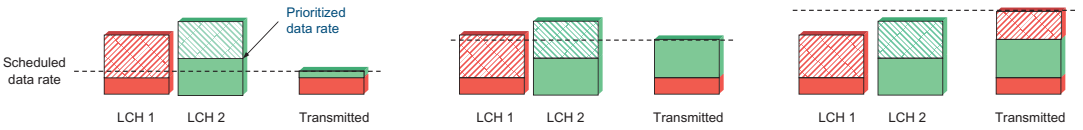


FIGURE 13.4

Prioritization of two logical channels for three different uplink grants.

fill up the granted resources. Hence, as a minimum, the scheduler needs to know whether the terminal has data to transmit and should be given a grant. This is known as a *scheduling request*.

A scheduling request is a simple flag, raised by the terminal to request uplink resources from the uplink scheduler. Since the terminal requesting resources by definition has no PUSCH resource, the scheduling request is transmitted on the PUCCH. Each terminal can be assigned a dedicated PUCCH scheduling request resource, occurring every *n*th subframe, as described in Chapter 11. With a dedicated scheduling-request mechanism, there is no need to provide the identity of the terminal requesting to be scheduled as the identity of the terminal is implicitly known from the resources upon which the request is transmitted. When data with higher priority than already existing in the transmit buffers arrives at the terminal and the terminal has no grant and hence cannot transmit the data, the terminal transmits a scheduling request at the next possible instant, as illustrated in Figure 13.5. Upon reception of the request, the scheduler can assign a grant to the terminal. If the terminal does not receive a scheduling grant until the next possible scheduling-request instant, then the scheduling request is repeated. There is only a single scheduling-request bit, irrespective of the number of uplink component carriers the terminal is capable of. In the case of carrier aggregation, the scheduling request is transmitted on the primary component carrier, in line with the general principle of PUCCH transmission on the primary component carrier only.

The use of a single bit for the scheduling request is motivated by the desire to keep the uplink overhead small, as a multi-bit scheduling request would come at a higher cost. A consequence of the single-bit scheduling request is the limited knowledge at the eNodeB about the buffer situation at the terminal when receiving such a request. Different scheduler implementations handle this differently. One possibility is to assign a small amount of resources to ensure that the terminal can exploit them efficiently without becoming power limited. Once the terminal has started to transmit on the UL-SCH, more detailed information about the buffer status and power headroom can be provided through the inband MAC control message, as discussed below. Knowledge of the service type may also be used – for example, in the case of voice the uplink resource to grant is preferably the size of a typical voice-over-IP package. The scheduler may also exploit, for example, path-loss measurements used for mobility and handover decisions to estimate the amount of resources the terminal may efficiently utilize.

An alternative to a dedicated scheduling-request mechanism would be a contention-based design. In such a design, multiple terminals share a common resource and provide their identity as part of the request. This is similar to the design of the random access. The number of bits transmitted from a terminal as part of a request would in this case be larger, with the correspondingly larger need for resources. In contrast, the resources are shared by multiple users. Basically, contention-based designs

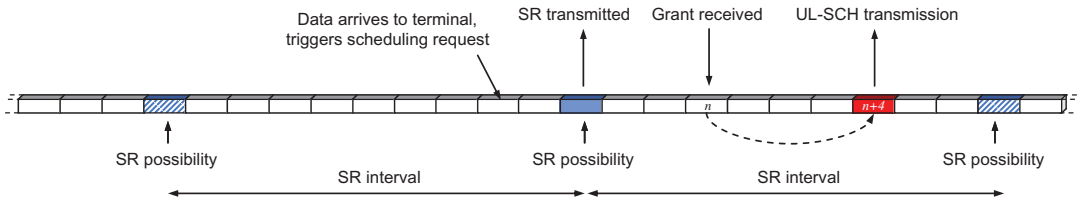


FIGURE 13.5

Scheduling-request transmission.

are suitable for a situation where there are a large number of terminals in the cell and the traffic intensity, and hence the scheduling intensity, is low. In situations with higher intensities, the collision rate between different terminals simultaneously requesting resources would be too high and lead to an inefficient design.

Although the scheduling-request design for LTE relies on dedicated resources, a terminal that has not been allocated such resources obviously cannot transmit a scheduling request. Instead, terminals without scheduling-request resources configured rely on the random-access mechanism described in Chapter 14. In principle, an LTE terminal can therefore be configured to rely on a contention-based mechanism if this is advantageous in a specific deployment.

Terminals that already have a valid grant obviously do not need to request uplink resources. However, to allow the scheduler to determine the amount of resources to grant to each terminal in future subframes, information about the buffer situation and the power availability is useful, as discussed above. This information is provided to the scheduler as part of the uplink transmission through MAC control elements (see Chapter 8 for a discussion on MAC control elements and the general structure of a MAC header). The LCID field in one of the MAC subheaders is set to a reserved value indicating the presence of a buffer status report, as illustrated in Figure 13.6.

From a scheduling perspective, buffer information for each logical channel is beneficial, although this could result in a significant overhead. Logical channels are therefore grouped into logical-channel groups and the reporting is done per group. The buffer-size field in a buffer-status report indicates the amount of data awaiting transmission across all logical channels in a logical-channel group. A buffer-status report represents one or all four logical-channel groups and can be triggered for the following reasons:

- Arrival of data with higher priority than currently in the transmission buffer – that is, data in a logical-channel group with higher priority than the one currently being transmitted – as this may impact the scheduling decision.
- Change of serving cell, in which case a buffer-status report is useful to provide the new serving cell with information about the situation in the terminal.
- Periodically as controlled by a timer.

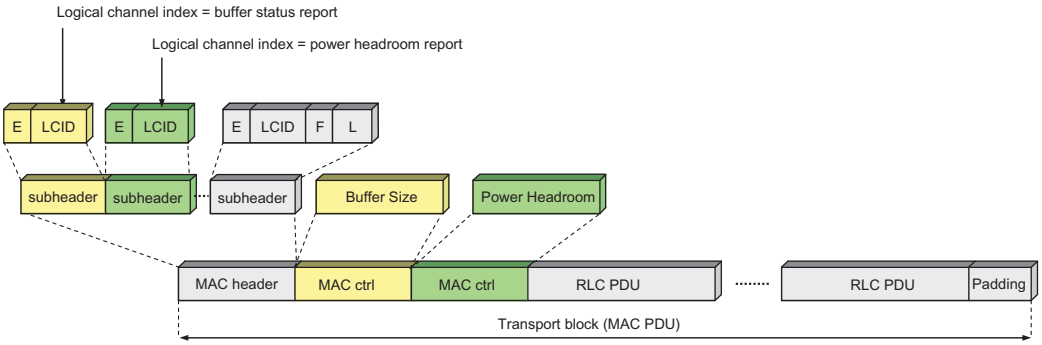


FIGURE 13.6

Signaling of buffer status and power-headroom reports.

- Instead of padding. If the amount of padding required to match the scheduled transport block size is larger than a buffer-status report, a buffer-status report is inserted. Clearly it is better to exploit the available payload for useful scheduling information instead of padding if possible.

In addition to buffer status, the amount of transmission power available in each terminal is also relevant for the uplink scheduler. Obviously, there is little reason to schedule a higher data rate than the available transmission power can support. In the downlink, the available power is immediately known to the scheduler as the power amplifier is located in the same node as the scheduler. For the uplink, the power availability, or power headroom (as discussed in Section 13.1.5), is defined as the difference between the nominal maximum output power and the estimated output power for UL-SCH transmission. This quantity can be positive as well as negative (on a dB scale), where a negative value would indicate that the network has scheduled a higher data rate than the terminal can support given its current power availability. The power headroom depends on the power-control mechanism and thereby indirectly on factors such as the interference in the system and the distance to the base stations.

Information about the power headroom is fed back from the terminals to the eNodeB in a similar way as the buffer-status reports – that is, only when the terminal is scheduled to transmit on the UL-SCH. Type-1 reports are provided for all component carriers simultaneously, while Type-2 reports are provided for the primary component carrier only.

A power headroom report can be triggered for the following reasons:

- Periodically as controlled by a timer.
- Change in path loss, since the last power headroom report is larger than a (configurable) threshold.
- Instead of padding (for the same reason as buffer-status reports).

It is also possible to configure a prohibit timer to control the minimum time between two power-headroom reports and thereby the signaling load on the uplink.

13.2.3 Semi-Persistent Scheduling

The basis for uplink and downlinks scheduling is dynamic scheduling, as described in Sections 13.2.1 and 13.2.2. dynamic scheduling with a new scheduling decision taken in each subframe allows for full flexibility in terms of the resources used and can handle large variations in the amount of data to transmit at the cost of the scheduling decision being sent on a PDCCH in each subframe. In many situations, the overhead in terms of control signaling on the PDCCH is well motivated and relatively small compared to the payload on DL-SCH/UL-SCH. However, some services, most notably voice-over IP, are characterized by regularly occurring transmission of relatively small payloads. To reduce the control signaling overhead for those services, LTE provides semi-persistent scheduling in addition to dynamic scheduling.

With semi-persistent scheduling, the terminal is provided with the scheduling decision on the PDCCH, together with an indication that this applies to every nth subframe until further notice. Hence, control signaling is only used once and the overhead is reduced, as illustrated in Figure 13.7. The periodicity of semi-persistently scheduled transmissions – that is, the value of n – is configured by RRC signaling in advance, while activation (and deactivation) is done using the PDCCH using the semi-persistent C-RNTI.[3] For example, for voice-over IP the scheduler can configure a periodicity

[3]Each terminal has two identities, the "normal" C-RNTI for dynamic scheduling and the semi-persistent C-RNTI for semi-persistent scheduling.

Petitioners' Exhibit 1003, p. 639
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

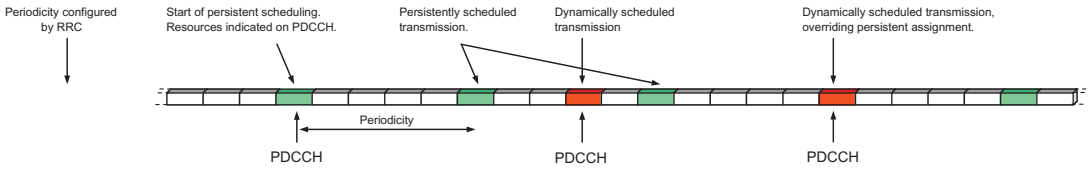


FIGURE 13.7

Example of semi-persistent scheduling.

of 20 ms for semi-persistent scheduling and, once a talk spurt starts, the semi-persistent pattern is triggered by the PDCCH.

After enabling semi-persistent scheduling, the terminal continues to monitor the PDCCH for uplink and downlink scheduling commands. When a dynamic scheduling command is detected, it takes precedence over the semi-persistent scheduling in that particular subframe, which is useful if the semi-persistently allocated resources occasionally need to be increased. For example, for voice-over IP in parallel with web browsing it may be useful to override the semi-persistent resource allocation with a larger transport block when downloading the web page.

For the downlink, only initial transmissions use semi-persistent scheduling. Retransmissions are explicitly scheduled using a PDCCH assignment. This follows directly from the use of an asynchronous hybrid-ARQ protocol in the downlink. Uplink retransmissions, in contrast, can either follow the semi-persistently allocated subframes or be dynamically scheduled.

Semi-persistent scheduling is only supported on the primary component carrier and any transmission on a secondary component carrier must be dynamically scheduled. This is reasonable as semi-persistent scheduling is intended for low-rate services for which a single component carrier is sufficient.

13.2.4 Scheduling for Half-Duplex FDD

Half-duplex FDD implies that a single terminal cannot receive and transmit at the same time while the eNodeB still operates in full duplex. In LTE, half-duplex FDD is implemented as a scheduler constraint, implying it is up to the scheduler to ensure that a single terminal is not scheduled simultaneous in uplink and downlink. Hence, from a terminal perspective, subframes are dynamically used for uplink or downlink. Briefly, the basic principle for half-duplex FDD is that a terminal is receiving in the downlink unless it has been explicitly instructed to transmit in the uplink (either UL-SCH transmission or hybrid-ARQ acknowledgements triggered by a downlink transmission). The timing and structure for control signaling are identical between half- and-full duplex FDD terminals.

An alternative design approach would be to base half-duplex FDD on the TDD control signaling structure and timing, with a semi-static configuration of subframes to either downlink or uplink. However, this would complicate supporting a mixture of half- and-full duplex terminals in the same cell as the timing of the control signaling would differ. It would also imply a waste of uplink spectrum resources. All terminals need to be able to receive subframes 0 and 5, as those subframes are used for system information and synchronization signals. Hence, if a fixed uplink–downlink allocation were to be used, no uplink transmissions could take place in those two subframes, resulting in a

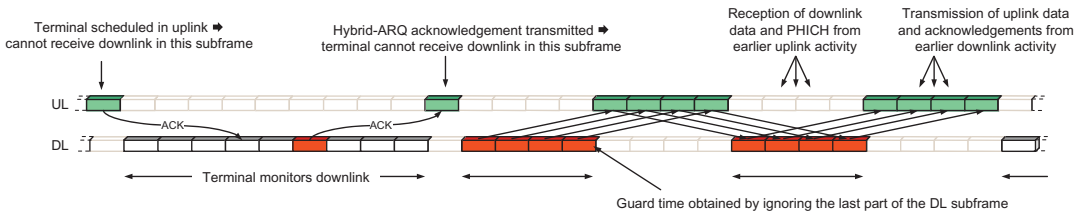


FIGURE 13.8

Example of half-duplex FDD terminal operation.

loss in uplink spectral efficiency of 20%. Clearly this is not attractive and led to the choice of implementing half-duplex FDD as a scheduling strategy instead.

An example of half-duplex operation as seen from a terminal perspective is shown in Figure 13.8. In the leftmost part of the figure, the terminal is explicitly scheduled in the uplink and, consequently, cannot receive data in the downlink in the same subframe. The uplink transmission implies the receipt of an acknowledgement on the PHICH four subframes later, as mentioned in Chapter 12, and therefore the terminal cannot be scheduled in the uplink in this subframe. Similarly, when the terminal is scheduled to receive data in the downlink in subframe n, the corresponding hybrid-ARQ acknowledgement needs to be transmitted in the uplink subframe $n + 4$, preventing downlink reception in subframe $n + 4$. The scheduler can exploit this by scheduling downlink data in four consecutive subframes and uplink transmission in the four next subframes when the terminal needs to transmit hybrid-ARQ acknowledgements in the uplink anyway, and so on. Hence, at most half of the time can be used in the downlink and half in the uplink or, in other words, the asymmetry in half-duplex FDD is 4:4. Efficient support of half-duplex FDD is one of the reasons why the same number of hybrid-ARQ processes was selected in uplink and downlink.

Note that, as the eNodeB is operating in full duplex, regardless of the duplex capability of the terminals, the cell capacity is hardly affected by the presence of half-duplex terminals as, given a sufficient number of terminals with data to transmit/receive, the scheduler can with a high likelihood find a set of terminals to schedule in the uplink and another set to schedule in the downlink in a given subframe.

Similar to TDD, a half-duplex terminal needs some guard time for switching between uplink and downlink. For half-duplex FDD, guard time for the downlink-to-uplink switch is created by allowing the terminal to skip receipt of the last OFDM symbols in a downlink subframe immediately preceding an uplink subframe, as described in Chapter 9. Guard time for the uplink-to-downlink switch is handled by setting the appropriate amount of timing advance in the terminals.

13.2.5 Channel-State Reporting

As mentioned several times, the possibility for downlink channel-dependent scheduling – that is, selecting the downlink transmission configuration and related parameters depending on the instantaneous downlink channel conditions – is a key feature of LTE. An important part of the support for downlink channel-dependent scheduling is *channel-state reports* provided by terminals to the network, reports on which the latter can base its scheduling decisions.

The channel-state reports consist of one or several pieces of information:

- *Rank indication* (RI), providing a recommendation on the transmission rank to use or, expressed differently, the number of layers that should preferably be used for downlink transmission to the terminal. RI only needs to be reported by terminals that are configured to be in one of the spatial-multiplexing transmission modes. There is at most one RI reported, valid across the full bandwidth – that is, the RI is frequency non-selective. Frequency-dependent transmission rank would be impossible to utilize since all layers are transmitted on the same set of resource blocks in LTE.
- *Precoder matrix indication* (PMI), indicating which of the precoder matrices (see Chapter 10) should preferably be used for the downlink transmission. The reported precoder matrix is determined assuming the number of layers indicated by the RI. The precoder recommendation may be frequency selective, implying that the terminal may recommend different precoders for different parts of the downlink spectrum. Furthermore, the network can restrict the set of matrices from which the terminal should select the recommended precoder, so-called codebook subset restriction, to avoid reporting precoders that are not useful in the antenna setup used.
- *Channel-quality indication* (CQI), representing the highest modulation-and-coding scheme that, if used, would mean PDSCCH transmissions (using the recommended RI and PMI) were received with a block-error rate of at most 10%. The reason to use CQI as a feedback quantity instead of, for example, the signal-to-noise ratio, is to account for different receiver implementation in the terminal. Also, basing the feedback reports on CQI instead of signal-to-noise ratio also simplifies the testing of terminals; a terminal delivering data with more than 10% block-error probability when using the modulation-and-coding scheme indicated by the CQI would fail the test. As will be discussed further below, multiple CQI reports, each representing the channel quality in a certain part of the downlink spectrum, can be part of a channel-state report.

Together, a combination of the RI, PMI, and CQI forms a channel-state report. Exactly what is included in a channel-state report depends on the reporting mode the terminal is configured to be in. As mentioned earlier, RI and PMI do not need to be reported unless the terminal is in a spatial-multiplexing transmission mode. However, also given the transmission mode, there are different reporting modes that typically differ as to what set of resource blocks the report is valid for and whether precoding information is reported or not. The type of information useful to the network also depends on the particular implementation and antenna deployment.

Although referred to as channel-state reports, what a terminal delivers to the network are not explicit reports of the downlink channel state. Rather, what the terminal delivers are *recommendations* on the transmission rank and precoding matrix to use, together with an indication of the highest possible modulation-and-coding scheme that the network preferably should not exceed. Information about the actual modulation scheme and coding rate used for DL-SCH transmission as well as the set of resource blocks used for the transmission is always included in the downlink scheduling assignment. Hence, the eNodeB is free to follow the CSI report or to select transmission parameters on its own.

The modulation-and-coding scheme used for DL-SCH transmission can, and often will, differ from the reported CQI as the scheduler needs to account for additional information not available to the terminal when recommending a certain CQI. For example, the set of resource blocks used for the DL-SCH transmission also need to account for other users. Furthermore, the amount of data awaiting transmission in the eNodeB also needs to be accounted for. Obviously, there is no need to select a very high data rate, even if the channel conditions would permit this, if there is only a small amount

Petitioners' Exhibit 1003, p. 642
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

of data to transmit and a sufficient number of resource blocks can be allocated to the terminal in question.

With regards to the precoder-related recommendations, the network has two choices:

- The network may follow the latest terminal recommendation, in which case the eNodeB only has to confirm (a one-bit indicator in the downlink scheduling assignment) that the precoder configuration recommended by the terminal is used for the downlink transmission. On receiving such a confirmation, the terminal will use its recommended configuration when demodulating and decoding the corresponding DL-SCH transmission. Since the PMI computed in the terminal can be frequency selective, an eNodeB following the precoding matrix recommended by the terminal may have to apply different precoding matrices for different (sets of) resource blocks.
- The network may select a different precoder, information about which then needs to be explicitly included in the downlink scheduling assignment. The terminal then uses this configuration when demodulating and decoding the DL-SCH. To reduce the amount of downlink signaling, only a single precoding matrix can be signaled in the scheduling assignment, implying that, if the network overrides the recommendation, then the precoding is frequency non-selective. The network may also choose to override the transmission rank only, in which case the terminal assumes that a subset of the columns in each of the recommended precoder matrices is used.

There are two types of channel-state reports in LTE, *aperiodic* and *periodic*, which are different in terms of how a report is triggered:

- Aperiodic channel-state reports are delivered when explicitly requested by the network by means of the channel-state-request flag included in uplink scheduling grants (see Section 10.4.5). An aperiodic channel-state report is always delivered using the PUSCH – that is, on a dynamically assigned resource.
- Periodic channel-state reports are configured by the network to be delivered with a certain periodicity, possibly as often as once every 2 ms, on a semi-statically configured PUCCH resource. However, similar to hybrid-ARQ acknowledgements normally delivered on PUCCH, channel-state reports are "re-routed" to the PUSCH[4] if the terminal has a valid uplink grant and is anyway to transmit on the PUSCH.

Aperiodic and periodic reports, despite both providing estimates on the channel conditions, are quite different in terms of their detailed contents and the usage. In general, aperiodic reports are larger and more detailed than their periodic counterparts. There are several reasons for this. First, the PUSCH, upon which the aperiodic report is transmitted, is capable of a larger payload, and hence a more detailed report, than the PUCCH used for the periodic reports. Furthermore, as aperiodic reports are transmitted on a per-need basis only, the overhead from these reports are less of an issue compared to periodic reports. Finally, if the network requests a report it is likely that it will transmit a large amount of data to the terminal, which makes the overhead from the report less of an issue compared to a periodic report that is transmitted irrespective of whether the terminal in question will be scheduled in the near future or not. Hence, as the structure and usage of aperiodic and periodic reports is different, they are described separately below, starting with aperiodic reports.

[4] In release 10, a terminal can be configured for simultaneous PUSCH and PUCCH transmission, in which case the periodic channel-state reports can remain on the PUCCH.

Petitioners' Exhibit 1003, p. 643
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Three aperiodic reporting modes are supported in LTE, where each mode has several submodes depending on the configuration:

- Wideband reports, reflecting the average channel quality across the entire cell bandwidth with a single CQI value. Despite a single average CQI value being provided for the whole bandwidth, the PMI reporting is frequency selective. Frequency-selective reporting is obtained, for reporting purposes only, by dividing the overall downlink bandwidth (of each component carrier) into a number of equally sized *sub-bands*, where each sub-band consists of a set of consecutive resource blocks. The size of a sub-band, ranging from four to eight resource blocks, depends on the cell bandwidth. The PMI is then reported for each sub-band. For transmission modes supporting spatial multiplexing, the CQI and the PMI are calculated assuming the channel rank indicated by the RI, otherwise rank-1 is assumed. Wideband reports are smaller than their frequency-selective counterparts, but obviously do not provide any information about the frequency domain.
- UE-selected reports, where the terminal selects the best M sub-bands and reports, in addition to the indices of the selected sub-bands, one CQI reflecting the average channel quality over the selected M sub-bands together with one wideband CQI reflecting the channel quality across the full downlink carrier bandwidth. This type of report thus provides frequency-domain information about the channel conditions. The sub-band size, ranging from two to four resource blocks, and the value of M, ranging from 1 to 6, depends on the downlink carrier bandwidth. Depending on the transmission mode configured, the PMI and RI are also provided as part of this type of report.
- Configured reports, where the network configured the set of sub-bands the terminal should generate reports for. The terminal reports one wideband CQI reflecting the channel quality across the full downlink carrier bandwidth and one CQI per configured sub-band. The sub-band size depends on the downlink carrier bandwidth and is in the range of four to eight resource blocks. Depending on the transmission mode configured, the PMI and RI are also provided as part of this type of report.

The different aperiodic reporting modes are summarized in Table 13.1.

Periodic reports are configured by the network to be delivered with a certain periodicity. The limited, compared to PUSCH, payload supported on the PUCCH also implies that the different types of information in a periodic report may not be possible to transmit in a single subframe. Therefore, some of the reporting modes will transmit one or several of the wideband CQI, the wideband CQI including PMI, the RI, and the CQI for the UE-selected sub-bands at different time points. Furthermore, the RI can typically be reported less often, compared to the reporting of PMI and CQI, reflecting the fact that the suitable number of layers typically varies on a slower basis, compared to the channel variations that impact the choice of precoder matrix and modulation rate, and coding scheme.

Two periodic reporting modes are supported in LTE, again with different submodes possible:

- Wideband reports, reflecting the average channel quality across the entire cell bandwidth with a single CQI value. If PMI reporting is enabled, a single PMI valid across the full bandwidth is reported.
- UE-selected reports. Although named in the same way as for aperiodic reports, the principle for UE-selected periodic reports is different. The total bandwidth (of a component carrier) is divided into one to four *bandwidth parts*, with the number of bandwidth parts obtained form the cell bandwidth. For each bandwidth part, the terminal selects the best sub-band within that part. The

Table 13.1 Possible Aperiodic Reporting Modes for Different Transmission Modes

Transmission Mode		Reporting Mode							
		Wideband CQI		Frequency-Selective CQI					
				UE-Selected Sub-Bands			Conf. Sub-Bands		
		1-0: No PMI	1-1: Wideband PMI	1-2: Selective PMI	2-0: No PMI	2-1: Wideband PMI	2-2: Selective PMI	3-0: No PMI	3-1: Wideband PMI
1	Single antenna, CRS				•			•	
2	Transmit diversity				•			•	
3	Open-loop spatial mux.				•			•	
4	Closed-loop spatial mux.			•			•		•
5	Multi-user MIMO								•
6	Codebook-based beam-forming			•			•		•
7	Single-layer trans., DM-RS				•			•	
8	Dual-layer trans., DM-RS			•	•		•	•	•
9	Multi-layer trans., DM-RS			•	•		•	•	•

sub-band size ranges from four to eight resource blocks. Since the supported payload size of the PUCCH is limited, the reporting cycles through the bandwidth parts and in one subframe report the wideband CQI and PMI (if enabled) for that bandwidth part, as well as the best sub-band and the CQI for that sub-band. The RI (if enabled) is reported in a separate subframe.

The different aperiodic reporting modes are summarized in Table 13.2. Note that all PMI reporting, if enabled, is of wideband type. There is no support for frequency-selective PMI in periodic reporting, as the amount of bits would result in a too large overhead.

A typical use of periodic and aperiodic reporting could be to configure lightweight periodic CSI reporting PUCCH, for example to provide feedback of the wideband CQI and no PMI information (mode 1-0). Upon arrival of data to transmit in the downlink to a specific terminal, aperiodic reports could be requested as needed, for example with frequency-selective CQI and PMI (mode 3-1).

Channel-state reports, irrespective of whether they are aperiodic or periodic, need a known reference signal as input to the CSI computation. The cell-specific reference signals can be used for this purpose, and is the only possibility in release 8/9, but in release 10 channel-state reports can also be based on the CSI-RS (see Chapter 10 for a discussion on CSI-RS). Which reference signal to base the channel-state reports upon is linked to the transmission mode. For transmission modes already supported in release 8/9, the cell-specific reference signals are used, while for transmission mode 9, introduced in release 10, the CSI-RS is used.

The discussion above also holds for carrier aggregation, although with some modifications and enhancements as channel-state reports for multiple downlink component carriers are needed.

For aperiodic reporting, the two-bit[5] CSI request in the downlink control signaling allows for three different types of CSI reports to be requested (the fourth bit combination represents no CSI request). Of these three alternatives, one is used to trigger a CSI reports for the downlink component carrier associated with the uplink component carrier for which the scheduling grant relates to. The remaining alternatives point to one of two configurable combinations of component carriers for which the CSI report should be generated. Thus, as an example, for a terminal capable of two downlink component carriers, aperiodic reports can, with the proper configuration, be requested for the primary component carrier, the secondary component carrier, or both.

For periodic reporting, the basic principle in the case of carrier aggregation is to configure the reporting cycles such that the CSI reports for the different component carriers are not transmitted simultaneously.

13.2.6 Discontinuous Reception (DRX) and Component Carrier Deactivation

Packet-data traffic is often highly bursty, with occasional periods of transmission activity followed by longer periods of silence. Clearly, from a delay perspective, it is beneficial to monitor the downlink control signaling in each subframe to receive uplink grants or downlink data transmissions and instantaneously react on changes in the traffic behavior. At the same time this comes at a cost in terms of power consumption at the terminal; the receiver circuitry in a typical terminal represents a non-negligible amount of power consumption. To reduce the terminal power consumption, LTE includes mechanisms for *discontinuous reception* (DRX).

[5]Recall from Chapter 10 that the CSI request field expanded from one to two bits in the case of carrier aggregation.

Table 13.2 Possible Periodic Reporting Modes for Different Transmission Modes

Transmission Mode		Reporting Mode							
		Wideband CQI		Frequency-Selective CQI					
				UE-Selected Sub-Bands			Conf. Sub-Bands		
		1-0: No PMI	1-1: Wideband PMI	1-2: Selective PMI	2-0: No PMI	2-1: Wideband PMI	2-2: Selective PMI	3-0: No PMI	3-1: Wideband PMI
1	Single antenna, CRS	•			•				
2	Transmit diversity	•			•				
3	Open-loop spatial mux.	•			•				
4	Closed-loop spatial mux.		•			•			
5	Multi-user MIMO		•			•			
6	Codebook-based beam-forming		•			•			
7	Single-layer trans., DM-RS	•			•				
8	Dual-layer trans., DM-RS	•	•		•	•			
9	Multi-layer trans., DM-RS	•	•		•	•			

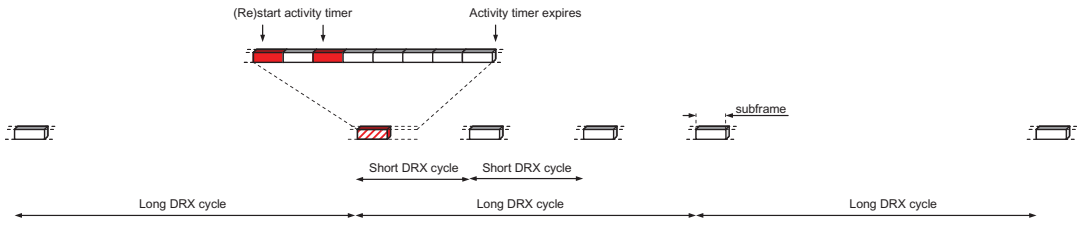


FIGURE 13.9

Illustration of DRX operation.

The basic mechanism for DRX is a configurable DRX cycle in the terminal. With a DRX cycle configured, the terminal monitors the downlink control signaling only in one subframe per DRX cycle, sleeping with the receiver circuitry switched off in the remaining subframes. This allows for a significant reduction in power consumption: the longer the cycle, the lower the power consumption. Naturally, this implies restrictions to the scheduler as the terminal can be addressed only in the active subframes.

In many situations, if the terminal has been scheduled and active with receiving or transmitting data in one subframe, it is highly likely it will be scheduled again in the near future. One reason could be that it was not possible to transmit all the data in the transmission buffer in one subframe and additional subframes are required. Waiting until the next active subframe according to the DRX cycle, although possible, would result in additional delays. Hence, to reduce the delays, the terminal remains in the active state for a certain configurable time after being scheduled. This is implemented by the terminal (re)starting an inactivity timer every time it is scheduled and remaining awake until the time expires, as illustrated at the top of Figure 13.9.

Retransmissions take place regardless of the DRX cycle. Thus, the terminal receives and transmits hybrid-ARQ acknowledgements as normal in response to data transmission. In the uplink, this also includes retransmissions in the subframes given by the synchronous hybrid-ARQ timing relation. In the downlink, where asynchronous hybrid ARQ is used, the retransmission time is not fixed in the specifications. To handle this, the terminal monitors the downlink for retransmissions in a configurable time window after the previous transmission.

The above mechanism, a (long) DRX cycle in combination with the terminal remaining awake for some period after being scheduled, is sufficient for most scenarios. However, some services, most notably voice-over IP, are characterized by periods of regular transmission, followed by periods of no or very little activity. To handle these services, a second short DRX cycle can optionally be used in addition to the long cycle described above. Normally, the terminal follows the long DRX cycle, but if it has recently been scheduled, it follows a shorter DRX cycle for some time. Handling voice-over IP in this scenario can be done by setting the short DRX cycle to 20 ms, as the voice codec typically delivers a voice-over-IP packet per 20 ms. The long DRX cycle is then used to handle longer periods of silence between talk spurts.

The DRX mechanism described above is common to all component carriers configured in the terminal. Hence, if the terminal is in DRX it is not receiving on any component carrier, but when it wakes up, all (activated) component carriers will be woken up. Although discontinuous reception greatly reduces the terminal power consumption, it is possible to go one step further in the case of

Petitioners' Exhibit 1003, p. 648
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

carrier aggregation. Obviously, from a power-consumption perspective, it is beneficial to receive on as few component carriers as possible. LTE therefore supports deactivation of downlink component carriers. A deactivated component carrier maintains the configuration provided by RRC but cannot be used for reception, neither PDCCH nor PDSCH. When the need arises, a downlink component carrier can be activated rapidly and used for reception within a few subframes. A typical use would be to configure several component carriers but deactivate all component carriers except the primary one. When a data burst starts, the network could activate several component carriers to maximize the downlink data rate. Once the data burst is delivered, the component carriers could be deactivated again to reduce terminal power consumption.

Activation and deactivation of downlink component carriers are done through MAC control elements. A command to activate a component carrier takes effect eight subframes after receipt – that is, if the MAC control element is received in subframe n, then the additional component carriers are activated starting from subframe $n + 8$. There is also a timer-based mechanism for deactivation such that a terminal may, after a configurable time with no activity on a certain component carrier, deactivate that component carrier. The primary component carrier is always active as it must be possible for the network to communicate with the terminal.

In the uplink there is no explicit activation of uplink component carriers. However, whenever a downlink component carrier is activated or deactivated, the corresponding uplink component carrier is also activated or deactivated.

13.3 INTER-CELL INTERFERENCE COORDINATION

Like all modern mobile-communication technologies, LTE can be deployed with one-cell frequency reuse. Fundamentally, this implies that the LTE transmission structure has been designed so that reliable transmission is also possible for the low signal-to-interference ratios (SIR) that may occur in a reuse-one deployment when the same time–frequency resource issued in neighboring cells (SIR as low as -5 dB or even somewhat lower in the worst case[6]). This is especially true for transmission of critical information such as system information and L1/L2 control signaling. It should be noted that data transmission on DL-SCH can always be made sufficiently reliable by selecting a sufficiently low instantaneous data rate in combination with hybrid-ARQ retransmissions.

Still, a one-cell frequency reuse typically implies relatively large SIR variations over the cell area. As a consequence, the data rates that can be offered to the end-user may also vary substantially, with only relatively low data rates being available at the "cell edge".

If one was *only* interested in maximizing the data rates that could be offered to users at the cell edge – that is, maximizing the "worst-case-user" quality – a reuse larger than one could actually be preferred. For cell-edge users receiving high interference from neighboring cells, the negative impact of reduced bandwidth availability due to frequency reuse larger than one could be more than compensated for by the higher SIR and corresponding higher achievable data rate per MHz, leading to overall higher achievable data rates. However, the overall system efficiency would be degraded as the

[6]This assumes a relatively homogeneous deployment. In *heterogeneous network deployments* with large differences in the cell output powers, the SIR could be even lower and special means may need to be taken to ensure reliable transmission, as discussed in Section 13.4.

Petitioners' Exhibit 1003, p. 649
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

majority of users are not at the cell edge and thus have a relatively good SIR even with one-cell reuse. For such users, any further SIR improvement due to larger reuse would typically not be able to compensate for the reduced bandwidth availability for at least two reasons:

- The relative interference reduction and corresponding increase in SIR would not be as large as for users on the cell edge.
- The achievable data rates do not vary linearly with the SIR and, especially for high SIR, a further SIR improvement may give a relatively small increase in achievable data rate per MHz, as was discussed in Chapter 2.

Furthermore, the assumption of low SIR at the cell edge in the case of one-cell reuse is based on the assumption that there really are transmissions ongoing in the neighboring cells. There are always time instances when there is no or at least limited transmission ongoing in a cell, especially at low-load conditions. The cell-edge SIR may then be relatively good even with a one-cell reuse and a higher reuse with a corresponding reduction in the bandwidth available per cell would not be beneficial even from a cell-edge-user point of view.

Thus, the basic mode of operation should be one-cell reuse, giving each cell access to the overall available spectrum. However, system performance, and especially the quality for cell-edge users, could be further enhanced if one could at least partly coordinate the scheduling between neighboring cells. The basic principle of such *inter-cell interference coordination* (ICIC) would be to, if possible, avoid high-power transmission on time–frequency resources on which cell-edge users are scheduled in neighboring cells, users that would otherwise experience high interference and correspondingly low data rates. This kind of "selective" interference avoidance would benefit the cell-edge-user quality and could also enhance overall system performance.

The above discussion implicitly assumed downlink transmission with terminals at the cell edge being interfered by downlink transmissions from other cells. The concept of inter-cell interference coordination is equally applicable to the uplink, although the interference situation in this case is somewhat different.

For the uplink, the interference level experienced by a certain link does not depend on where the transmitting terminal is located, but rather on the location of the *interfering* terminals, with interfering terminals closer to the cell border causing more interference to neighboring cells. The location of the transmitting terminal is still important though, as a terminal closer to the cell site can raise its transmission power to compensate for high interference coming from terminals in neighboring cells, something that may not be possible for cell-edge terminals. Thus, the fundamental goal of uplink inter-cell interference is the same as for the downlink – that is, to coordinate the, in this case, uplink scheduling between cells to avoid simultaneous transmissions from terminals at the cell border in neighboring cells causing severe interference to each other.

In the case of scheduling located at a higher-level node above the eNodeB, coordinated scheduling between cells of different eNodeB would, at least conceptually, be straightforward. However, in LTE there is no higher-level node and scheduling is carried out locally at the eNodeB – that is, in practice at the cell site.[7] Thus, the best that can be done in the radio-access specifications is to introduce messages that convey information about the scheduling strategy between neighboring eNodeBs using the

[7] As discussed below, in case of so-called centralized RAN (C-RAN) this may change somewhat.

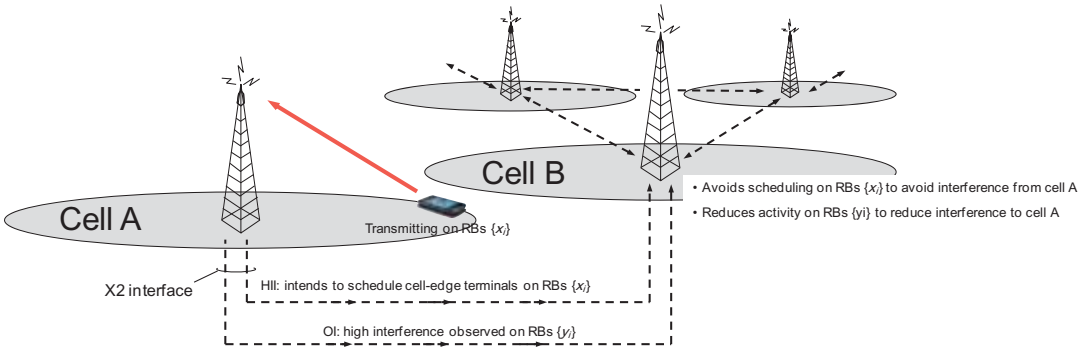


FIGURE 13.10

Illustration of uplink ICIC based on HII and OI X2 signaling.

X2 interface. An eNodeB can then use the information provided by a neighboring eNodeB as input to its own scheduling process. For LTE, a number of such ICIC-related X2 messages have been defined.

To assist uplink interference coordination, two messages are defined, the *High Interference Indicator* (HII) and the *Overload Indicator* (OI), see also Figure 13.10.

The *High Interference Indicator* provides information about the set of resource blocks within which an eNodeB is likely to schedule transmissions from cell-edge terminals – that is, resource blocks on which a neighboring cell can expect higher interference. Although nothing is explicitly specified on how an eNodeB should react to the HII (or any other ICIC-related X2 signaling) received from a neighboring eNodeB, a reasonable action for the receiving eNodeB would be to try to avoid scheduling its own cell-edge terminals on the same resource blocks, thereby reducing the uplink interference to cell-edge transmissions in its own cell as well as in the cell from which the HII was received. The HII can thus be seen as a *proactive* tool for ICIC, trying to prevent the occurrence of *too-low-SIR* situations.

In contrast to the HII, the *Overload Indicator* (OL) is a *reactive* ICIC tool, essentially indicating, at three levels (Low/Medium/High), the uplink interference experienced by a cell on its different resource blocks. A neighboring eNodeB receiving the OI could then change its scheduling behavior to improve the interference situation for the eNodeB issuing the OI.

For the downlink, *the Relative Narrowband Transmit Power* (RNTP) is defined to support ICIC operation (see Figure 13.11). The RNTP is similar to the HII in the sense that it provides information, for each resource block, whether or not the relative transmit power of that resource block is to exceed a certain level. Similar to the HII, a neighboring cell can use the information provided by the received RNTP when scheduling its own terminals, especially terminals on the cell edge that are more likely to be interfered by the neighboring cell.

One kind of deployment that has recently received some interest is the *Centralized RAN* (C-RAN) [73], where the baseband processing of the eNodeBs is located in a central office, geographically separate from the actual cell sites. In such a scenario it is more straightforward to coordinate the scheduling between multiple geographically separate cells, either by introducing inter-eNodeB coordination within the central office or by simply deploying a massive eNodeB able to handle all the

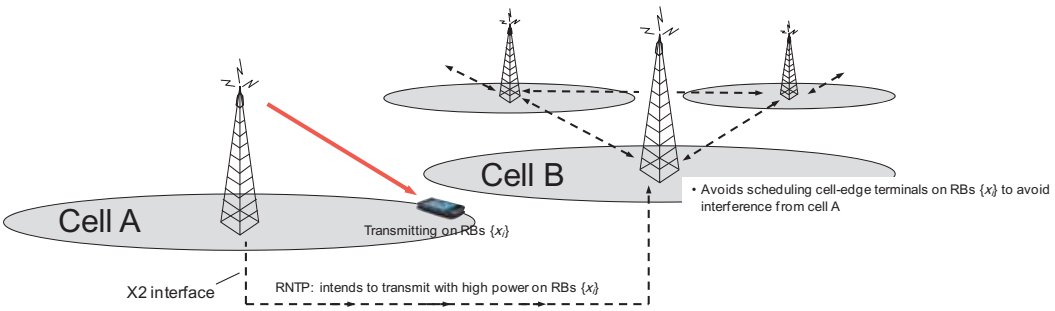


FIGURE 13.11

Illustration of downlink ICIC based on RNTP X2 signaling.

cells connected to the central office. As an eNodeB is anyway just a logical node, in terms of physical realization these two approaches are essentially the same thing.

13.4 HETEROGENEOUS NETWORK DEPLOYMENTS

The continuous increase in traffic within mobile-broadband systems and an equally continuous increase in terms of the data rates requested by end-users will impact how cellular networks are deployed in the future. In general, providing very high system capacity (traffic per m^2) and very high per-user data rates will require a densification of the radio-access network – that is, the deployment of additional network nodes. By increasing the number of cells, the traffic per m^2 can be increased without requiring a corresponding increase in the traffic that needs to be supported per network node. Also, by increasing the number of network nodes, the base-station-to-terminal distances will, in general, be shorter, implying a link-budget improvement and a corresponding improvement in achievable data rates.

A general densification of the macro-cell layer – that is, reducing the coverage area of each cell and increasing the total number of macro-cell sites[8] – as illustrated in the upper part of Figure 13.12, is a path that has already been taken by many operators. As an example, in many major cities the distance between macro-cell sites is often less than a few hundred meters in many cases.

An alternative or complement to a uniform densification of the macro-cell layer is to deploy additional lower-power nodes under the coverage area of a macro cell, as illustrated in the lower part of Figure 13.12. In such a *heterogeneous* or *multi-layered* network deployment, the underlaid *pico-cell* layer does not need to provide full-area coverage. Rather, pico sites can be deployed to increase capacity and achievable data rates where needed. Outside of the pico-layer coverage, terminals would access the network by means of the overlaid macro cell.

Another example of heterogeneous network deployment is the complementary use of so-called *home-eNodeBs*, also often referred to as *femto* base stations. A home-eNodeB corresponds to a small low-power base station deployed by the end-user, typically within the home, and connecting to the operator network using the end-user's wireline broadband connection.

[8] A macro cell is herein defined as a high-power cell with its antennas typically located above rooftop level.

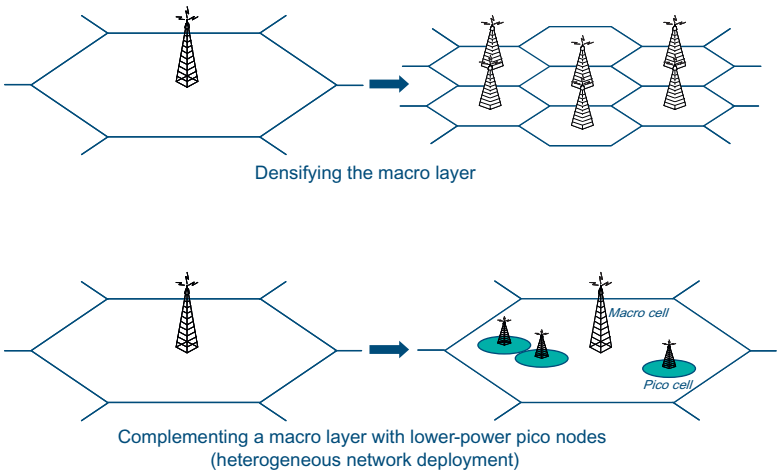


FIGURE 13.12

Network densification to enhance system capacity and support higher data rates.

A home-eNodeB is often associated with a so-called *Closed Subscriber Group* (CSG), with only users that are members of the CSG being allowed to access the home-eNodeB. Thus, users not being members of the CSG have to access the radio-access network via the overlaid macro-cell layer even when in close proximity to a home-eNodeB. As discussed further below, this causes additional interference problems with home-eNodeB deployments, beyond those of ordinary heterogeneous network deployments.

13.4.1 Interference Handling in a Heterogeneous Deployment

In itself, the use of heterogeneous network deployments in mobile-communication systems – that is, complementing a macro layer with lower-power pico nodes to increase traffic capacity and/or achievable data rates in specific areas – is nothing new and has been used for a relatively long time in, for example, GSM networks. Different sets of carrier frequencies have then typically been used in the different cell layers, thereby avoiding strong interference between the layers.

However, for a wideband radio-access technology such as LTE, using different carrier frequencies for different cell layers may lead to an undesirable spectrum fragmentation. As an example, for an operator having access to 20 MHz of spectrum, a static frequency separation between two cell layers would imply that the total available spectrum had to be divided, with less than 20 MHz of spectrum being available in each layer. This could obviously reduce the maximum achievable data rates within each cell layer. Also, assigning a substantial part of the overall available spectrum to a cell layer with relatively low traffic may lead to inefficient spectrum utilization. Thus, with a wideband high-data-rate system such as LTE, it should preferably be possible to deploy a multi-layer network structure with the same spectrum being available in the different cell layers.

However, the simultaneous use of the same spectrum in different cell layers will obviously imply interference between the layers. Due to the difference in transmit power between the nodes of a

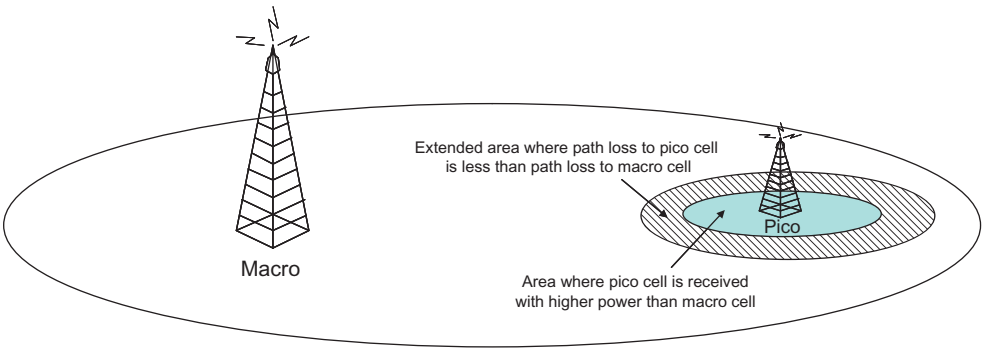


FIGURE 13.13

Illustration of high-interference area in a heterogeneous network deployment with range extension.

heterogeneous network deployment, such *inter-layer interference* may be more severe compared to inter-cell interference between cells of the same layer.

The characteristics of the inter-layer interference in a heterogeneous network deployment will also depend on the exact cell-selection strategy being used. Conventional cell selection is typically based on terminal measurements of the received power of some downlink signal, more specifically the cell-specific reference signals in the case of LTE. However, in a heterogeneous network deployment with cells with substantially different transmit power, including different power of the reference signals, selecting the cell that is received with the highest power implies that the terminal may often select the higher-power macro cell even if the path loss to a pico cell is significantly smaller. This will obviously not be optimal from an uplink coverage and capacity point of view.

It should also be noted that, even in terms of downlink system efficiency, it may not be optimal to select the cell with the highest received power in a heterogeneous network deployment. Although the high-power macro cell is received with higher power, this is at least partly due to the higher macro-cell transmit power. In that case, transmission from the macro cell is associated with a higher "cost" in terms of interference to other cells. Expressed alternatively, a transmission from the macro cell will prohibit the use of the same physical resource in *any* of the underlaid pico cells.

Alternatively, at the other extreme, cell selection could be based on estimates of the (uplink) path loss. In practice this can be achieved by applying a cell-specific offset to the received-power measurements used in conventional cell selection, an offset that would compensate for the difference in cell transmit power.[9] Such a cell-selection strategy would extend the area in which the pico-cell is selected, as illustrated in Figure 13.13. It is therefore also sometimes referred to as *range extension*.

Selecting the cell to which the path loss is the smallest – that is, applying range extension – would maximize the uplink received power/SINR, thus maximizing the achievable uplink data rates. Alternatively, for a given target received power, the terminal transmit power, and thus the interference to other cells, would be reduced, leading to higher overall uplink system efficiency. Also, it could allow for the same downlink physical resource to also be used in other pico cells, thereby also improving downlink system efficiency.

[9]Such offsets or *cell-selection biasing* is already supported by LTE.

Petitioners' Exhibit 1003, p. 654
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

However, due to the difference in transmit power between the cells of the different cell layers, there is an area (illustrated by the dashed region in Figure 13.13) where the pico cell is selected while, at the same time, the downlink transmission from the macro cell is received with substantially higher power than the actual desired downlink transmission from the pico cell. Within this area, there is thus potential for severe downlink inter-cell interference from the macro cell to pico-cell terminals, interference that may require special means to handle.

In the following we will assume that the transmissions from the macro cell and its underlaid pico cells are relatively time aligned, implying, for example, that the macro-cell PDCCH (PDSCH) transmissions will interfere with PDCCH (PDSCH) transmissions in the pico cell and vice versa.[10]

The interference from PDSCH transmissions in the macro cell to lower-power PDSCH transmissions within a pico cell can be relatively straightforwardly handled by scheduling coordination between the cells according to the same principles as inter-cell interference coordination between cells within a layer, as described in Section 13.3. As an example, the overlaid macro cell could simply avoid high-power PDSCH transmission in resource blocks in which a terminal in the high-interference region of a pico cell is to receive downlink data transmission. Such coordination can be more or less dynamic depending on to what extent and on what time scale the overlaid macro cell and the underlaid pico cells can be coordinated. It should also be noted that, for a pico cell on the border between two macro cells, it may be necessary to coordinate scheduling simultaneously with both macro cells.

Less obvious is how to handle interference due to the macro-cell transmissions that cannot be dynamically scheduled, such as the L1/L2 control signaling (PDCCH, PCFICH, and PHICH). Within a cell layer, for example between two macro cells, interference between such transmissions is not a critical issue as LTE, including its control channels, has been designed to allow for one-cell frequency reuse and a corresponding SIR down to and even below -5 dB. However, in a heterogeneous network deployment with extensive range expansion, the downlink interference from the macro cell can be more than 15 dB above the signal received from the pico cell, corresponding to an SIR below -15 dB. In such low SIR it will not be possible to correctly decode even the very robust control channels. Instead, means are needed to avoid macro-to-pico interference for the L1/L2 control channels.

One possible approach to handle the extended interference in a heterogeneous network deployment with range-extended pico cells is to use carrier aggregation in combination with cross-carrier scheduling, as described in Section 10.4.6. The basic principle of such an approach is illustrated in Figure 13.14 for the case of two layers (macro and pico) and two downlink carriers (f_M and f_P).

In terms of data (PDSCH) transmission, both carriers are available in both cell layers and interference between the layers is handled by "conventional" inter-cell interference coordination, as discussed above. As already mentioned, such interference coordination can be more or less dynamic depending on the time scale on which the macro cell and its underlaid pico cells can be coordinated. Also, the possibility for carrier aggregation allows for both carriers – that is, the total available spectrum – to be assigned for transmission to a single terminal. Thus, at least for carrier-aggregation-capable terminals, there is no spectrum fragmentation in terms of data (PDSCH) transmission.

On the other hand, in terms of L1/L2 control signaling there is at least partly a more semi-static frequency separation between the layers. More specifically, the macro cell should avoid high-power

[10]This also assumes the same size of the control (PDCCH) region for macro and pico cells.

Petitioners' Exhibit 1003, p. 655
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

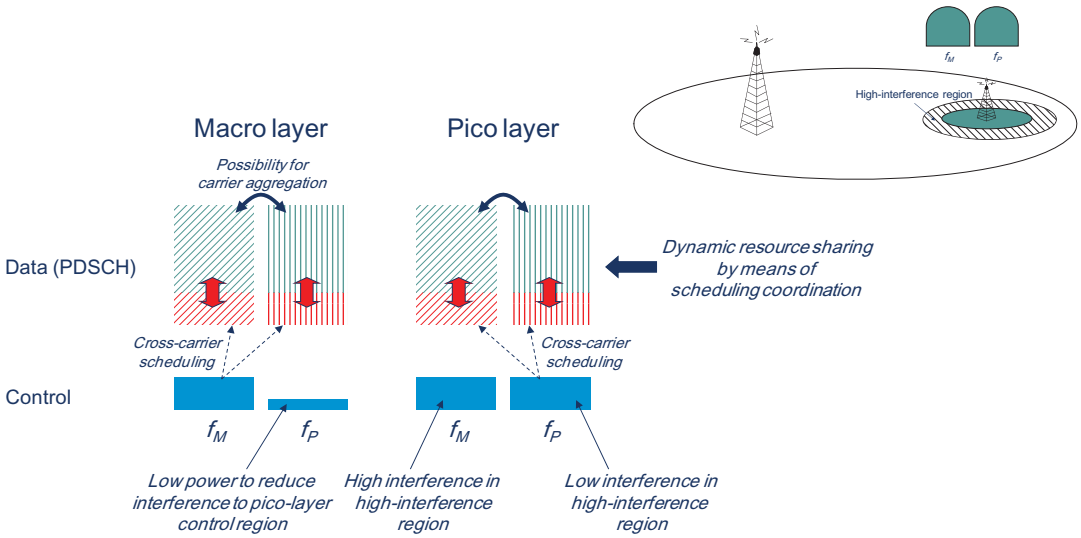


FIGURE 13.14

Carrier-aggregation approach to interference avoidance in a heterogeneous network deployment.

transmission within the control region on carrier f_P. In this way, interference to the control region of an underlaid pico cell is reduced on this carrier and the pico cells can use the carrier for control signaling to terminals in the high-interference region. Due to the possibility for cross-carrier scheduling, even if the macro cell only transmits control signaling, including downlink scheduling assignments, on carrier f_M, DL-SCH transmission on PDSCH can still be scheduled on both carriers as well as an aggregation of these. The same is true for the pico cell; even if the pico cell can only use carrier f_P for transmission of scheduling assignments to terminals in the high-interference region, DL-SCH transmissions can still be scheduled on both carriers.

It should be noted that, for terminals not in the high interference region, the pico cell could also use carrier f_M for L1/L2 control signaling. Similarly, the macro cell could use also carrier f_P for control signaling, assuming a reduced transmit power is used. Thus, the macro cell could use carrier f_P for lower-power control signaling, for example for terminals close to the macro-cell site.

The main drawback with the above-described carrier-aggregation-based approach to interference handling in a heterogeneous network deployment is that it requires terminal support for carrier aggregation in order to ensure full flexibility in spectrum usage. For terminals not capable of carrier aggregation, for example all pre-release-10 terminals, the frequency separation of control signaling between the layers implies a corresponding frequency separation in terms of data transmission as, for such terminals, scheduling assignments on carrier f_M can only schedule PDSCH transmissions on the same carrier. Thus, for such terminals there would be spectrum fragmentation.

If the carrier-aggregation approach described above cannot be used, one can instead apply more conventional interference coordination between the different layers, similar to interference coordination within one cell layer as described in Section 13.3, but extended to also cover interference between control-channel transmissions of the different cell layers.

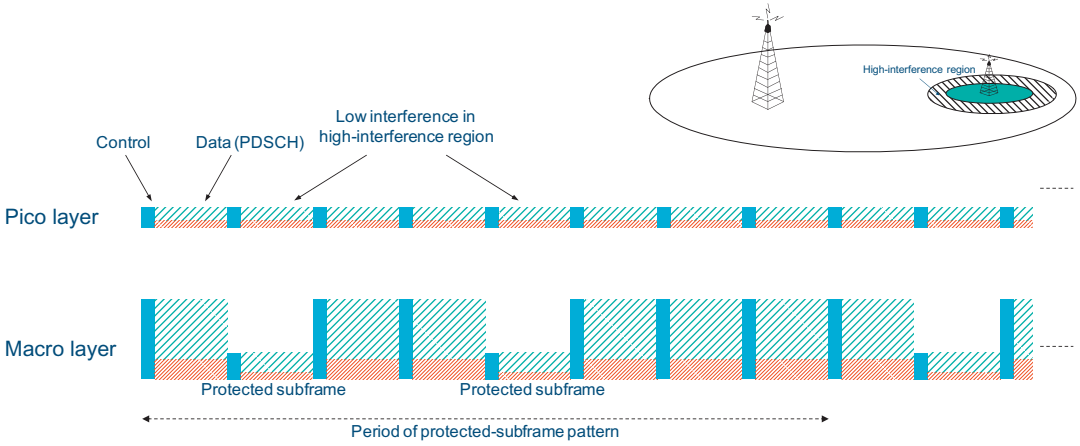


FIGURE 13.15

Single-carrier approach to interference avoidance in a heterogeneous network deployment.

With such an approach, the same carrier is used for transmission in both the macro layer and the underlaid pico cells. However, the power of macro-cell transmissions is restricted in some subframes. In contrast to conventional ICIC as described above, this restriction would not only apply to data (PDSCH) transmission, but also to the control region, as illustrated in Figure 13.15. In these *protected subframes* pico-cell terminals will thus experience less macro-cell interference for both data and control, and the pico cell can also use these subframes for transmission to terminals in the high-interference region. In the example illustrated in Figure 13.15, two of eight subframes are configured as protected subframes.

To support this second approach to interference handling in a heterogeneous network, signaling of *protected-subframe patterns* – that is, information about the set of protected subframes – is supported between eNodeBs of different cell layers. Note that the set of protected subframes could be more or less dynamic, once again depending on the time scale on which the macro cell and the underlaid pico cells can be coordinated.

It should be noted that the macro cell must not necessarily completely avoid control-signaling transmission in the protected subframes. In particular, it could be beneficial to retain the possibility for a limited amount of control signaling related to uplink transmissions, for example a limited amount of uplink scheduling grants and/or PHICH transmission, in order not to cause too much impact on the uplink scheduling. As long as the macro-cell control-signaling transmissions are limited and only occupy a small fraction of the overall control region, the interference to terminals in the high-interference region of the pico cell could be kept at an acceptable level. However, the signaling of protected-subframe patterns is also defined so that impact on the uplink scheduling is minimized even if no uplink scheduling grants and PHICH can be transmitted in protected subframes. This is achieved by having the protected-subframe patterns matched to the eight-subframe timing of the uplink hybrid-ARQ protocol. It should be noted that this implies that the pattern is not aligned to the 10 ms frame but only to a 40 ms four-frame structure for FDD. For TDD the periodicity also depends on the uplink-downlink configuration.

Petitioners' Exhibit 1003, p. 657
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Clearly, the interference experienced by pico-cell terminals may vary significantly between protected and non-protected subframes. CSI measurements carried out jointly on both the protected and non-protected subframes will thus not accurately reflect the interference of either type of subframes. Thus, as part of the enhanced support for heterogeneous network deployments, it is possible to configure a terminal with different *CSI-measurement subsets*, confining the terminal CSI measurements to subsets of the full set of subframes with terminals reporting CSI for each subset separately. The corresponding CSI reports should then preferably reflect the interference level in protected and non-protected subframes respectively. However, as mentioned above, the set of protected subframes may vary dynamically and it may not be feasible to update the CSI measurement sets accordingly. Thus, in practice, the CSI-measurement set corresponding to protected subframes may consist of only a subset of the protected subframes, a set that should be relatively static. Similarly, the CSI-measurement set corresponding to non-protected subframes may consist of only a subset of the non-protected subframes.

It should also be noted that, in some cases, a pico cell could be located at the border between, and suffer interference from, two macro cells. If the macro cells have different configured and only partly overlapping sets of protected subframes, the pico-cell scheduling as well as the configuration of the CSI-measurement sets need to take the structure of the protected sets of both macro cells into account.

13.4.2 Interference Coordination in the Case of Home-eNodeB

In the case of home-eNodeB with CSG there are additional interference issues due to the fact that a terminal can be very close to the home-eNodeB and still have to communicate with the overlaid macro cell. Such a terminal may then be severely interfered on the downlink by any home-eNodeB transmission and may also cause severe uplink interference to the home-eNodeB. In principle, this can be solved by the same means as above – that is, by relying on interference coordination between the scheduling in the home-eNodeB layer and an overlaid macro, possibly extended by the carrier-aggregation approach.

A key difference in this case, though, is that the interference avoidance must be two-way – that is, one must not only avoid interference from the macro cell to home-eNodeB terminals in the high-interference outer region of the home-eNodeB coverage area, but also home-eNodeB interference to terminals close to the home-eNodeB but not being part of the home-eNodeB CSG.

A further complicating factor in a home-eNodeB scenario is that there are obvious limitations in the coordination between the home-eNodeB and an overlaid macro layer due to limited backhaul capabilities of a home-eNodeB. In essence, there is no X2 interface to an Home-eNodeB and, in practice, the configuration of protected /non-protected subframes must be more or less static, something that could obviously affect the overall system efficiency.

Petitioners' Exhibit 1003, p. 658
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CHAPTER

Access Procedures 14

The previous chapters have described the LTE uplink and downlink transmission schemes. However, prior to transmission of data, the terminal needs to connect to the network. This chapter describes the procedures necessary for a terminal to be able to access an LTE-based network.

14.1 ACQUISITION AND CELL SEARCH

Before an LTE terminal can communicate with an LTE network it has to do the following:

- Find and acquire synchronization to a cell within the network.
- Receive and decode the information, also referred to as the *cell system information*, needed to communicate with and operate properly within the cell.

The first of these steps, often simply referred to as *cell search*, is discussed in this section. The next section then discusses, in more detail, the means by which the network provides the cell system information.

Once the system information has been correctly decoded, the terminal can access the cell by means of the random-access procedure as described in Section 14.3.

14.1.1 Overview of LTE Cell Search

A terminal does not only need to carry out cell search at power-up – that is, when initially accessing the system. Rather, to support mobility, terminals need to continuously search for, synchronize to, and estimate the reception quality of neighboring cells. The reception quality of the neighboring cells, in relation to the reception quality of the current cell, is then evaluated to conclude if a *handover* (for terminals in RRC_CONNECTED) or *cell reselection* (for terminals in RRC_IDLE) should be carried out.

LTE cell search consists of the following basic parts:

- Acquisition of frequency and symbol synchronization to a cell.
- Acquisition of frame timing of the cell – that is, determine the start of the downlink frame.
- Determination of the physical-layer cell identity of the cell.

As already mentioned (e.g. in Chapter 10), there are 504 different physical-layer cell identities defined for LTE, where each cell identity corresponds to one specific downlink reference-signal sequence. The set of physical-layer cell identities is further divided into 168 *cell-identity groups*, with three cell identities within each group.

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 660
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

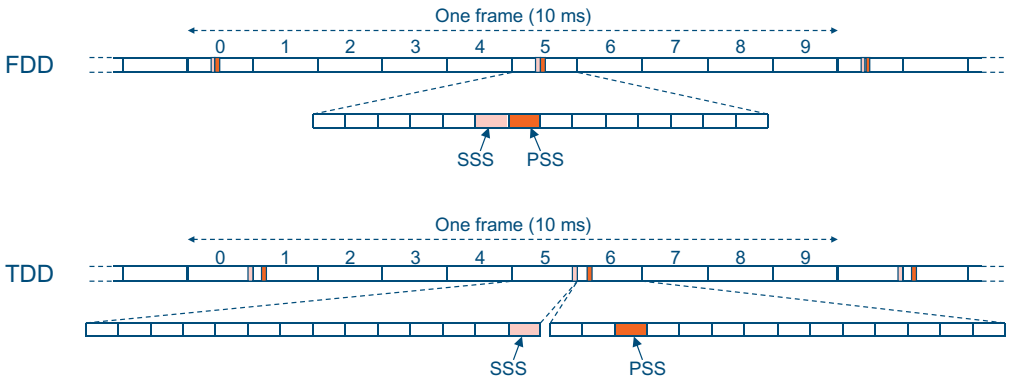


FIGURE 14.1

Time-domain position of PSS and SSS for FDD and TTD.

To assist the cell search, two special signals are transmitted on each downlink component carrier, the *Primary Synchronization Signal* (PSS) and the *Secondary Synchronization Signal* (SSS). Although having the same detailed structure, the time-domain positions of the synchronization signals within the frame differ somewhat depending on whether the cell is operating in FDD or TDD:

- In the case of FDD (upper part of Figure 14.1), the PSS is transmitted within the last symbol of the first slot of subframes 0 and 5, while the SSS is transmitted within the second last symbol of the same slot – that is, just prior to the PSS.
- In the case of TDD (lower part of Figure 14.1), the PSS is transmitted within the third symbol of subframes 1 and 6 – that is, within the DwPTS – while the SSS is transmitted in the last symbol of subframes 0 and 5 – that is, three symbols ahead of the PSS.

There are several reasons for the difference in the positions of the synchronization signals for FDD and TDD. For example, the difference allows for the detection of the duplex scheme used on a carrier if this is not known in advance.

Within one cell, the two PSSs within a frame are identical. Furthermore, the PSS of a cell can take three different values depending on the physical-layer cell identity of the cell. More specifically, the three cell identities within a cell-identity group always correspond to different PSS. Thus, once the terminal has detected and identified the PSS of the cell, it has found the following:

- Five-millisecond timing of the cell and thus also the position of the SSS, which has a fixed offset relative to the PSS.
- The cell identity within the cell-identity group. However, the terminal has not yet determined the cell-identity group itself – that is, the number of possible cell identities has been reduced from 504 to 168.

Thus, from the SSS, the position of which is known once the PSS has been detected, the terminal should find the following:

- frame timing (two different alternatives given the found position of the PSS); and
- the cell-identity group (168 alternatives).

Petitioners' Exhibit 1003, p. 661
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

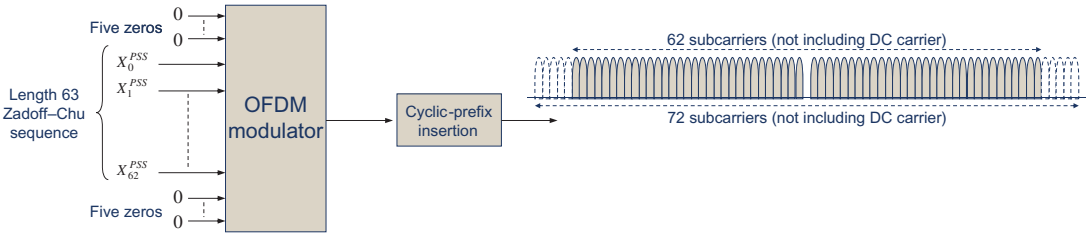


FIGURE 14.2

Definition and structure of PSS.

Furthermore, it should be possible for a terminal to do this by the reception of one single SSS. The reason is that, for example, in the case when the terminal is searching for cells on other carriers, the search window may not be sufficiently large to cover more than one SSS.

To enable this, each SSS can take 168 different values corresponding to the 168 different cell-identity groups. Furthermore, the set of values valid for the two SSSs within a frame (SSS_1 in subframe 0 and SSS_2 in subframe 5) are different, implying that, from the detection of a single SSS, the terminal can determine whether SSS_1 or SSS_2 has been detected and thus determine frame timing.

Once the terminal has acquired frame timing and the physical-layer cell identity, it has identified the cell-specific reference signal. The behavior is slightly different depending on whether it is an initial cell search or cell search for the purpose of neighboring cell measurements:

- In the case of initial cell search – that is, the terminal state is in RRC_IDLE mode – the reference signal will be used for channel estimation and subsequent decoding of the BCH transport channel to obtain the most basic set of system information.
- In the case of mobility measurements – that is, the terminal is in RRC_CONNECTED mode – the terminal will measure the received power of the reference signal. If the measurement fulfills a configurable condition, it will trigger sending of a *reference signal received power* (RSRP) measurement report to the network. Based on the measurement report, the network will conclude whether a handover should take place. The RSRP reports can also be used for component carrier management,[1] for example whether an additional component carrier should be configured or if the primary component carrier should be reconfigured.

14.1.2 PSS Structure

On a more detailed level, the three PSSs are three length-63 Zadoff–Chu (ZC) sequences extended with five zeros at the edges and mapped to the center 73 subcarriers (center six resource blocks) as illustrated in Figure 14.2. It should be noted though that the center subcarrier is actually not transmitted as it coincides with the DC subcarrier. Thus, only 62 elements of the length-63 ZC sequences are actually transmitted (element X_{32}^{PSS} is not transmitted).

[1]As discussed in Chapter 9, the specifications use the terms primary and secondary cells instead of primary and secondary component carriers.

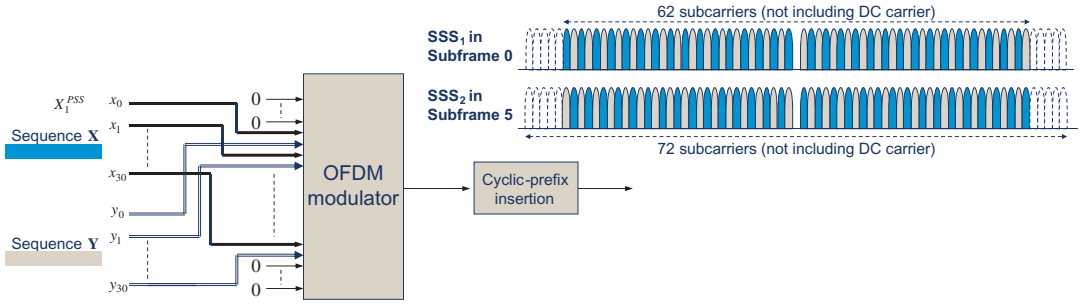


FIGURE 14.3

Definition and structure of SSS.

The PSS thus occupies 72 resource elements (not including the DC carrier) in subframes 0 and 5 (FDD) and subframes 1 and 6 (TDD). These resource elements are then not available for transmission of DL-SCH.

14.1.3 SSS Structure

Similar to PSS, the SSS occupies the center 72 resource elements (not including the DC carrier) in subframes 0 and 5 (for both FDD and TDD). As described above, the SSS should be designed so that:

- The two SSS (SSS_1 in subframe 0 and SSS_2 in subframe 5) take their values from sets of 168 possible values corresponding to the 168 different cell-identity groups.
- The set of values applicable for SSS_2 is different from the set of values applicable for SSS_1 to allow for frame-timing detection from the reception of a single SSS.

The structure of the two SSS is illustrated in Figure 14.3. SSS_1 is based on the frequency interleaving of two length-31 *m*-sequences *X* and *Y*, each of which can take 31 different values (actually 31 different shifts of the same *m*-sequence). Within a cell, SSS_2 is based on exactly the same two sequences as SSS_1. However, the two sequences have been swapped in the frequency domain, as outlined in Figure 14.3. The set of valid combinations of *X* and *Y* for SSS_1 has then been selected so that a swapping of the two sequences in the frequency domain is not a valid combination for SSS_1. Thus, the above requirements are fulfilled:

- The set of valid combinations of *X* and *Y* for SSS_1 (as well as for SSS_2) are 168, allowing for detection of the physical-layer cell identity.
- As the sequences *X* and *Y* are swapped between SSS_1 and SSS_2, frame timing can be found.

14.2 SYSTEM INFORMATION

By means of the basic cell-search procedure described in Section 14.1, a terminal synchronizes to a cell, acquires the physical-layer identity of the cell, and detects the cell frame timing. Once this has

been achieved, the terminal has to acquire the cell *system information*. This is information that is repeatedly broadcast by the network and which needs to be acquired by terminals in order for them to be able to access and, in general, operate properly within the network and within a specific cell. The system information includes, among other things, information about the downlink and uplink cell bandwidths, the uplink/downlink configuration in the case of TDD, detailed parameters related to random-access transmission and uplink power control, etc.

In LTE, system information is delivered by two different mechanisms relying on two different transport channels:

- A limited amount of system information, corresponding to the so-called *Master-Information Block* (MIB), is transmitted using the BCH.
- The main part of the system information, corresponding to different so-called *System-Information Blocks* (SIBs), is transmitted using the downlink shared channel (DL-SCH).

It should be noted that system information in both the MIB and the SIBs corresponds to the BCCH logical channel. Thus, as also illustrated in Figure 8.7 in Chapter 8, BCCH can be mapped to both BCH and DL-SCH depending on the exact BCCH information.

14.2.1 MIB and BCH Transmission

As mentioned above, the MIB transmitted using BCH consists of a very limited amount of system information, mainly such information that is absolutely needed for a terminal to be able to read the remaining system information provided using DL-SCH. More specifically, the MIB includes the following information:

- *Information about the downlink cell bandwidth*. Four bits are available within the MIB to indicate the downlink bandwidth. Thus, up to 16 different bandwidths, measured in number of resource blocks, can be defined for each frequency band.
- *Information about the PHICH configuration of the cell*. As mentioned in Section 10.4.2, the terminal must know the PHICH configuration to be able to receive the L1/L2 control signaling on PDCCH which, in turn, is needed to receive DL-SCH. Thus, information about the PHICH configuration (three bits) is included in the MIB – that is, transmitted using BCH, which can be received and decoded without first receiving any PDCCH.
- *The System Frame Number (SFN)* or, more exactly, all bits except the two least significant bits of the SFN are included in the MIB. As described below, the terminal can indirectly acquire the two least significant bits of the SFN from the BCH decoding.

BCH physical-layer processing, such as channel coding and resource mapping, differs quite substantially from the corresponding processing and mapping for DL-SCH outlined in Chapter 10.

As can be seen in Figure 14.4, one BCH transport block, corresponding to the MIB, is transmitted every 40 ms. The BCH Transmissions Time Interval (TTI) thus equals 40 ms.

The BCH relies on a 16-bit CRC, in contrast to a 24-bit CRC used for all other downlink transport channels. The reason for the shorter BCH CRC is to reduce the relative CRC overhead, having the very small BCH transport-block size in mind.

BCH channel coding is based on the same rate-1/3 tail-biting convolutional code as is used for the PDCCH control channel. The reason for using convolutional coding for BCH, rather than the Turbo

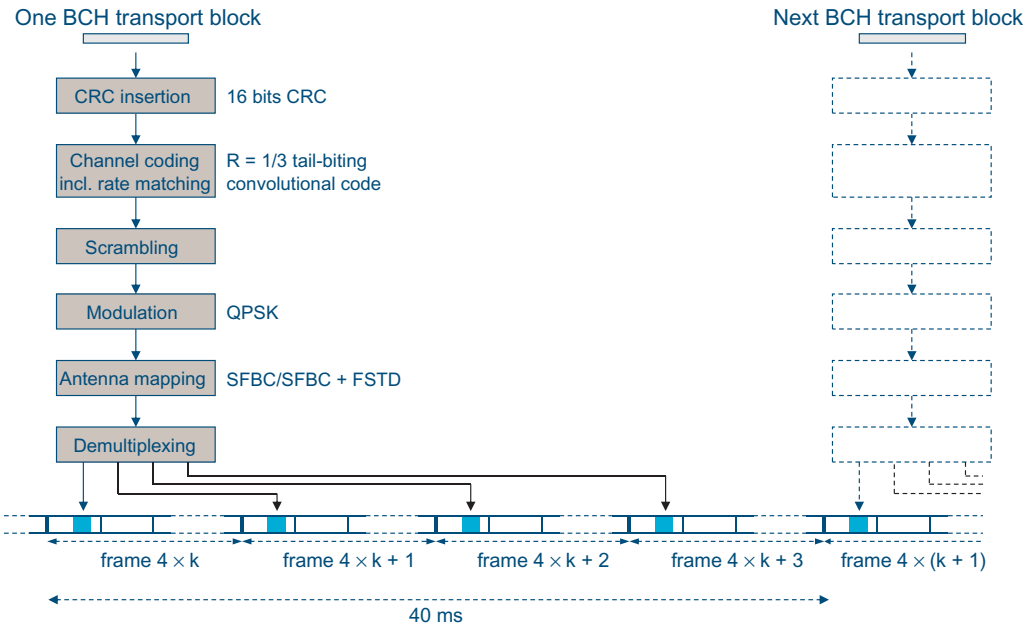


FIGURE 14.4

Channel coding and subframe mapping for the BCH transport channel.

code used for all other transport channels, is the small size of the BCH transport block. With such small blocks, tail-biting convolutional coding actually outperforms Turbo coding. The channel coding is followed by rate matching, in practice repetition of the coded bits, and bit-level scrambling. QPSK modulation is then applied to the coded and scrambled BCH transport block.

BCH multi-antenna transmission is limited to transmit diversity – that is, SFBC in the case of two antenna ports and combined SFBC/FSTD in the case of four antenna ports. Actually, as mentioned in Chapter 10, if two antenna ports are available within the cell, SFBC *must* be used for BCH. Similarly, if four antenna ports are available, combined SFBC/FSTD *must* be used. Thus, by blindly detecting what transmit-diversity scheme is used for BCH, a terminal can indirectly determine the number of cell-specific antenna ports within the cell and also the transmit-diversity scheme used for the L1/L2 control signaling.

As can also be seen from Figure 14.4, the coded BCH transport block is mapped to the first subframe of each frame in four consecutive frames. However, as can be seen in Figure 14.5 and in contrast to other downlink transport channels, the BCH is not mapped on a resource-block basis. Instead, the BCH is transmitted within the first four OFDM symbols of the second slot of subframe 0 and only over the 72 center subcarriers.[2] Thus, in the case of FDD, BCH follows immediately after the PSS and SSS in subframe 0. The corresponding resource elements are then not available for DL-SCH transmission.

The reason for limiting the BCH transmission to the 72 center subcarriers, regardless of the cell bandwidth, is that a terminal may not know the downlink cell bandwidth when receiving BCH. Thus,

[2]Not including the DC carrier.

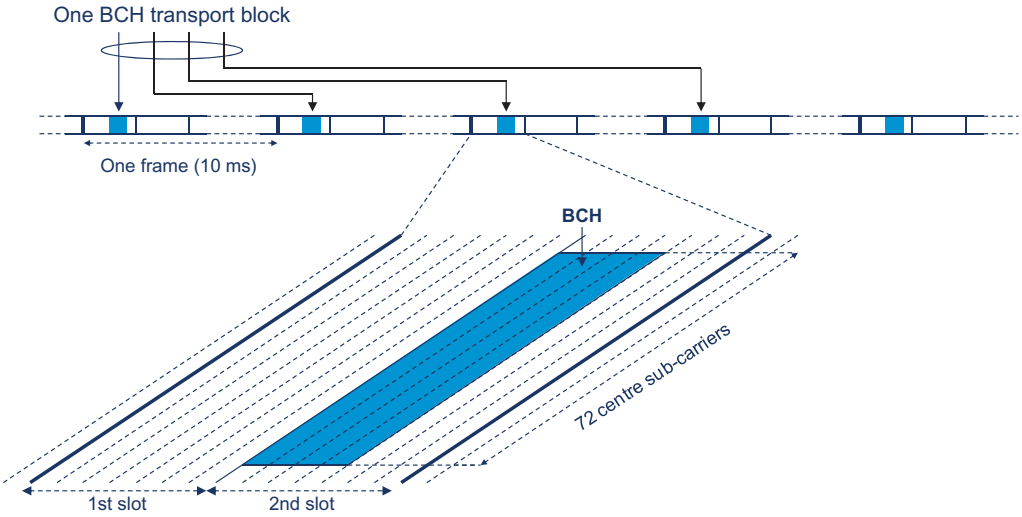


FIGURE 14.5

Detailed resource mapping for the BCH transport channel.

when first receiving BCH of a cell, the terminal can assume a cell bandwidth equal to the minimum possible downlink bandwidth – that is, six resource blocks corresponding to 72 subcarriers. From the decoded MIB, the terminal is then informed about the actual downlink cell bandwidth and can adjust the receiver bandwidth accordingly.

Clearly, the total number of resource elements to which the coded BCH is mapped is very large compared to the size of the BCH transport block, implying extensive repetition coding or, equivalently, massive processing gain for the BCH transmission. Such large processing gain is needed as it should be possible to receive and correctly decode the BCH also by terminals in neighboring cells, implying potentially very low receiver *Signal-to-Interference-and-Noise Ratio* (SINR) when decoding the BCH. At the same time, many terminals will receive BCH in much better channel conditions. Such terminals then do not need to receive the full set of four subframes over which a BCH transport block is transmitted to acquire sufficient energy for correct decoding of the transport block. Instead, already by receiving only a few or perhaps only a single subframe, the BCH transport block may be decodable.

From the initial cell search, the terminal has found only the cell frame timing. Thus, when receiving BCH, the terminal does not know to what set of four subframes a certain BCH transport block is mapped. Instead, a terminal must try to decode the BCH at four possible timing positions. Depending on which decoding is successful, indicated by a correct CRC check, the terminal can implicitly determine 40 ms timing or, equivalently, the two least significant bits of the SFN.[3] This is the reason why these bits do not need to be explicitly included in the MIB.

[3]BCH scrambling is defined with 40 ms periodicity, hence even if the terminal successfully decodes the BCH after observing only a single transmission instant, it can determine the 40 ms timing.

14.2.2 System-Information Blocks

As already mentioned, the MIB on the BCH only includes a very limited part of the system information. The main part of the system information is instead included in different *System-Information Blocks* (SIBs) that are transmitted using the DL-SCH. The presence of system information on DL-SCH in a subframe is indicated by the transmission of a corresponding PDCCH marked with a special *System-Information RNTI* (SI-RNTI). Similar to the PDCCH providing the scheduling assignment for "normal" DL-SCH transmission, this PDCCH also indicates the transport format and physical resource (set of resource blocks) used for the system-information transmission.

LTE defines a number of different SIBs characterized by the type of information that is included within them:

- SIB1 includes information mainly related to whether a terminal is allowed to camp on the cell. This includes information about the operator/operators of the cell, if there are restrictions with regards to what users may access the cell, etc. SIB1 also includes information about the allocation of subframes to uplink/downlink and configuration of the special subframe in the case of TDD. Finally, SIB1 includes information about the time-domain scheduling of the remaining SIBs (SIB2 and beyond).
- SIB2 includes information that terminals need in order to be able to access the cell. This includes information about the uplink cell bandwidth, random-access parameters, and parameters related to uplink power control.
- SIB3 mainly includes information related to cell reselection.
- SIB4–SIB8 include neighboring-cell-related information, including information related to neighboring cells on the same carrier, neighboring cells on different carriers, and neighboring non-LTE cells, such as WCDMA/HSPA, GSM, and CDMA2000 cells.
- SIB9 contains the name of the home-eNodeB.
- SIB10–SIB12 contain public warning messages, for example earthquake information.
- SIB13 contains information necessary for MBMS reception (see also Chapter 15).

Not all the SIBs need to be present. For example, SIB9 is not relevant for an operator-deployed node and SIB13 is not necessary if MBMS is not provided in the cell.

Similar to the MIB, the SIBs are broadcasted repeatedly. How often a certain SIB needs to be transmitted depends on how quickly terminals need to acquire the corresponding system information when entering the cell. In general, a lower-order SIB is more time critical and is thus transmitted more often compared to a higher-order SIB. SIB1 is transmitted every 80 ms, whereas the transmission period for the higher-order SIBs is flexible and can be different for different networks.

The SIBs represent the basic system information to be transmitted. The different SIBs are then mapped to different *System-Information messages* (SIs), which correspond to the actual transport blocks to be transmitted on DL-SCH. SIB1 is always mapped, by itself, on to the first system-information message SI-1,[4] whereas the remaining SIBs may be group-wise multiplexed on to the same SI subject to the following constraints:

- The SIBs mapped to the same SI must obviously have the same transmission period. Thus, as an example, two SIBs with a transmission period of 320 ms can be mapped to the same SI, whereas an SIB with a transmission period of 160 ms must be mapped to a different SI.

[4] Strictly speaking, as SIB1 is not multiplexed with any other SIBs, it is not even said to be mapped to an SI. Rather, SIB1 in itself directly corresponds to the transport block.

Petitioners' Exhibit 1003, p. 667
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

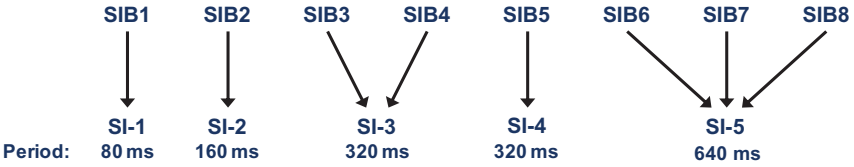


FIGURE 14.6

Example of mapping of SIBs to SIs.

- The total number of information bits that is mapped to a single SI must not exceed what is possible to transmit within a transport block.

It should be noted that the transmission period for a given SIB might be different in different networks. For example, different operators may have different requirements concerning the period when different types of neighboring-cell information needs to be transmitted. Furthermore, the amount of information that can fit into a single transport block very much depends on the exact deployment situation, such as cell bandwidth, cell size, and so on.

Thus, in general, the SIB-to-SI mapping for SIBs beyond SIB1 is flexible and may be different for different networks or even within a network. An example of SIB-to-SI mapping is illustrated in Figure 14.6. In this case, SIB2 is mapped to SI-2 with a transmission period of 160 ms. SIB3 and SIB4 are multiplexed into SI-3 with a transmission period of 320 ms, whereas SIB5, which also requires a transmission period of 320 ms, is mapped to a separate SI (SI-4). Finally, SIB6, SIB7, and SIB8 are multiplexed into SI-5 with a transmission period of 640 ms. Information about the detailed SIB-to-SI mapping, as well as the transmission period of the different SIs, is provided in SIB1.

Regarding the more detailed transmission of the different system-information messages there is a difference between the transmission of SI-1, corresponding to SIB1, and the transmission of the remaining SIs.

The transmission of SI-1 has only a limited flexibility. More specifically, SI-1 is always transmitted within subframe 5. However, the bandwidth or, in general, the set of resource blocks over which SI-1 is transmitted, as well as other aspects of the transport format, may vary and is signaled on the associated PDCCH.

For the remaining SIs, the scheduling on DL-SCH is more flexible in the sense that each SI can, in principle, be transmitted in any subframe within *time windows* with well-defined starting points and durations. The starting point and duration of the time window of each SI are provided in SIB-1. It should be noted that an SI does not need to be transmitted on consecutive subframes within the time window, as is illustrated in Figure 14.7. Within the time window, the presence of system information in a subframe is indicated by the SI-RNTI on PDCCH, which also provides the frequency-domain scheduling as well as other parameters related to the system-information transmission.

Different SIs have different non-overlapping time windows. Thus, a terminal knows what SI is being received without the need for any specific identifier for each SI.

In the case of a relatively small SI and a relatively large system bandwidth, a single subframe may be sufficient for the transmission of the SI. In other cases, multiple subframes may be needed for the transmission of a single SI. In the latter case, instead of segmenting each SI into sufficiently small



FIGURE 14.7

Transmission window for the transmission of an SI.

blocks that are separately channel coded and transmitted in separate subframes, the complete SI is channel coded and mapped to multiple, not necessarily consecutive, subframes.

Similar to the case of the BCH, terminals that are experiencing good channel conditions may then be able to decode the complete SI after receiving only a subset of the subframes to which the coded SI is mapped, while terminals in bad positions need to receive more subframes for proper decoding of the SI. This approach has two benefits:

- Similar to BCH decoding, terminals in good positions need to receive fewer subframes, implying the possibility for reduced terminal power consumption.
- The use of larger code blocks in combination with Turbo coding leads to improved channel-coding gain.

Strictly speaking the single transport block containing the SI is not transmitted over multiple subframes. Rather, the subsequent SI transmissions are seen as autonomous hybrid-ARQ retransmissions of the first SI transmission – that is, retransmissions taking place without any explicit feedback signaling provided on the uplink.

For terminals capable of carrier aggregation, the system information for the primary component carrier is obtained as described above. For secondary component carriers, the terminal does not need to read the system-information blocks but assumes that the information obtained for the primary component carrier also holds for the secondary component carriers. System information specific for the secondary component carrier is provided through dedicated RRC signaling as part of the procedure to configure an additional secondary component carrier. Using dedicated signaling instead of reading the system information on the secondary component carrier enables faster activation of secondary component carriers as the terminal otherwise would have to wait until the relevant system information had been transmitted.

14.3 RANDOM ACCESS

A fundamental requirement for any cellular system is the possibility for the terminal to request a connection setup, commonly referred to as *random access*. In LTE, random access is used for several purposes, including:

- for initial access when establishing a radio link (moving from RRC_IDLE to RRC_CONNECTED; see Chapter 8 for a discussion on different terminal states);
- to re-establish a radio link after radio-link failure;

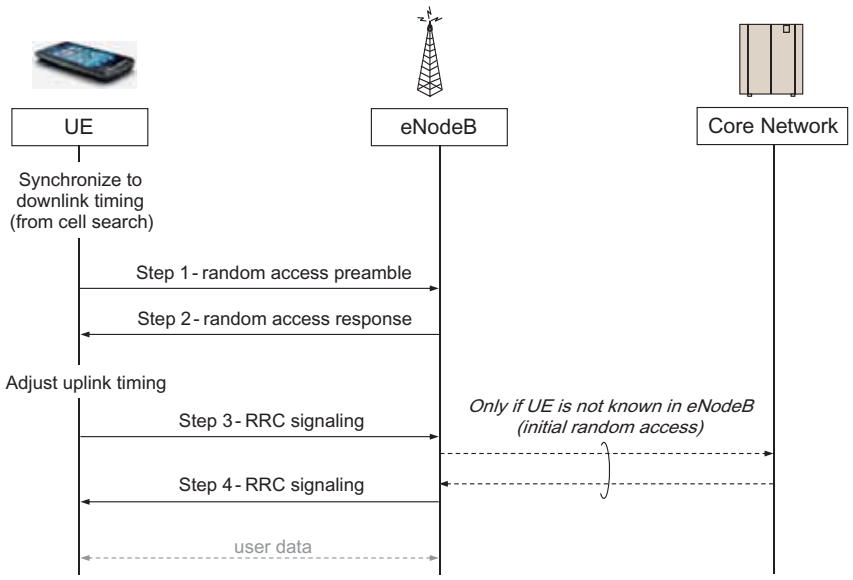


FIGURE 14.8

Overview of the random-access procedure.

- for handover when uplink synchronization needs to be established to the new cell;
- to establish uplink synchronization if uplink or downlink data arrives when the terminal is in RRC_CONNECTED and the uplink is not synchronized;
- for the purpose of positioning using positioning methods based on uplink measurements;
- as a scheduling request if no dedicated scheduling-request resources have been configured on PUCCH (see Chapter 13 for a discussion on uplink scheduling procedures).

Acquisition of uplink timing is a main objective for all the cases above; when establishing an initial radio link (that is, when moving from RRC_IDLE to RRC_CONNECTED), the random-access procedure also serves the purpose of assigning a unique identity, the C-RNTI, to the terminal.

A terminal may perform random access on its primary component carrier only.[5] Either a contention-based or a contention-free scheme can be used.

Contention-based random access uses a four-step procedure, illustrated in Figure 14.8, with the following steps:

1. The transmission of a random-access preamble, allowing the eNodeB to estimate the transmission timing of the terminal. Uplink synchronization is necessary as the terminal otherwise cannot transmit any uplink data.
2. The network transmits a timing advance command to adjust the terminal transmit timing, based on the timing estimate obtained in the first step. In addition to establishing uplink synchronization,

[5]The primary component carrier is UE specific, as already discussed; hence, from an eNodeB perspective, random access may occur on multiple component carriers.

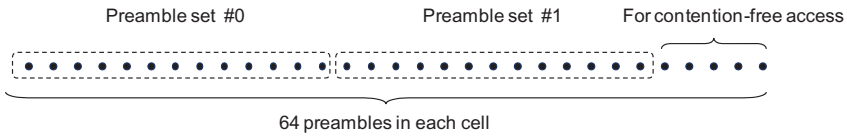


FIGURE 14.9

Preamble subsets.

the second step also assigns uplink resources to the terminal to be used in the third step in the random-access procedure.

3. The transmission of the mobile-terminal identity to the network using the UL-SCH similar to normal scheduled data. The exact content of this signaling depends on the state of the terminal, in particular whether it is previously known to the network or not.
4. The final step consists of transmission of a contention-resolution message from the network to the terminal on the DL-SCH. This step also resolves any contention due to multiple terminals trying to access the system using the same random-access resource.

Only the first step uses physical-layer processing specifically designed for random access. The subsequent three steps utilize the same physical-layer processing as used for normal uplink and downlink data transmission. In the following, each of these steps is described in more detail.

Contention-free random access can only be used for re-establishing uplink synchronization upon downlink data arrival, handover, and positioning. Only the first two steps of the procedure above are used as there is no need for contention resolution in a contention-free scheme.

14.3.1 Step 1: Random-Access Preamble Transmission

The first step in the random-access procedure is the transmission of a random-access preamble. The main purpose of the preamble transmission is to indicate to the base station the presence of a random-access attempt and to allow the base station to estimate the delay between the eNodeB and the terminal. The delay estimate will be used in the second step to adjust the uplink timing.

The time–frequency resource on which the random-access preamble is transmitted is known as the *Physical Random-Access Channel* (PRACH). The network broadcasts information to all terminals in which time–frequency resource random-access preamble transmission is allowed (that is, the PRACH resources, in SIB-2). As part of the first step of the random-access procedure, the terminal selects one preamble to transmit on the PRACH.

In each cell, there are 64 preamble sequences available. Two subsets of the 64 sequences are defined as illustrated in Figure 14.9, where the set of sequences in each subset is signaled as part of the system information. When performing a (contention-based) random-access attempt, the terminal selects at random one sequence in one of the subsets. As long as no other terminal is performing a random-access attempt using the same sequence at the same time instant, no collisions will occur and the attempt will, with a high likelihood, be detected by the eNodeB.

The subset to select the preamble sequence from is given by the amount of data the terminal would like to (and from a power perspective can) transmit on the UL-SCH in the third random-access

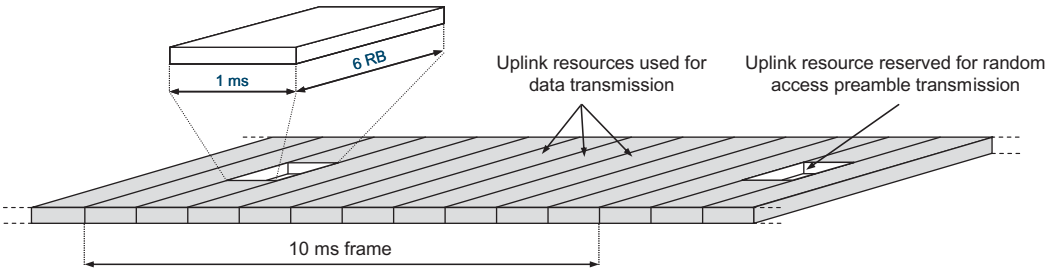


FIGURE 14.10

Principal illustration of random-access preamble transmission.

step. Hence, from the preamble the terminal used, the eNodeB, will get some guidance on the amount of uplink resources to be granted to the terminal.

If the terminal has been requested to perform a contention-free random access, for example for handover to a new cell, the preamble to use is explicitly indicated from the eNodeB. To avoid collisions, the eNodeB should preferably select the contention-free preamble from sequences outside the two subsets used for contention-based random access.

14.3.1.1 PRACH Time–Frequency Resources

In the frequency domain, the PRACH resource, illustrated in Figure 14.10, has a bandwidth corresponding to six resource blocks (1.08 MHz). This nicely matches the smallest uplink cell bandwidth of six resource blocks in which LTE can operate. Hence, the same random-access preamble structure can be used, regardless of the transmission bandwidth in the cell.

In the time domain, the length of the preamble region depends on configured preamble, as will be discussed further below. The basic random-access resource is 1 ms in duration, but it is also possible to configure longer preambles. Also, note that the eNodeB uplink scheduler in principle can reserve an arbitrary long-random-access region by simply avoiding scheduling terminals in multiple subsequent subframes.

Typically, the eNodeB avoids scheduling any uplink transmissions in the time–frequency resources used for random access, resulting in the random-access preamble being *orthogonal* to user data. This avoids interference between UL-SCH transmissions and random-access attempts from different terminals. However, from a specification perspective, nothing prevents the uplink scheduler from scheduling transmissions in the random-access region. Hybrid-ARQ retransmissions are examples of this; synchronous non-adaptive hybrid-ARQ retransmissions may overlap with the random-access region and it is up to the implementation to handle this, either by moving the retransmissions in the frequency domain as discussed in Chapter 12 or by handling the interference at the eNodeB receiver.

For FDD, there is at most one random-access region per subframe – that is, multiple random-access attempts are not multiplexed in the frequency domain. From a delay perspective, it is better to spread out the random-access opportunities in the time domain to minimize the average waiting time before a random-access attempt can be initialized.

For TDD, multiple random-access regions can be configured in a single subframe. The reason is the smaller number of uplink subframes per radio frame in TDD. To maintain the same

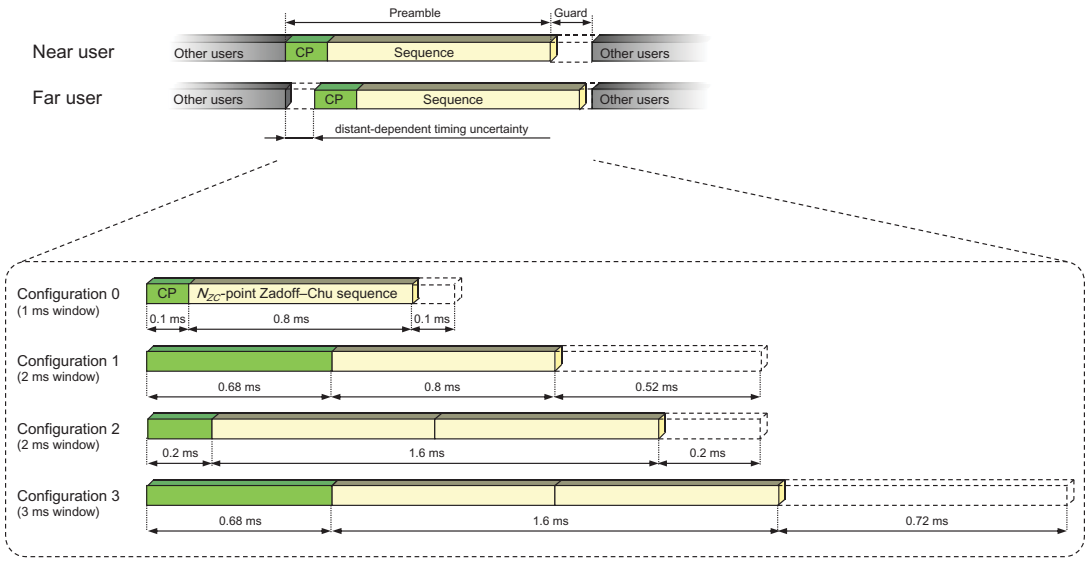


FIGURE 14.11

Different preamble formats.

random-access capacity as in FDD, frequency-domain multiplexing is sometimes necessary. The number of random-access regions is configurable and can vary from one per 20 ms to one per 1 ms for FDD; for TDD up to six attempts per 10 ms radio frame can be configured.

14.3.1.2 Preamble Structure and Sequence Selection

The preamble consists of two parts:

- Preamble sequence.
- Cyclic prefix.

Furthermore, the preamble transmission uses a guard period to handle the timing uncertainty. Prior to starting the random-access procedure, the terminal has obtained downlink synchronization from the cell-search procedure. However, as uplink synchronization has not yet been established prior to random access, there is an uncertainty in the uplink timing[6] as the location of the terminal in the cell is not known. The uplink timing uncertainty is proportional to the cell size and amounts to 6.7 μs/km. To account for the timing uncertainty and to avoid interference with subsequent subframes not used for random access, a guard time is used as part of the preamble transmission – that is, the length of the actual preamble is shorter than 1 ms.

Including a cyclic prefix as part of the preamble is beneficial as it allows for frequency-domain processing at the base station (discussed further below), which can be advantageous from a complexity perspective. Preferably, the length of the cyclic prefix is approximately equal to the length

[6]The start of an uplink frame at the terminal is defined relative to the start of a downlink frame received at the terminal.

of the guard period. With a preamble sequence length of approximately 0.8 ms, there is 0.1 ms cyclic prefix and 0.1 ms guard time. This allows for cell sizes up to 15 km and is the typical random-access configuration, configuration 0 in Figure 14.11. To handle larger cells, where the timing uncertainty is larger, preamble configurations 1–3 can be used. Some of these configurations also support a longer preamble sequence to increase the preamble energy at the detector, which can be beneficial in larger cells. The preamble configuration used in a cell is signaled as part of the system information. Finally, note that guard times larger than those in Figure 14.11 can easily be created by not scheduling any uplink transmissions in the subframe following the random-access resource.

The preamble formats in Figure 14.11 are applicable to both FDD and TDD. However, for TDD, there is an additional fourth preamble configuration for random access. In this configuration, the random-access preamble is transmitted in the UpPTS field of the special subframe instead of in a normal subframe. Since this field is at most two OFDM symbols long, the preamble and the possible guard time are substantially shorter than the preamble formats described above. Hence, format 4 is applicable to very small cells only. The location of the UpPTS, next to the downlink-to-uplink switch for TDD, also implies that the interference from distant base stations may interfere with this short random-access format, which limits its usage to small cells and certain deployment scenarios.

14.3.1.3 PRACH Power Setting

The basis for setting the transmission power of the random-access preamble is a downlink path-loss estimate obtained from measuring the cell-specific reference signals on the primary downlink component carrier. From this path-loss estimate, the initial PRACH transmission power is obtained by adding a configurable offset.

The LTE random-access mechanism allows power ramping where the actual PRACH transmission power is increased for each unsuccessful random-access attempt. For the first attempt, the PRACH transmission power is set to the initial PRACH power. In most cases, this is sufficient for the random-access attempts to be successful. However, if the random-access attempt fails (random-access failures are detected at the second of four random-access steps, as described in the following sections), the PRACH transmission power for the next attempt is increased by a configurable step size to increase the likelihood of the next attempt being successful.

Since the random-access preamble is orthogonal to the user data, the need for power ramping to control intra-cell interference is smaller than in other systems with non-orthogonal random access and in many cases the transmission power is set such that the first random-access attempt with a high likelihood is successful. This is beneficial from a delay perspective.

14.3.1.4 Preamble Sequence Generation

The preamble sequences are generated from cyclic shifts of root Zadoff–Chu sequences [74]. Zadoff–Chu sequences are also used for creating the uplink reference signals as described in Chapter 11, where the structure of those sequences is described. From each root Zadoff–Chu sequence, $X_{\mathrm{ZC}}^{(u)}(k)$, $[N_{\mathrm{ZC}}/N_{\mathrm{CS}}]$ cyclically shifted[7] sequences are obtained by cyclic shifts of N_{CS} each, where N_{ZC} is the length of the root Zadoff–Chu sequence. The generation of the random-access preamble is illustrated

[7]The cyclic shift is in the time domain. Similar to the uplink reference signals and control signaling, this can equivalently be described as a phase rotation.

Petitioners' Exhibit 1003, p. 674
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

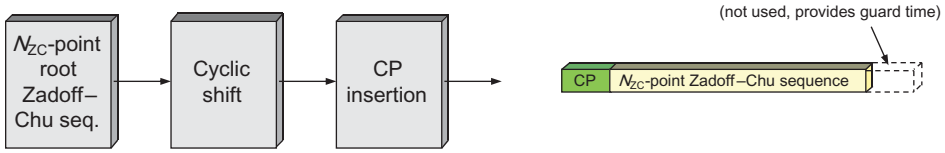


FIGURE 14.12

Random-access preamble generation.

in Figure 14.12. Although the figure illustrates generation in the time domain, frequency-domain generation can equally well be used in an implementation.

Cyclically shifted Zadoff–Chu sequences possess several attractive properties. The amplitude of the sequences is constant, which ensures efficient power amplifier utilization and maintains the low PAR properties of the single-carrier uplink. The sequences also have ideal cyclic auto-correlation, which is important for obtaining an accurate timing estimation at the eNodeB. Finally, the cross-correlation between different preambles based on cyclic shifts of the same Zadoff–Chu root sequence is zero at the receiver as long as the cyclic shift N_{CS} used when generating the preambles is larger than the maximum round-trip propagation time in the cell plus the maximum delay spread of the channel. Therefore, due to the ideal cross-correlation property, there is no intra-cell interference from multiple random-access attempts using preambles derived from the same Zadoff–Chu root sequence.

To handle different cell sizes, the cyclic shift N_{CS} is signaled as part of the system information. Thus, in smaller cells, a small cyclic shift can be configured, resulting in a larger number of cyclically shifted sequences being generated from each root sequence. For cell sizes below 1.5 km, all 64 preambles can be generated from a single root sequence. In larger cells, a larger cyclic shift needs to be configured and to generate the 64 preamble sequences, multiple root Zadoff–Chu sequences must be used in the cell. Although the larger number of root sequences is not a problem in itself, the zero cross-correlation property only holds between shifts of the *same* root sequence and from an interference perspective it is therefore beneficial to use as few root sequences as possible.

Reception of the random-access preamble is discussed further below, but in principle it is based on correlation of the received signal with the root Zadoff–Chu sequences. One disadvantage of Zadoff–Chu sequences is the difficulties in separating a frequency offset from the distance-dependent delay. A frequency offset results in an additional correlation peak in the time domain, a correlation peak that corresponds to a spurious terminal-to-base-station distance. In addition, the true correlation peak is attenuated. At low-frequency offsets, this effect is small and the detection performance is hardly affected. However, at high Doppler frequencies, the spurious correlation peak can be larger than the true peak. This results in erroneous detection; the correct preamble may not be detected or the delay estimate may be incorrect.

To avoid the ambiguities from spurious correlation peaks, the set of preamble sequences generated from each root sequence can be restricted. Restrictions imply that only some of the sequences that can be generated from a root sequence are used to define random-access preambles. Whether restriction should be applied or not to the preamble generation is signaled as part of the system information. The location of the spurious correlation peak relative to the "true" peak depends on the root sequence and hence different restrictions have to be applied to different root sequences. The restrictions to apply are broadcast as part of the system information in the cell.

Petitioners' Exhibit 1003, p. 675
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

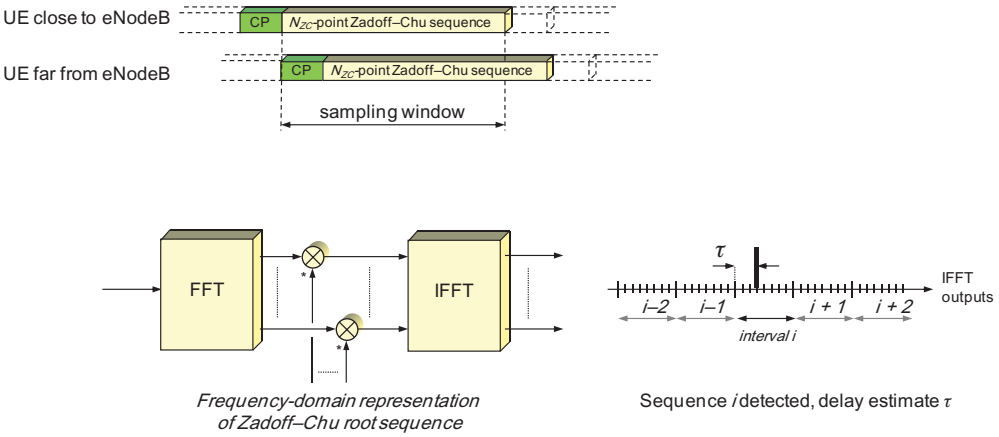


FIGURE 14.13

Random-access preamble detection in the frequency domain.

14.3.1.5 *Preamble Detection*

The base-station processing is implementation specific, but due to the cyclic prefix included in the preamble, low-complexity frequency-domain processing is possible. An example hereof is shown in Figure 14.13. Samples taken in a time-domain window are collected and converted into the frequency-domain representation using an FFT. The window length is 0.8 ms, which is equal to the length of the Zadoff-Chu sequence without a cyclic prefix. This allows handling timing uncertainties up to 0.1 ms and matches the guard time defined for the basic preamble configuration.

The output of the FFT, representing the received signal in the frequency domain, is multiplied by the complex-conjugate frequency-domain representation of the root Zadoff-Chu sequence and the result is fed through an IFFT. By observing the IFFT outputs, it is possible to detect which of the shifts of the root Zadoff-Chu sequence has been transmitted and its delay. Basically, a peak of the IFFT output in interval i corresponds to the ith cyclically shifted sequence and the delay is given by the position of the peak within the interval. This frequency-domain implementation is computationally efficient and allows simultaneous detection of multiple random-access attempts using different cyclically shifted sequences generated from the same root Zadoff-Chu sequence; in the case of multiple attempts there will simply be a peak in each of the corresponding intervals.

14.3.2 Step 2: Random-Access Response

In response to the detected random-access attempt, the eNodeB will, as the second step of the random-access procedure, transmit a message on the DL-SCH, containing:

- The index of the random-access preamble sequences the network detected and for which the response is valid.
- The timing correction calculated by the random-access preamble receiver.

- A scheduling grant, indicating resources the terminal will use for the transmission of the message in the third step.
- A temporary identity, the TC-RNTI, used for further communication between the terminal and the network.

If the network detects multiple random-access attempts (from different terminals), the individual response messages of multiple terminals can be combined in a single transmission. Therefore, the response message is scheduled on the DL-SCH and indicated on a PDCCH using an identity reserved for random-access response, the RA-RNTI. All terminals that have transmitted a preamble monitor the L1/L2 control channels for random-access response within a configurable time window. The timing of the response message is not fixed in the specification in order to be able to respond to sufficiently many simultaneous accesses. It also provides some flexibility in the base-station implementation. If the terminal does not detect a random-access response within the time window, the attempt will be declared as failed and the procedure will repeat from the first step again, possibly with an increased preamble transmission power.

As long as the terminals that performed random access in the same resource used different preambles, no collision will occur and from the downlink signaling it is clear to which terminal(s) the information is related. However, there is a certain probability of contention – that is, multiple terminals using the same random-access preamble at the same time. In this case, multiple terminals will react upon the same downlink response message and a collision occurs. Resolving these collisions is part of the subsequent steps, as discussed below. Contention is also one of the reasons why hybrid ARQ is not used for transmission of the random-access response. A terminal receiving a random-access response intended for another terminal will have incorrect uplink timing. If hybrid ARQ were used, the timing of the hybrid-ARQ acknowledgement for such a terminal would be incorrect and may disturb uplink control signaling from other users.

Upon reception of the random-access response in the second step, the terminal will adjust its uplink transmission timing and continue to the third step. If contention-free random access using a dedicated preamble is used, then this is the last step of the random-access procedure as there is no need to handle contention in this case. Furthermore, the terminal already has a unique identity allocated in the form of a C-RNTI.

14.3.3 Step 3: Terminal Identification

After the second step, the uplink of the terminal is time synchronized. However, before user data can be transmitted to/from the terminal, a unique identity within the cell, the C-RNTI, must be assigned to the terminal. Depending on the terminal state, there may also be a need for additional message exchange for setting up the connection.

In the third step, the terminal transmits the necessary messages to the eNodeB using the UL-SCH resources assigned in the random-access response in the second step. Transmitting the uplink message in the same manner as scheduled uplink data instead of attaching it to the preamble in the first step is beneficial for several reasons. First, the amount of information transmitted in the absence of uplink synchronization should be minimized, as the need for a large guard time makes such transmissions relatively costly. Secondly, the use of the "normal" uplink transmission scheme for message transmission allows the grant size and modulation scheme to be adjusted to, for example, different radio conditions. Finally, it allows for hybrid ARQ with soft combining for the uplink message. The latter is

Petitioners' Exhibit 1003, p. 677
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

an important aspect, especially in coverage-limited scenarios, as it allows for the use of one or several retransmissions to collect sufficient energy for the uplink signaling to ensure a sufficiently high probability of successful transmission. Note that RLC retransmissions are not used for the uplink RRC signaling in step 3.

An important part of the uplink message is the inclusion of a terminal identity, as this identity is used as part of the contention-resolution mechanism in the fourth step. If the terminal is in the RRC_CONNECTED state – that is, connected to a known cell and therefore has a C-RNTI assigned – this C-RNTI is used as the terminal identity in the uplink message.[8] Otherwise, a core-network terminal identifier is used and the eNodeB needs to involve the core network prior to responding to the uplink message in step 3.

UE-specific scrambling is used for transmission on UL-SCH, as described in Chapter 11. However, as the terminal may not yet have been allocated its final identity, the scrambling cannot be based on the C-RNTI. Instead, a temporary identity is used (TC-RNTI).

14.3.4 Step 4: Contention Resolution

The last step in the random-access procedure consists of a downlink message for contention resolution. Note that, from the second step, multiple terminals performing simultaneous random-access attempts using the same preamble sequence in the first step listen to the same response message in the second step and therefore have the same temporary identifier. Hence, in the fourth step, each terminal receiving the downlink message will compare the identity in the message with the identity transmitted in the third step. Only a terminal which observes a match between the identity received in the fourth step and the identity transmitted as part of the third step will declare the random-access procedure successful. If the terminal has not yet been assigned a C-RNTI, the TC-RNTI from the second step is promoted to the C-RNTI; otherwise the terminal keeps its already assigned C-RNTI.

The contention-resolution message is transmitted on the DL-SCH, using the temporary identity from the second step for addressing the terminal on the L1/L2 control channel. Since uplink synchronization has already been established, hybrid ARQ is applied to the downlink signaling in this step. Terminals with a match between the identity they transmitted in the third step and the message received in the fourth step will also transmit a hybrid-ARQ acknowledgement in the uplink.

Terminals that do not find a match between the identity received in the fourth step and the respective identity transmitted as part of the third step are considered to have failed the random-access procedure and need to restart the procedure from the first step. Obviously, no hybrid-ARQ feedback is transmitted from these terminals. Furthermore, a terminal that has not received the downlink message in step 4 within a certain time from the transmission of the uplink message in step 3 will declare the random-access procedure as failed and need to restart from the first step.

14.4 PAGING

Paging is used for network-initiated connection setup when the terminal is in RRC_IDLE. In LTE, the same mechanism as for "normal" downlink data transmission on the DL-SCH is used and the mobile terminal monitors the L1/L2 control signaling for downlink scheduling assignments related to paging.

[8]The terminal identity is included as a MAC control element on the UL-SCH.

Petitioners' Exhibit 1003, p. 678
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 14.1 Paging Cycles and Paging Subframes

		Number of Paging Subframes per Paging Cycle							
		1/32	**1/16**	**1/8**	**1/4**	**1/2**	**1**	**2**	**4**
Paging subframes in a paging frame	FDD	9	9	9	9	9	9	4, 9	0, 4, 5, 9
	TDD	0	0	0	0	0	0	0, 5	0, 1, 5, 6

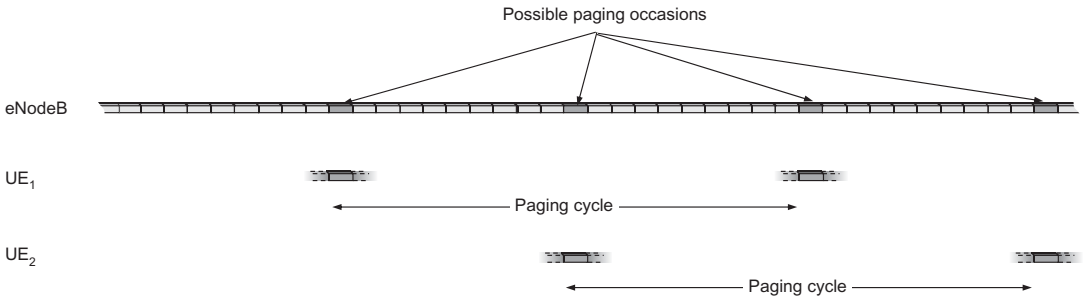


FIGURE 14.14

Illustration of paging cycles.

Since the location of the terminal typically is not known on a cell level, the paging message is typically transmitted across multiple cells in the so-called *tracking area* (the tracking area is controlled by the MME; see [9] for a discussion on tracking areas).

An efficient paging procedure should allow the terminal to sleep with no receiver processing most of the time and to briefly wake up at predefined time intervals to monitor paging information from the network. Therefore, a paging cycle is defined, allowing the terminal to sleep most of the time and only briefly wake up to monitor the L1/L2 control signaling. If the terminal detects a group identity used for paging (the P-RNTI) when it wakes up, it will process the corresponding downlink paging message transmitted on the PCH. The paging message includes the identity of the terminal(s) being paged, and a terminal not finding its identity will discard the received information and sleep according to the DRX cycle. Obviously, as the uplink timing is unknown during the DRX cycles, no hybrid-ARQ acknowledgements can be transmitted and consequently hybrid ARQ with soft combining is not used for paging messages.

The network configures in which subframes a terminal should wake up and listen for paging. Typically, the configuration is cell specific, although there is a possibility to complement the setting by UE-specific configuration. In which frame a given terminal should wake up and search for the P-RNTI on a PDCCH is determined by an equation taking as input the identity of the terminal as well as a cell-specific and (optionally) a UE-specific paging cycle. The identity used is the so-called IMSI, an identity coupled to the subscription, as an idle mode terminal does not have a C-RNTI allocated, and the paging cycle for a terminal can range from once per 256 up to once per 32 frames. The subframe within a frame to monitor for paging is also derived from the IMSI. Since different terminals

have different IMSI, they will compute different paging instances. Hence, from a network perspective, paging may be transmitted more often than once per 32 frames, although not all terminals can be paged at all paging occasions as they are distributed across the possible paging instances as shown in Figure 14.14.

Paging messages can only be transmitted in some subframes, ranging from one subframe per 32 frames up to a very high paging capacity with paging in four subframes in every frame. The configurations are shown in Table 14.1. Note that, from a network perspective, the cost of a short paging cycle is minimal as resources not used for paging can be used for normal data transmission and are not wasted. However, from a terminal perspective, a short paging cycle increases the power consumption as the terminal needs to wake up frequently to monitor the paging instants.

In addition to initiating connection to terminals being in RRC_IDLE, paging can also be used to inform terminals in RRC_IDLE as well as RRC_CONNECTED about changes of system information. A terminal being paged for this reason knows that the system information will change and therefore needs to acquire the update system information as described in Section 14.2.

Petitioners' Exhibit 1003, p. 680
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CHAPTER

Multimedia Broadcast/Multicast Services

15

In the past, cellular systems have mostly focused on transmission of data intended for a single user and not on multicast/broadcast services. Broadcast networks, exemplified by the radio and TV broadcasting networks, have on the other hand focused on covering very large areas with the same content and have offered no or limited possibilities for transmission of data intended for a single user. *Multimedia Broadcast Multicast Services* (MBMS) support multicast/broadcast services in a cellular system, thereby combining the provision of multicast/broadcast and unicast services within a single network.

With MBMS, the same content is transmitted to multiple users located in a specific area, known as the *MBMS service area* and typically comprising multiple cells. In each cell participating in the transmission, a point-to-multipoint radio resource is configured and all users subscribing to the MBMS service simultaneously receive the same transmitted signal. No tracking of users' movement in the radio-access network is performed and users can receive the content without notifying the network.

When providing multicast/broadcast services for mobile devices there are several aspects to take into account, of which two deserve special attention and will be elaborated upon further below: good coverage and low terminal power consumption.

The coverage, or more accurately the data rate possible to provide, is basically determined by the link quality of the worst-case user, as no user-specific adaptation of transmission parameters can be used in a multicast/broadcast system providing the same information to multiple users. As discussed in Chapter 3, OFDM transmission provides specific benefits for provision of multi-cell multicast/broadcast services. If the transmissions from the different cells are time synchronized, the resulting signal will, from a terminal point of view, appear as a transmission from a single point over a time-dispersive channel. As mentioned in Chapter 7, for LTE this kind of transmission is referred to as an *MBMS Single-Frequency Network* (MBSFN). MBSFN transmission provides several benefits:

- Increased received signal strength, especially at the border between cells involved in the MBSFN transmission, as the terminal can utilize the signal energy received from multiple cells.
- Reduced interference level, once again especially at the border between cells involved in the MBSFN transmission, as the signals received from neighboring cells will not appear as interference but as useful signals.
- Additional diversity against fading on the radio channel as the information is received from several, geographically separated locations, typically making the overall aggregated channel appear highly time-dispersive or, equivalently, highly frequency selective.

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 682
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

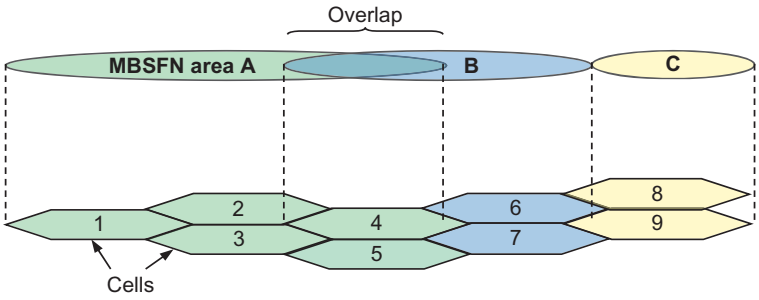


FIGURE 15.1

Example of MBSFN areas.

Altogether, this allows for significant improvements in the multicast/broadcast reception quality, especially at the border between cells involved in the MBSFN transmission, and, as a consequence, significant improvements in the achievable multicast/broadcast data rates.

Providing for power-efficient reception in the terminal in essence implies that the structure of the overall transmission should be such that data for a service-of-interest is provided in short high-data-rate bursts rather than longer low-data-rate bursts. This allows the terminal to occasionally wake up to receive data with long periods of DRX in between. In LTE, this is catered for by time-multiplexing unicast and broadcast transmissions, as well as by the scheduling of different MBMS services, as discussed further below.

15.1 ARCHITECTURE

An *MBSFN area* is a specific area where one or several cells transmit the same content. For example, in Figure 15.1, cells 8 and 9 both belong to MBSFN area C. Not only can an MBSFN area consist of multiple cells, a single cell can also be part of multiple, up to eight, MBSFN areas, as shown in Figure 15.1, where cells 4 and 5 are part of both MBSFN areas A and B. Note that, from an MBSFN reception point of view, the individual cells are invisible, although the terminal needs to be aware of the different cells for other purposes, such as reading system information and notification indicators, as discussed below. The MBSFN areas are static and do not vary over time.

The usage of MBSFN transmission obviously requires not only time synchronization among the cells participating in an MBSFN area, but also usage of the same set of radio resources in each of the cells for a particular service. This coordination is the responsibility of the *Multi-cell/multicast Coordination Entity* (MCE), which is a logical node in the radio-access network handling allocation of radio resources and transmission parameters (time–frequency resources and transport format) across the cells in the MBSFN area. As shown in Figure 15.2, the MCE[1] can control multiple eNodeBs, each handling one or more cells.

[1]There is an alternative architecture supported where MCE functionality is included in every eNodeB. However, as there is no communication between MCEs in different eNodeBs, the MBSFN area would in this case be limited to the set of cells controlled by a single eNodeB.

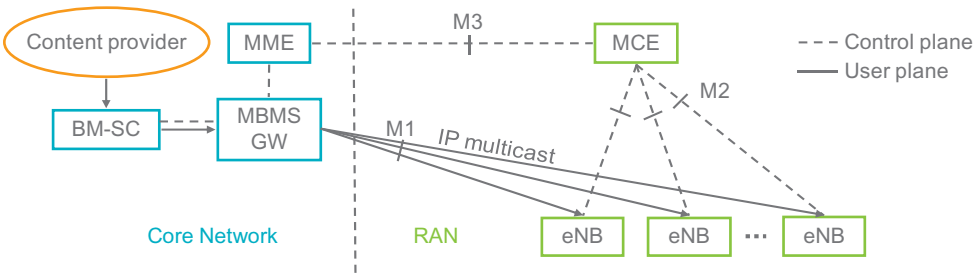


FIGURE 15.2

LTE MBMS architecture.

The *Broadcast Multicast Service Center* (BM-SC), located in the core network, is responsible for authorization and authentication of content providers, charging, and the overall configuration of the data flow through the core network. The MBMS gateway (MBMS-GW) is a logical node handling multicast of IP packets from the BM-SC to all eNodeBs involved in transmission in the MBSFN area. It also handles session control signaling via the MME.

From the BM-SC, the MBMS data is forwarded using IP multicast, a method of sending an IP packet to multiple receiving network nodes in a single transmission, via the MBMS gateway to the cells from which the MBMS transmission is to be carried out. Hence, MBMS is not only efficient from a radio-interface perspective, but it also saves resources in the transport network by not having to send the same packet to multiple nodes individually unless necessary. This can lead to significant savings in the transport network.

15.2 OVERALL CHANNEL STRUCTURE AND PHYSICAL-LAYER PROCESSING

The basis for MBSFN transmission is the *Multicast Channel* (MCH), a transport channel type supporting MBSFN transmission. Two types of logical channels can be multiplexed and mapped to the MCH:

- *Multicast Traffic Channel* (MTCH)
- *Multicast Control Channel* (MCCH).

The MTCH is the logical channel type used to carry MBMS data corresponding to a certain MBMS service. If the number of services to be provided in an MBSFN area is large, multiple MTCHs can be configured. Obviously, as no acknowledgements are transmitted by the terminals, no RLC retransmissions can be used and consequently the RLC unacknowledged mode is used.

The MCCH is the logical channel type used to carry control information necessary for reception of a certain MBMS service, including the subframe allocation and modulation-and-coding scheme for each MCH. There is one MCCH per MBSFN area. Similarly to the MTCH, the RLC uses unacknowledged mode.

Petitioners' Exhibit 1003, p. 684
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

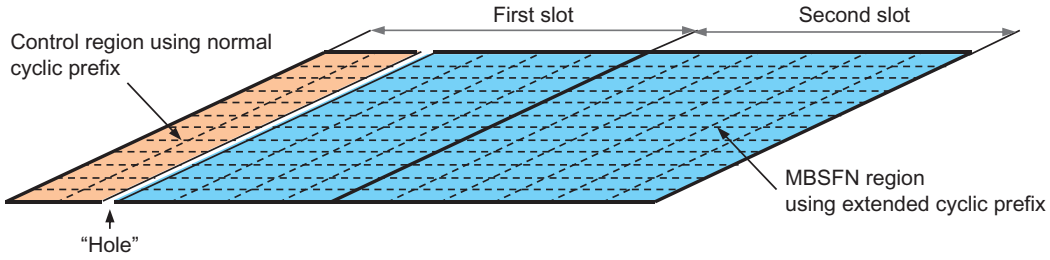


FIGURE 15.3

Resource-block structure for MBSFN subframes, assuming normal cyclic prefix for the control region.

One or several MTCHs and, if applicable,[2] one MCCH are multiplexed at the MAC layer to form an MCH transport channel. As already described in Chapter 8, the MAC header contains information about the logical-channel multiplexing, in this specific case the MTCH/MCCH multiplexing, such that the terminal can demultiplex the information upon reception. The MCH is transmitted using MBSFN in one MBSFN area.

The transport-channel processing for MCH is, in most respects, the same as that for DL-SCH as described in Section 10.1, with some exceptions:

- In the case of MBSFN transmission, the same data is to be transmitted with the same transport format using the same physical resource from multiple cells typically belonging to different eNodeBs. Thus, the MCH transport format and resource allocation cannot be dynamically adjusted by the eNodeB. As described above, the transport format is instead determined by the MCE and signaled to the terminals as part of the information sent on the MCCH.
- As the MCH transmission is simultaneously targeting multiple terminals and therefore no feedback is used, hybrid ARQ is not applicable in the case of MCH transmission.
- As already mentioned, multi-antenna transmission (transmit diversity and spatial multiplexing) does not apply to MCH transmission.

Furthermore, as also mentioned in Chapter 10, the PMCH scrambling should be *MBSFN-area specific* – that is, identical for all cells involved in the MBSFN transmission.

The MCH is mapped to the PMCH physical channel and transmitted in MBSFN subframes, illustrated in Figure 15.3. As discussed in Chapter 9, an MBSFN subframe consists of two parts: a *control region*, used for transmission of regular unicast L1/L2 control signaling; and an *MBSFN region*, used for transmission of the MCH.[3] Unicast control signaling may be needed in an MBSFN subframe, for example to schedule uplink transmissions in a later subframe, but is also used for MBMS-related signaling, as discussed further below.

[2]One MCCH per MBSFN area is needed, but it does not have to occur in every MCH TTI, nor on all MCHs in the MBSFN area.

[3]As discussed in Chapter 9, MBSFN subframes can be used for multiple purposes and not all of them have to be used for MCH transmission.

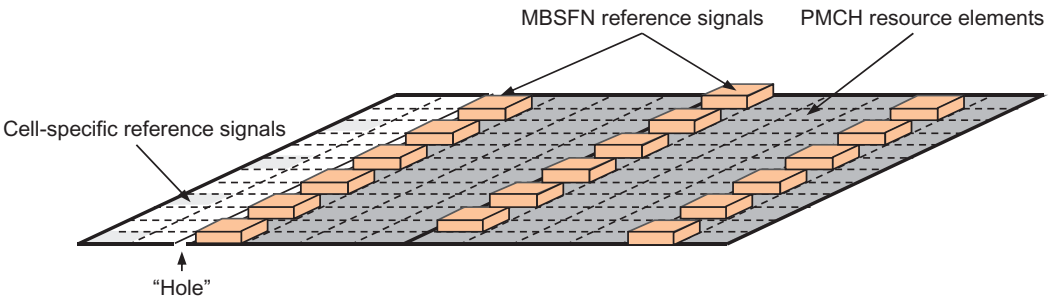


FIGURE 15.4

Reference-signal structure for PMCH reception.

As already discussed in Chapter 3, in the case of MBSFN-based multicast/broadcast transmission, the cyclic prefix should not only cover the main part of the actual channel time dispersion but also the timing difference between the transmissions received from the cells involved in the MBSFN transmission. Therefore, MCH transmissions, which can take place in the MBSFN region only, use an extended cyclic prefix. If a normal cyclic prefix is used for normal subframes, and therefore also in the control region of MBSFN subframes, there will be a small "hole" between the two parts of an MBSFN subframe, as illustrated in Figure 15.3. The reason is to keep the start timing of the MBSFN region fixed, irrespective of the cyclic prefix used for the control region.

As already mentioned, the MCH is transmitted by means of MBSFN from the set of cells that are part of the corresponding MBSFN area. Thus, as seen from the terminal point of view, the radio channel that the MCH has propagated over is the aggregation of the channels of each cell within the MBSFN area. For channel estimation for coherent demodulation of the MCH, the terminal can thus not rely on the normal cell-specific reference signals transmitted from each cell. Rather, in order to enable coherent demodulation for MCH, special MBSFN reference symbols are inserted within the MBSFN part of the MBSFN subframe, as illustrated in Figure 15.4. These reference symbols are transmitted by means of MBSFN over the set of cells that constitute the MBSFN area – that is, they are transmitted at the same time–frequency position and with the same reference-symbol values from each cell. Channel estimation using these reference symbols will thus correctly reflect the overall aggregated channel corresponding to the MCH transmissions of all cells that are part of the MBSFN area.

MBSFN transmission in combination with specific MBSFN reference signals can be seen as transmission using a specific antenna port, referred to as *antenna port 4*.

A terminal can assume that all MBSFN transmissions within a given subframe correspond to the same MBSFN area. Hence, a terminal can interpolate over all MBSFN reference symbols within a given MBSFN subframe when estimating the aggregated MBSFN channel. In contrast, MCH transmissions in different subframes may, as already discussed, correspond to different MBSFN areas. Consequently, a terminal cannot necessarily interpolate the channel estimates across multiple subframes.

As can be seen in Figure 15.4, the frequency-domain density of MBSFN reference symbols is higher than the corresponding density of cell-specific reference symbols. This is needed as the

Petitioners' Exhibit 1003, p. 686
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

aggregated channel of all cells involved in the MBSFN transmission will be equivalent to a highly time-dispersive or, equivalently, highly frequency-selective channel. Consequently, a higher frequency-domain reference-symbol density is needed.

There is only a single MBSFN reference signal in MBSFN subframes. Thus, multi-antenna transmission such as transmit diversity and spatial multiplexing is not supported for MCH transmission. The main argument for not supporting any standardized transmit diversity scheme for MCH transmission is that the high frequency selectivity of the aggregated MBSFN channel in itself provides substantial (frequency) diversity.

15.3 SCHEDULING OF MBMS SERVICES

Good coverage throughout the MBSFN area is, as already explained, one important aspect of providing broadcast services. Another important aspect, as mentioned in the introduction, is to provide for energy-efficient reception. In essence, for a given service, this translates into transmission of short high-rate bursts in between which the terminal can enter a DRX state to reduce power consumption. LTE therefore makes extensive use of time-multiplexing of MBMS services and the associated signaling, as well as provides a mechanism to inform the terminal *when* in time a certain MBMS service is transmitted. Fundamental to the description of this mechanism are the *Common Subframe Allocation* (CSA) period and the *MCH Scheduling Period* (MSP).

All MCHs that are part of the same MBSFN area occupy a pattern of MBSFN subframes known as the *Common Subframe Allocation* (CSA). The CSA is periodic, as illustrated in Figure 15.5.

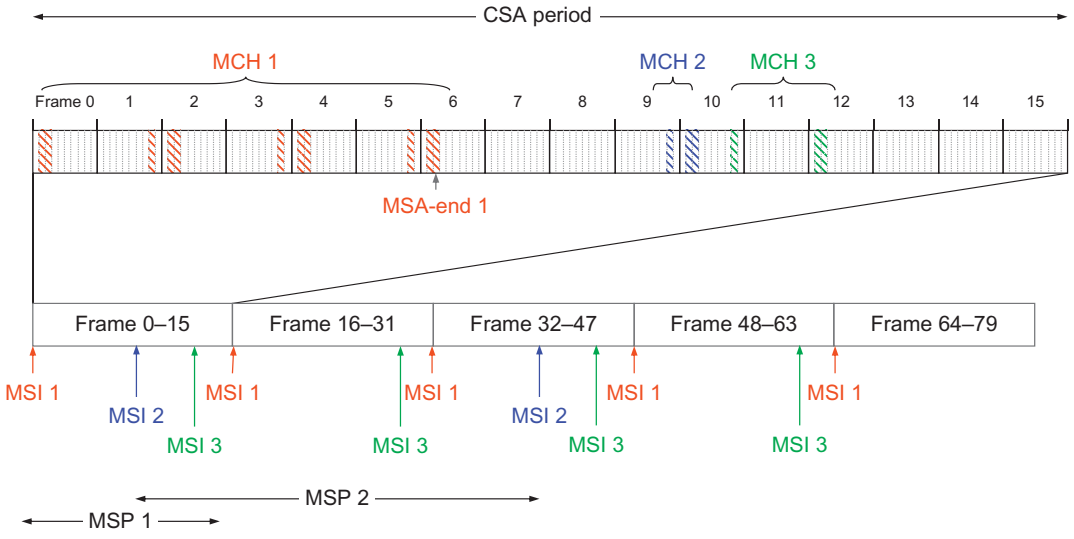


FIGURE 15.5

Example of scheduling of MBMS services.

Obviously, the subframes used for transmission of the MCH must be configured as MBSFN subframes, but the opposite does not hold – MBSFN subframes can be configured for other purposes as well, for example to support the backhaul link in the case of relaying, as described in Chapter 16. Furthermore, the allocation of MBSFN subframes for MCH transmission should obviously be identical across the MBSFN area as there otherwise will not be any MBSFN gain. This is the responsibility of the MCE.

Transmission of a specific MCH follows the *MCH subframe allocation* (MSA). The MSA is periodic and at the beginning of each *MCH Scheduling Period* (MSP), a MAC control element is used to transmit the *MCH Scheduling Information* (MSI). The MSI indicates which subframes are used for a certain MTCH in the upcoming scheduling period. Not all possible subframes need to be used; if a smaller number than allocated to an MCH is required by the MTCH(s), the MSI indicates the last MCH subframe to be used for this particular MTCH (*MSA end* in Figure 15.5), while the remaining subframes are not used for MBMS transmission. The different MCHs are transmitted in consecutive order within a CSA period – that is, all subframes used by MCH n in a CSA are transmitted before the subframes used for MCH $n + 1$ in the same CSA period.

The fact that the transport format is signaled as part of the MCCH implies that the MCH transport format may differ between MCHs but must remain constant across subframes used for the same MCH. The only exception is subframes used for the MCCH and MSI, where the MCCH-specific transport format, signaled as part of the system information, is used instead.

In the example in Figure 15.5, the scheduling period for the first MCH is 16 frames, corresponding to one CSA period, and the scheduling information for this MCH is therefore transmitted once every 16 frames. The scheduling period for the second MCH, on the other hand, is 32 frames, corresponding to two CSA periods, and the scheduling information is transmitted once every 32 frames. The MCH scheduling periods can range from 80 ms to 10.24 s.

To summarize, for each MBSFN area, the MCCH provides information about the CSA pattern, the CSA period, and, for each MCH in the MBSFN area, the transport format and the scheduling period. This information is necessary for the terminal to properly receive the different MCHs. However, the MCCH is a logical channel and itself mapped to the MCH, which would result in a chicken-and-egg problem – the information necessary for receiving the MCH is transmitted on the MCH. Hence, in TTIs when the MCCH (or MSI) is multiplexed into the MCH, the MCCH-specific transport format is used for the MCH. The MCCH-specific transport format is provided as part of the system information (SIB13; see Chapter 14 for a discussion about system information). The system information also provides information about the scheduling and modifications periods of the MCCH (but not about CSA period, CSA pattern, and MSP, as those quantities are obtained from the MCCH itself). Reception of a specific MBMS service can thus be described by the following steps:

- Receive SIB13 to obtain knowledge on how to receive the MCCH for this particular MBSFN area.
- Receive the MCCH to obtain knowledge about the CSA period, CSA pattern, and MSP for the service of interest.
- Receive the MSI at the beginning of each MSP. This provides the terminal with information on which subframes the service of interest can be found in.

After the second step above, the terminal has acquired the CSA period, CSA pattern, and MSP. These parameters typically remain fixed for a relatively long time. The terminal therefore only needs to receive the MSI and the subframes in which the MTCH carrying the service of interest are located,

Petitioners' Exhibit 1003, p. 688
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

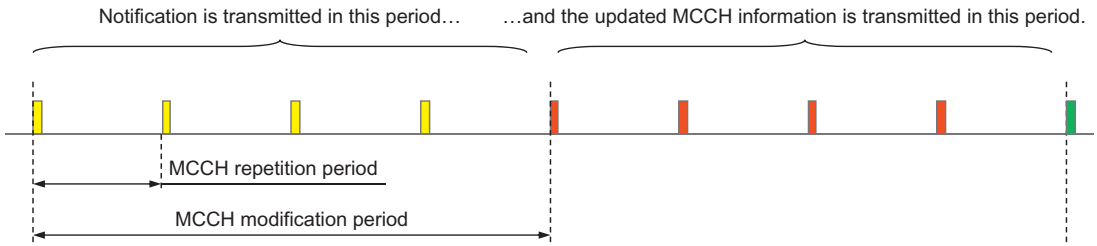


FIGURE 15.6

MCCH transmission schedule.

as described in the third bullet above. This greatly helps to reduce the power consumption in the terminal as it can sleep in most of the subframes.

Occasionally there may be a need to update the information provided on the MCCH, for example when starting a new service. Requiring the terminal to repeatedly receive the MCCH comes at a cost in terms of terminal power consumption. Therefore, a fixed schedule for MCCH transmission is used in combination with a change-notification mechanism, as described below.

The MCCH information is transmitted repeatedly with a fixed repetition period and changes to the MCCH information can only occur at specific time instants. When (parts of) the MCCH information is changed, which can only be done at the beginning of a new modification period, as shown in Figure 15.6, the network notifies the terminals about the upcoming MCCH information change in the preceding MCCH modification period. The notification mechanism uses the PDCCH for this purpose. An eight-bit bitmap, where each bit represents a certain MBSFN area, is transmitted on the PDCCH in an MBSFN subframe using DCI format 1C and a reserved identifier, the M-RNTI. The notification bitmap is only transmitted when there are any changes in the services provided (in release 10, notification is also used to indicate a counting request in an MBSFN area) and follows the modification period described above.

The purpose of the concept of notification indicators and modification periods is to maximize the amount of time the terminal may sleep to save battery power. In the absence of any changes to the MCCH information, a terminal currently not receiving MBMS may enter DRX and only wake up when the notification indicator is transmitted. As a PDCCH in an MBSFN subframe spans at most two OFDM symbols, the duration during which the terminal needs to wake up to check for notifications is very short, translating to a high degree of power saving. Repeatedly transmitting the MCCH is useful to support mobility; a terminal entering a new area or a terminal missing the first transmission does not have to wait until the start of a new modification period to receive the MCCH information.

Petitioners' Exhibit 1003, p. 689
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CHAPTER

16 Relaying

The possibility of a terminal communicating with the network, and the data rate that can be used, depends on several factors, the path loss between the terminal and the base station being one. The link performance of LTE is already quite close to the Shannon limit and from a pure link-budget perspective, the highest data rates supported by LTE require a relatively high signal-to-noise ratio. Unless the link budget can be improved, for example with different types of beam-forming solutions, a denser infrastructure is required to reduce the terminal-to-base-station distance and thereby improve the link budget.

A denser infrastructure is mainly a deployment aspect, but in later releases of LTE, various tools enhancing the support for low-power base stations are included. One of these tools is *relaying*, which can be used to reduce the distance between the terminal and the infrastructure, resulting in an improved link budget and an increased possibility for high data rates. In principle this reduction in terminal-to-infrastructure distance could be achieved by deploying traditional base stations with a wired connection to the rest of the network. However, relays with a shorter deployment time can often be an attractive alternative, as there is no need to deploy a specific backhaul.

A wide range of relay types can be envisioned, some of which could already be deployed in release 8.

Amplify-and-forward relays, commonly referred to as *repeaters*, simply amplify and forward the received analog signals and are, on some markets, relatively common as a tool for handling coverage holes. Traditionally, once installed, repeaters continuously forward the received signal regardless of whether there is a terminal in their coverage area or not, although more advanced repeaters can be considered as well. Repeaters are transparent to both the terminal and the base station and can therefore be introduced in existing networks. The fact that the basic principle of a repeater is to amplify whatever it receives, including noise and interference as well as the useful signal, implies that repeaters are mainly useful in high-SNR environments. Expressed differently, the SNR at the output of the repeater can never be higher than at the input.

Decode-and-forward relays decode and re-encode the received signal prior to forwarding it to the served users. The decode-and-re-encode process results in this class of relays not amplifying noise and interference, as is the case with repeaters. They are therefore also useful in low-SNR environments. Furthermore, independent rate adaptation and scheduling for the base station–relay and relay–terminal links is possible. However, the decode-and-re-encode operation implies a larger delay than for an amplify-and-forward repeater, longer than the LTE subframe duration of 1 ms. As for repeaters, many different options exist depending on supported features (support of more than two hops, support for mesh structures, etc) and, depending on the details of those features, a decode-and-forward relay may or may not be transparent to the terminal.

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 690
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

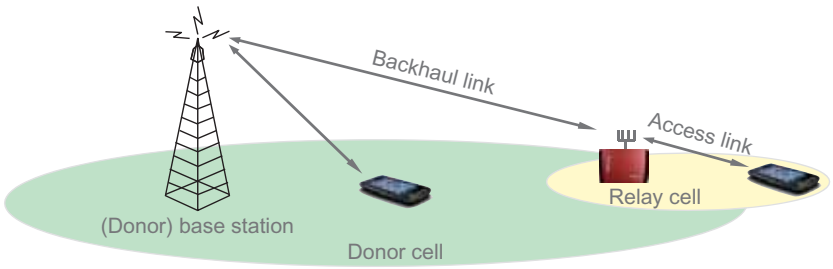


FIGURE 16.1

Access and backhaul links.

16.1 RELAYS IN LTE

LTE release 10 introduces support for a decode-and-forward relaying scheme (repeaters require no additional standardization support other than RF requirements and are available already in release 8). A basic requirement in the development of LTE relaying solutions was that the relay should be transparent to the terminal – that is, the terminal should not be aware of whether it is connected to a relay or to a conventional base station. This ensures that release-8/9 terminals can also be served by relays, despite relays being introduced in release 10. Therefore, so-called *self-backhauling* was taken as the basis for the LTE relaying solution. In essence, from a logical perspective, a relay is an eNodeB wirelessly connected to the rest of the radio-access network by using the LTE radio interface. It is important to note that, even though the relay from a terminal perspective is identical to an eNodeB, the physical implementation may differ significantly, from a traditional base station, for example in terms of output power.

In conjunction with relaying, the terms *backhaul link* and *access link* are often used to refer to the base station–relay connection and the relay–terminal connection respectively. The cell to which the relay is connected using the backhaul link is known as the *donor cell* and the donor cell may, in addition to one or several relays, also serve terminals not connected via a relay. This is illustrated in Figure 16.1.

Since the relay communicates both with the donor cell and terminals served by the relay, interference between the access and backhaul links must be avoided. Otherwise, since the power difference between access-link transmissions and backhaul-link reception at the relay can easily be more than 100 dB, the possibility of receiving the backhaul link may be completely ruined. Similarly, transmissions on the backhaul link may cause significant interference to the reception of the access link. These two cases are illustrated in Figure 16.2. Therefore, isolation between the access and backhaul links is required, isolation that can be obtained in one or several of the frequency, time, and/or spatial domains.

Depending on the spectrum used for access and backhaul links, relaying can be classified into *outband* and *inband* types.

Outband relaying implies that the backhaul operates in a spectrum separate from that of the access link, using the same radio interface as the access link. Provided that the frequency separation between the backhaul and access links is sufficiently large, interference between the backhaul and access links can be avoided and the necessary isolation is obtained in the frequency domain. Consequently, no enhancements to the release-8 radio interface are needed to operate an outband relay. There are no

Petitioners' Exhibit 1003, p. 691
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

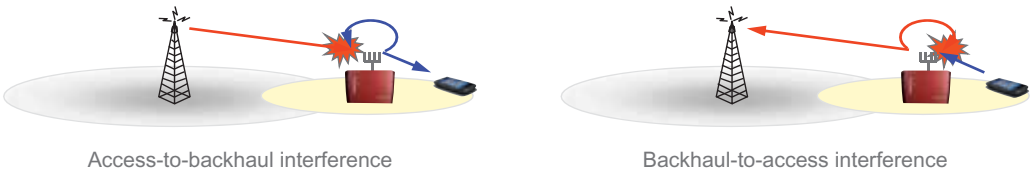


FIGURE 16.2

Interference between access and backhaul links.

restrictions on the activity on the access and backhaul links and the relay can in principle operate with full duplex.

Inband relaying implies that the backhaul and access links operate in the same spectrum. Depending on the deployment and operation of the relay, this may, as the access and backhaul link share the same spectrum, require additional mechanisms to avoid interference between the access and backhaul links. Unless this interference can be handled by proper antenna arrangements, for example with the relay deployed in a tunnel with the backhaul antenna placed outside the tunnel, a mechanism to separate activity on the access and backhaul links in the time domain is required. Such a mechanism was introduced as part of release 10 and will be described in more detail in the following. Since the backhaul and access links are separated in the time domain, there is a dependency on the transmission activity and the two links cannot operate simultaneously.

16.2 OVERALL ARCHITECTURE

From an architectural perspective, a relay can, on a high level, be thought of as having a "base-station side" and a "terminal side". Towards terminals, it behaves as a conventional eNodeB using the access link, and a terminal is not aware of whether it is communicating with a relay or a "traditional" base station. Relays are therefore transparent for the terminals and terminals from the first LTE release, release 8, can also benefit from relays. This is important from an operator's perspective, as it allows a gradual introduction of relays without affecting the existing terminal fleet.

Towards the donor cell, a relay initially operates as a terminal, using the LTE radio interface to connect to the donor cell. Once connection is established and the relay is configured, the relay uses a subset of the "terminal side" functionality for communication on the backhaul link. In this phase, the relay-specific enhancements described in this chapter may be used for the backhaul.

In release 10, the focus is on two-hop relaying and scenarios with a relay connected to the network via another relay are not considered. Furthermore, relays are stationary – that is, handover of a relay from one donor cell to another donor cell is not supported. The case for using mobile relays is not yet clear and therefore it was decided in release 10 not to undertake the relatively large task of adapting existing core-network procedures to handle cells that are moving over time, something that could have been a consequence of a mobile relay.

The overall LTE relaying architecture is illustrated in Figure 16.3. One key aspect of the architecture is that the donor eNodeB acts as a proxy between the core network and the relay. From a relay perspective, is appears as if it is connected directly to the core network as the donor eNodeB appears

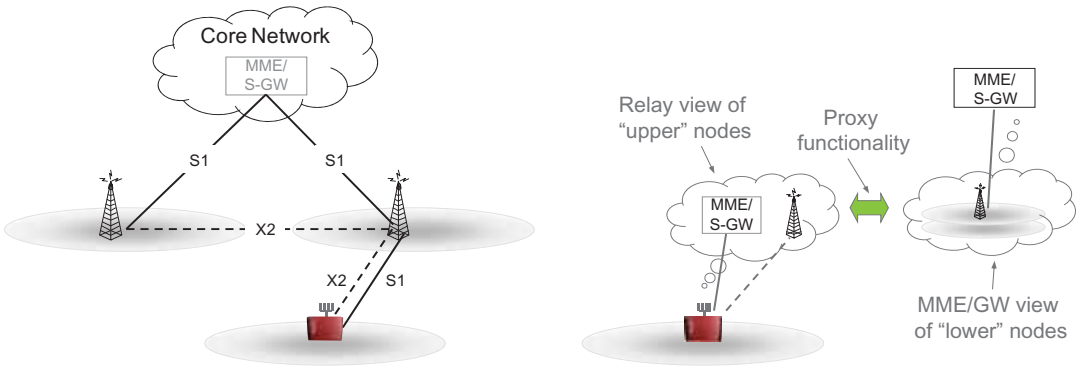


FIGURE 16.3

LTE relaying architecture.

as an MME for the S1 interface and an eNodeB for X2 towards the relay. From a core-network perspective, on the other hand, the relay cells appear as if they belong to the donor eNodeB. It is the task of the proxy in the donor eNodeB to connect these two views. The use of a proxy is motivated by the desire to minimize the impact to the core network from the introduction of relays, as well as to allow for features such as tight coordination of radio-resource management between the donor eNodeB and the relay.

16.3 BACKHAUL DESIGN FOR INBAND RELAYING

In the case of inband relaying, the backhaul and access links operate in the same spectrum. As discussed in the previous section, a mechanism to separate activity on the access and backhaul links in the time domain is required unless sufficient isolation between the two links can be achieved in other ways, for example through appropriate antenna arrangements. Such a mechanism should ensure that the relay is not transmitting on the access link at the same time as it is receiving on the backhaul link (and vice versa).

An obvious way to handle this is to "blank" some subframes on the access link to provide the relay with the possibility to communicate with the donor eNodeB on the backhaul link. In the uplink, the scheduler in the relay can in principle schedule such that there is no access-link activity in certain subframes. These subframes can then be used for uplink transmissions on the backhaul link as the relay does not need to receive anything on the access link in these subframes. However, blanking subframes on the access downlink is not possible. Although a release-10 terminal in principle could have been designed to cope with blank subframes, terminals from earlier releases expect at least cell-specific reference signals to be present in all downlink subframes. Hence, to preserve the possibility of also serving release-8/9 terminals, which was an important requirement during standardization of release 10, the design of the backhaul link must be based on the assumption that the access link can operate with release-8 functionality only.

Petitioners' Exhibit 1003, p. 693
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

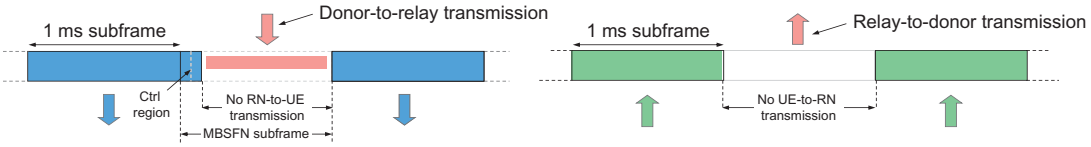


FIGURE 16.4

Multiplexing between access and backhaul links.

Fortunately, already from the first release LTE included the possibility of configuring MBSFN subframes (see Chapter 9). In an MBSFN subframe, terminals expect cell-specific reference signals and (possibly) L1/L2 control signaling to be transmitted only in the first one or two OFDM symbols, while the remaining part of the subframe can be empty. By configuring some of the access-link subframes as MBSFN subframes, the relay can stop transmitting in the latter part of these subframes and receive transmissions from the donor cell. As seen in Figure 16.4, the gap during which the relay can receive transmissions from the donor cell is shorter than the full subframe duration. In particular, as the first OFDM symbols in the subframe are unavailable for reception of donor-cell transmissions, L1/L2 control signaling from the donor to the relay cannot be transmitted using the regular PDCCH. Instead, a relay-specific control channel, the R-PDCCH, is introduced in release 10.

Not only are transmission gaps in the access downlink required in order to receive transmissions from the donor cell, but also reception gaps in the access link are needed in order to transmit on the backhaul from the relay to the donor cell. As already mentioned, such gaps can be created through proper scheduling of uplink transmissions.

The detailed specifications of the physical-layer enhancements introduced in release 10 to support the backhaul can be found in [75].

16.3.1 Access-Link Hybrid-ARQ Operation

The access-link gaps discussed above, MBSFN subframes in the downlink and scheduling gaps in the uplink, used in order to be able to receive and transmit respectively on the backhaul link, affect the hybrid-ARQ operation. Note that hybrid ARQ is used on both the access and backhaul links. Since compatibility with release 8 was a fundamental requirement in the development of the LTE relaying solution, there are no changes to access-link hybrid-ARQ operation.

For uplink transmissions on PUSCH, hybrid-ARQ acknowledgements are transmitted on PHICH. Since the PHICH can be transmitted by the relay even in MBSFN subframes, the operation is identical to that in earlier releases of the LTE standard. However, although the hybrid-ARQ acknowledgement can be received, the subframe where the retransmission should take place (8 ms after the initial transmission for FDD, configuration dependent for TDD) may be used by the backhaul link and not be available for the access link. In that case the corresponding uplink hybrid-ARQ process needs to be suspended by transmitting a positive acknowledgement on the PHICH, irrespective of the outcome of the decoding. By using PDCCH, a retransmission can instead be requested in a later subframe available for the same hybrid-ARQ process, as described in Chapter 12. The hybrid-ARQ round-trip time will be larger in those cases (for example, 16 ms instead of 8 ms for FDD).

Petitioners' Exhibit 1003, p. 694
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Downlink transmissions on PDSCH trigger hybrid-ARQ acknowledgements to be sent on PUCCH and, for proper operation, the relay should be able to receive those acknowledgements. The possibility to receive PUCCH on the access link depends on the backhaul operation, more specifically on the allocation of subframes for backhaul communication.

In FDD, backhaul subframes are configured such that an uplink subframe occurs 4 ms after a downlink subframe. This is chosen to match the access-link hybrid-ARQ timing relations, where an uplink subframe follows 4 ms after a downlink subframe As the relay cannot transmit on the access link simultaneously with the backhaul link, there is no access-link transmission in subframe n and, consequently, no hybrid-ARQ transmission in subframe $n + 4$. Hence, the inability to receive access-link hybrid-ARQ acknowledgements in some subframes is of no concern as the corresponding downlink subframes cannot be used for access-link transmission anyway. Downlink retransmissions are not an issue as they are asynchronous and can be scheduled in any suitable downlink subframe on the access link.

In TDD, the relay node may not be able to receive hybrid-ARQ feedback on PUCCH in uplink subframes used for transmission on the backhaul link. One possibility is to restrict the downlink scheduler such that no terminals transmit PUCCH in uplink subframes the relay cannot receive. However, such a restriction may be too limiting. Alternatively, the relay can schedule without restrictions in the downlink and ignore the hybrid-ARQ acknowledgement. Retransmissions can then either be handled blindly – that is, the relay has to make an educated "guess" on whether a retransmission is required based on, for example, CSI feedback – or RLC retransmissions are used to handle missing packets. Another possibility is to configure repetition of the hybrid-ARQ acknowledgements such that at least some of the repeated acknowledgements are receivable by the relay.

16.3.2 Backhaul-Link Hybrid-ARQ Operation

For the backhaul link, the underlying principle in the design is to maintain the same timing relations as in release 8 for scheduling grants and hybrid-ARQ acknowledgements. As the donor cell may schedule both relays and terminals, such a principle simplifies the scheduling implementation, as scheduling and retransmission decisions for terminals and relays are taken at the same point in time. It also simplifies the overall structure, as release-8 solutions can be reused for the relay backhaul design.

For FDD, the subframes configured for downlink backhaul transmission therefore follow a period of 8 ms in order to match the hybrid-ARQ round-trip time to the extent possible. This also ensures that the PUCCH can be received in the access link, as discussed in the previous section. However, as the possible configurations of MBSFN subframes have an inherent 10 ms structure while the hybrid-ARQ timing follows an 8 ms periodicity, there is an inherent mismatch between the two. Hence, as illustrated in Figure 16.5, some backhaul subframes may be spaced 16 ms apart, as subframes 0, 4, 5, and 9 cannot be configured as MBSFN subframes (see Chapter 9). Uplink backhaul subframes follow 4 ms after a downlink backhaul subframe, following the principle discussed in the previous paragraph.

For TDD, there is an inherent 10 ms component in the hybrid-ARQ timing relations, which matches the 10 ms MBSFN structure and makes it possible to keep a regular spacing of the backhaul transmission attempts. Subframes 0, 1, 5, and 6 cannot be configured as MBSFN subframes. Hence, TDD configuration 0, where subframes 0 and 5 are the only downlink subframes, cannot be used in a relay cell since this configuration does not support any MBSFN subframes. For configuration 5, there

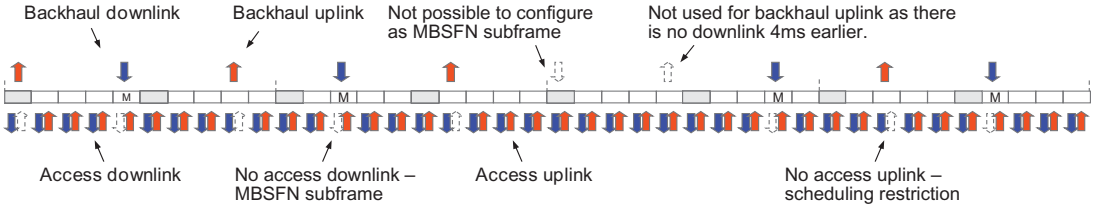


FIGURE 16.5

Example of backhaul configuration for FDD.

is only a single uplink subframe and in order to support both the backhaul and access links at least two uplink subframes are needed. Therefore, of the seven TDD configurations supported in LTE, only configurations 1, 2, 3, 4, and 6 are supported in relay cells. For each TDD configuration, one or several backhaul configurations are supported, as shown in Table 16.1.

The underlying timing principles for hybrid-ARQ acknowledgements and uplink scheduling grants are, as mentioned above, to keep the same principles as for the access link. However, obviously backhaul transmissions may occur in backhaul subframes only. Therefore, for TDD, the acknowledgement of a transport block on the backhaul link in subframe n is transmitted in subframe $n + k$, where $k \geq 4$ and is selected such that $n + k$ is an uplink *backhaul* subframe if the acknowledgement is to be transmitted from the relay and a downlink *backhaul* subframe if the acknowledgement is transmitted from the eNodeB.

The numbering of uplink hybrid-ARQ processes on the backhaul link is similar to the TDD numbering on the access link, where uplink hybrid-ARQ process numbers are assigned sequentially to the available backhaul occasions as shown in Figure 16.6, taking into account the same processing times as for the access link (see Chapter 12). This is in contrast to the FDD access link, where the uplink hybrid-ARQ process number can be directly derived from the subframe number. The reason for adopting a somewhat different strategy is to minimize the maximum hybrid-ARQ round-trip time. Due to the fact that a pure 8 ms periodicity does not always match the MBSFN allocation, the actual uplink round-trip time, unlike the FDD access link, is not constant but, similar to the TDD access link, is dependent on the subframe number.

16.3.3 Backhaul Downlink Control Signaling

The gap during which the relay can receive transmissions from the donor cell is, as seen in Figure 16.4, shorter than the full subframe duration. In particular, as the first OFDM symbols in the subframe are unavailable for reception of transmissions from the donor cell, L1/L2 control signaling from the donor to the relay cannot be transmitted using the regular PDCCH.[1] Instead, a relay-specific control channel, the R-PDCCH, is introduced in release 10.

[1] In principle, the PDCCH could be received if the subframe structures of the access and backhaul links are offset by two to three OFDM symbols, but with the drawback that relay and donor cells would not be time aligned, which is beneficial, for example, in heterogeneous deployments.

Table 16.1 Supported Backhaul Configurations for TDD

Backhaul Subframe Configuration	Uplink–Downlink Configuration in Relay Cell	Backhaul DL:UL Ratio	Subframe Number									
			0	1	2	3	4	5	6	7	8	9
0	1	1:1					D				U	
1						U						D
2		2:1					D				U	D
3						U	D					D
4		2:2				U	D				U	D
5	2	1:1			U						D	
6						D				U		
7		2:1			U		D				D	
8						D				U		D
9					U	D	D				D	
10		3:1				D				U	D	D
11	3	2:1				U				D		D
12		3:1				U				D	D	D
13		1:1				U						D
14		2:1				U				D		D
15	4					U					D	D
16		3:1				U				D	D	D
17		4:1				U	D			D	D	D
18	6	1:1					U					D

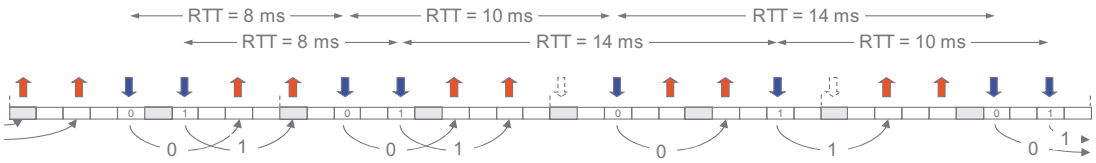


FIGURE 16.6

Example of hybrid-ARQ process numbering for FDD.

The R-PDCCH carries downlink scheduling assignments and uplink scheduling grants, using the same DCI formats as for the PDCCH. However, there is no support for power control commands using DCI formats 3/3A. The main function of DCI formats 3/3A is to support semi-persistent scheduling, a feature mainly targeting overhead reduction for low-rate services and not supported for the backhaul link.

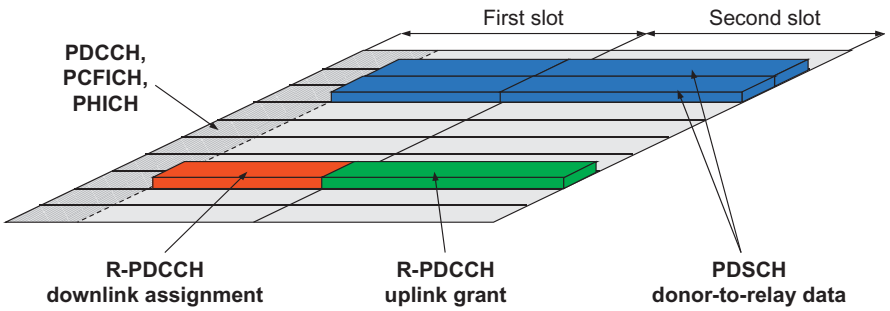


FIGURE 16.7

Example of R-PDCCH transmission.

In the time domain, the R-PDCCH is, as already mentioned, received in the "MBSFN region" of the subframe, while in the frequency domain, transmission of the R-PDCCH occurs in a set of semi-statically allocated resource blocks. From a latency perspective it is beneficial to locate transmissions of downlink scheduling assignments as early as possible in the subframe. As discussed in Chapter 10, this was the main motivation for dividing normal subframes into a control region and a data region. In principle, a similar approach could be taken for the R-PDCCH, namely dividing the set of resource blocks used for R-PDCCH transmission into a control part and a data part. However, as it is not possible to exploit fractions of a subframe for transmission of PDSCH to terminals connected directly to the donor cell, transmission of a single R-PDCCH could block usage of a relatively large number of resource blocks. From an overhead and scheduling flexibility perspective, a structure where the frequency span of the R-PDCCH is minimized (while still providing sufficient diversity) and resources are allocated mainly in the time dimension is preferable. In the release-10 design of the R-PDCCH, these seemingly contradicting requirements have been addressed through a structure where downlink assignments are located in the first slot and uplink grants, which are less time critical, in the second slot of a subframe (see Figure 16.7). This structure allows the time-critical downlink assignments to be decoded early. To handle the case when there is no uplink grant to transmit to the relay, the R-PDCCH resources in the second slot may be used for PDSCH transmission *to the same relay*.

Coding, scrambling, and modulation for the R-PDCCH follows the same principles as for the PDCCH (see Chapter 10), with the same set of aggregation levels supported (one, two, four, and eight CCEs). However, the mapping of the R-PDCCH to time–frequency resources is, for obvious reasons, different. Two different mapping methods, illustrated in Figure 16.8, are supported:

- Without cross-PDCCH interleaving
- With cross-PDCCH interleaving.

Without cross-interleaving, one R-PDCCH is mapped to one set of virtual resource blocks, where the number of resource blocks (one, two, four, or eight) depends on the aggregation level. No other R-PDCCHs are transmitted using the same set of resource blocks. If the resource blocks are located sufficiently apart in the frequency domain, frequency diversity can be obtained, at least for the higher aggregation levels. Non-interleaved mapping is, for example, useful for beam-forming of the backhaul transmissions or when applying frequency-selective scheduling to the R-PDCCH. Either

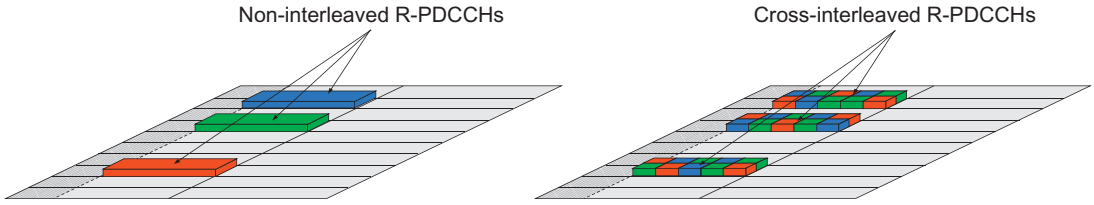


FIGURE 16.8

R-PDCCH mapping types: no cross-interleaving (left) and cross-interleaving (right).

cell-specific reference signals (CRS) or demodulation reference signals (DM-RS) can be used for demodulation.

Cross-interleaved mapping is similar to the strategy used for the PDCCH and reuses most of the PDCCH processing structures except for the mapping to resource elements. A set of R-PDCCHs is multiplexed together, interleaved, and mapped to a set of resource blocks allocated for R-PDCCH transmission. Obviously, as transmissions to multiple relays may share the same set of resource blocks, cell-specific reference signals are the only possibility for demodulation. The motivation for this mapping method is to obtain frequency diversity also for the lowest aggregation level. However, it also comes at the cost of blocking additional resource blocks from PDSCH transmission as, even at low aggregation levels, several resource blocks in the frequency domain are used for the R-PDCCH.

For both mapping cases, cross-interleaved as well as non-cross-interleaved, a set of candidate R-PDCCHs is monitored by the relay node. The set of resource blocks upon which the relay monitors for R-PDCCH transmission is configurable by the donor cell by signaling a set of virtual resource blocks using resource allocation type 0, 1, or 2 (see Chapter 10 for a discussion on resource allocation types). The sets may or may not overlap across multiple relay nodes. In the subframes used for backhaul reception, the relay attempts to receive and decode each of the R-PDCCHs candidates as illustrated in Figure 16.9 and, if valid downlink control information is found, applies this information to downlink reception or uplink transmission. This approach is in essence similar to the blind decoding procedure used in the terminals, although there are some differences. First, there are no common search spaces for the relays as there is no need to receive broadcast information. Any information necessary for relay operation is transmitted using dedicated signaling. Secondly, the search spaces for the non-interleaved mapping are not time varying as in terminals, but remain static in time.

The number of blind decoding attempts is the same as for a terminal – that is, six, six, two, and two attempts for aggregation levels one, two, four, and eight respectively. However, note that an R-PDCCH can be transmitted in either the first or second slot. Hence, the total number of decoding attempts performed by a relay is 64.[2]

No PHICH channel is defined for the backhaul. The main reason for the PHICH in release 8 was efficient support of non-adaptive retransmissions for delay-sensitive low-rate applications such as voice-over IP. The backhaul from a relay, on the other hand, typically uses a higher data rate as multiple terminals are served by the relay. Hence, as control signaling overhead is less of an issue, the

[2]Two slots and two DCI formats per transmission mode results in $2 \cdot 2 \cdot (6 + 6 + 2 + 2) = 64$.

Petitioners' Exhibit 1003, p. 699
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

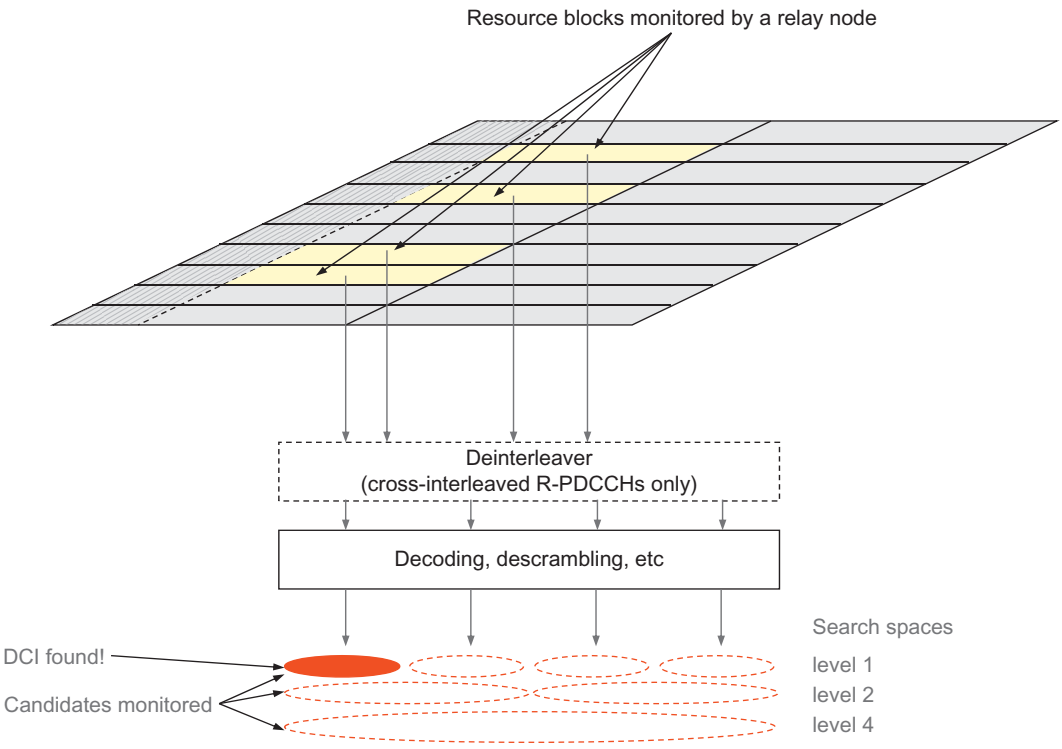


FIGURE 16.9

Illustration of the principle of R-PDCCH monitoring.

PHICH was omitted from the backhaul in order to simplify the overall design. Retransmissions are still supported through the use of the R-PDCCH.

16.3.4 Reference Signals for the Backhaul Link

Backhaul reception at the relay can use cell-specific reference signals (CRS) or demodulation reference signals (DM-RS), described in Chapter 10. Different reference-signal types can be used for R-PDCCH and PDSCH, but if the R-PDCCH is received using demodulation reference signals, then demodulation reference signals should be used for PDSCH as well. This is a reasonable restriction as DM-RS for R-PDCCH is motivated by beam-forming. If beam-forming is used for the R-PDCCH there is no incentive not to use beam-forming also for the PDSCH. The opposite scenario, CRS for R-PDCCH and DM-RS for the PDSCH, does make sense though. One example is interleaved mapping of the control signaling, where multiple R-PDCCHs are multiplexed and individual beam-forming cannot be used, together with beam-forming of the PDSCH. The different combinations of reference signals supported for the backhaul link are summarized in Table 16.2.

Table 16.2 Combinations of Reference Signals and R-PDCCH Mapping Schemes

Reference Signal Type Used For Demodulation Of		R-PDCCH Mapping Scheme
R-PDCCH	PDSCH	
CRS	CRS	Cross-interleaved or non-cross-interleaved
CRS	DM-RS	Cross-interleaved or non-cross-interleaved
DM-RS	DM-RS	Non-cross-interleaved

Note also that in the case of (global) time alignment between the donor and relay cell, the last OFDM symbol cannot be received by the relay as it is needed for reception-transmission switching. Hence, the demodulation reference signals on the last OFDM symbols in the subframe cannot be received. For transmission ranks up to 4 this is not a problem, as the necessary reference signals are also available earlier in the subframe. However, for spatial multiplexing with five or more layers, the first set of reference signals in the subframe is used for the lower layers while the second set of reference signals, located at the end of the subframe and that cannot be received, is used for the higher layers. This implies that reference signals for rank 5 and higher cannot be received by the relay, and backhaul transmissions are therefore restricted to at most four-layer spatial multiplexing, irrespective of the timing relation used.

16.3.5 Backhaul–Access Link Timing

To ensure that the relay is able to receive transmissions from the donor cell, some form of timing relation between the downlink transmissions in the donor and relay cells must be defined, including any guard time needed to allow the relay to switch between access-link transmission to backhaul-link reception and vice versa.

A natural choice for the timing of the access link is to synchronize it to the frame timing of the backhaul link as observed by the relay. From this backhaul downlink timing reference, the timing of the access-link transmission is derived as shown at the bottom of Figure 16.10. The backhaul uplink timing is subject to the normal timing advance controlled by the donor cell, ensuring that the backhaul uplink transmissions are time aligned with other uplink transmissions received by the donor base station.

In the backhaul downlink, the first OFDM symbol in the data region is left unused to provide the guard time for relay switching, and a small time offset is used to distribute the guard between Tx–Rx and Rx–Tx switching at the relay. This case is shown at the bottom of Figure 16.11. Locating the guard symbol at the beginning of the data region instead of at the end is beneficial as the guard symbol is needed at the relay side only and can therefore still be used for transmission of PDCCHs to terminals in the donor cell. In principle, the guard time comes "for free" from a donor cell perspective and the freedom in shifting the relay node frame timing relative to the donor cell timing is used to move the "free" guard period to where it is needed.

The backhaul uplink is subject to the normal timing advance controlled by the donor cell, ensuring that the backhaul uplink transmissions are time aligned with other uplink transmissions received by the donor base station. Similarly to the guard time needed to switch from access-link transmission to backhaul-link reception, which influenced the downlink timing relation between the access and

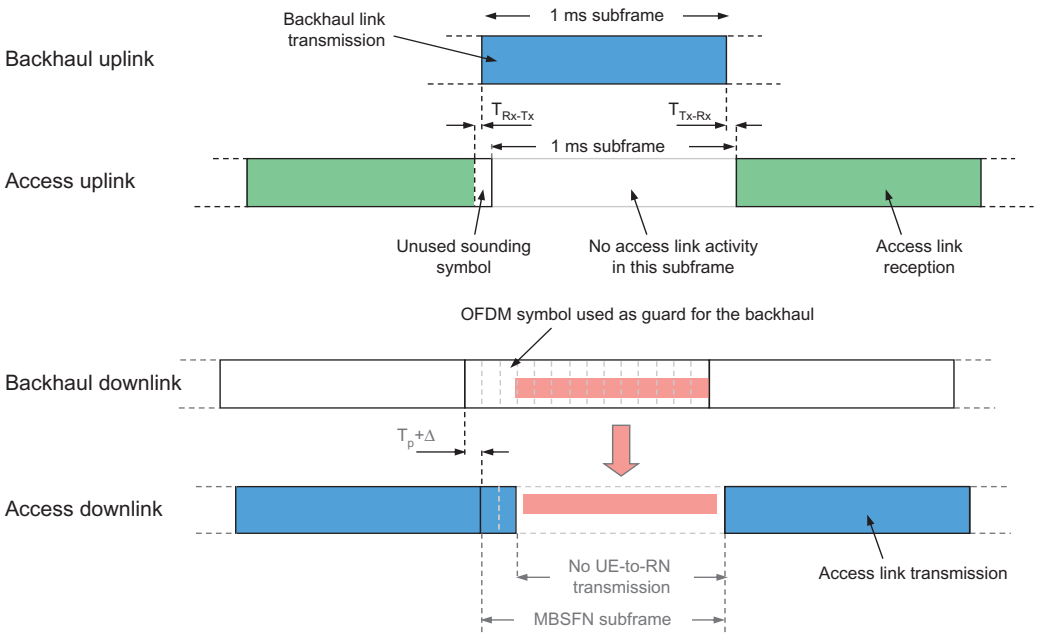


FIGURE 16.10

Backhaul timing relations when the relay cell timing is derived from the backhaul timing.

backhaul links, there may also be the need for a guard time in the uplink direction to switch from access-link reception to backhaul-link transmission. However, unlike the downlink case, how to handle this is not standardized but left for implementation, noting that functionality already present in release 8 is sufficient for providing the necessary guard time.

In principle, if the relay could switch from access-link reception to backhaul-link transmission within the cyclic prefix, no provisions for additional switching time would be necessary. However, the switching time is implementation dependent and typically larger than the cyclic prefix. For larger switching times, one possibility is to use the shortened transmission format on the access link, originally intended for sounding, as shown in the top part of Figure 16.10. By configuring all the terminals in the relay cell to reserve the last OFDM symbol of the preceding subframe for sounding-reference signals but not to transmit any sounding-reference signals, a guard period of one OFDM symbol is created. This guard time can then be divided into Rx–Tx and Tx–Rx switching times through a time offset between the frame timing of the backhaul and access links.

For some deployments, it is desirable to align the access-link transmission timing of the relay with the transmission timing of the donor cell – that is, to use a global timing reference for all the cells. One example hereof is TDD. In such deployments, the necessary guard times are obtained in a slightly different manner compared to the case of using reception timing of the backhaul downlink. In this case it is obviously not possible to obtain the necessary guard time by shifting the subframe timing at the relay. Hence, the guard time for switching from backhaul-link reception to access-link

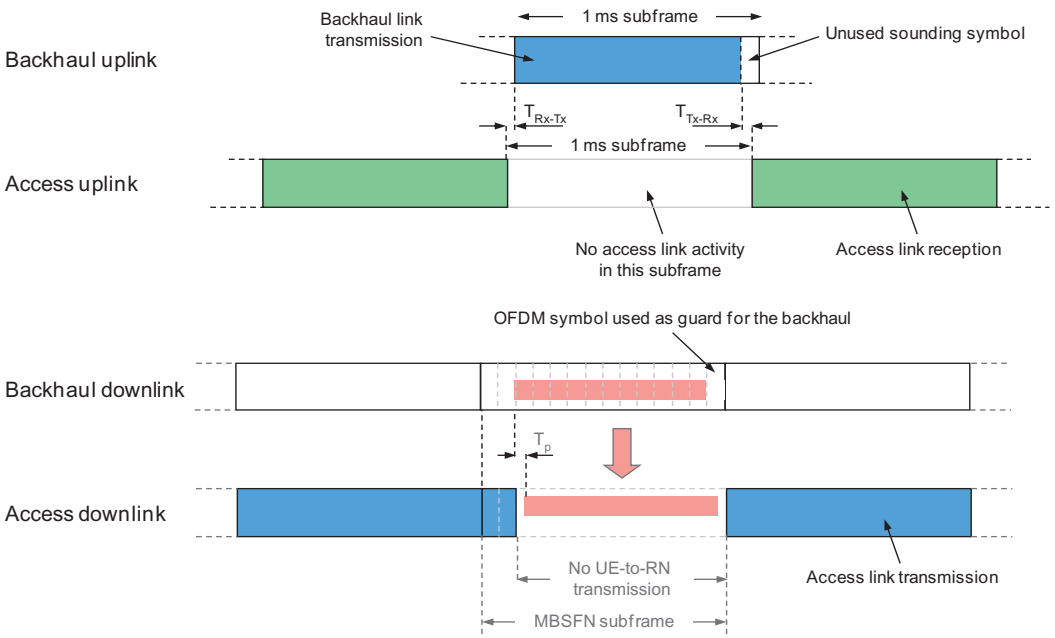


FIGURE 16.11

Backhaul timing relations in access-link transmission in the relay and donor cells are time synchronized.

transmission will also be visible at the donor cell, as the last OFDM symbol in the resource blocks used for the backhaul transmission cannot be used for other transmissions in the relay cell. If the time for Tx–Rx switching is longer than the donor-cell-to-relay-node propagation delay, then the first OFDM symbol has to be left unused as well. This case is shown in the bottom part of Figure 16.11.

In the backhaul uplink, the guard time necessary, similar to the previous timing case, is obtained through configuration of (unused) sounding instances. However, unlike the previous case, sounding is configured in the *backhaul* link, as shown at the top of Figure 16.11. Note that this implies that sounding cannot be used for the backhaul link as the OFDM symbol intended as a sounding-reference symbol is used as guard time.

In the case of TDD operation, guard time for the access–backhaul switch can, in addition to the methods discussed above, be obtained from the guard period required for TDD operation itself. This is shown in Figure 16.12 and is a matter of using the appropriate settings of timing advance and timing offsets.

Backhaul downlink transmissions consist of data transmitted on the PDSCH and L1/L2 control signaling transmitted on the R-PDCCH, as already discussed. Both these types of transmission obviously must follow one of the timing scenarios discussed above. In order to allow for different implementations and deployments, the LTE specifications provide not only the possibility to configure which of the two access–backhaul downlink timing relations to use, but also flexibility in terms of the time span of the channels transmitted on the backhaul link.

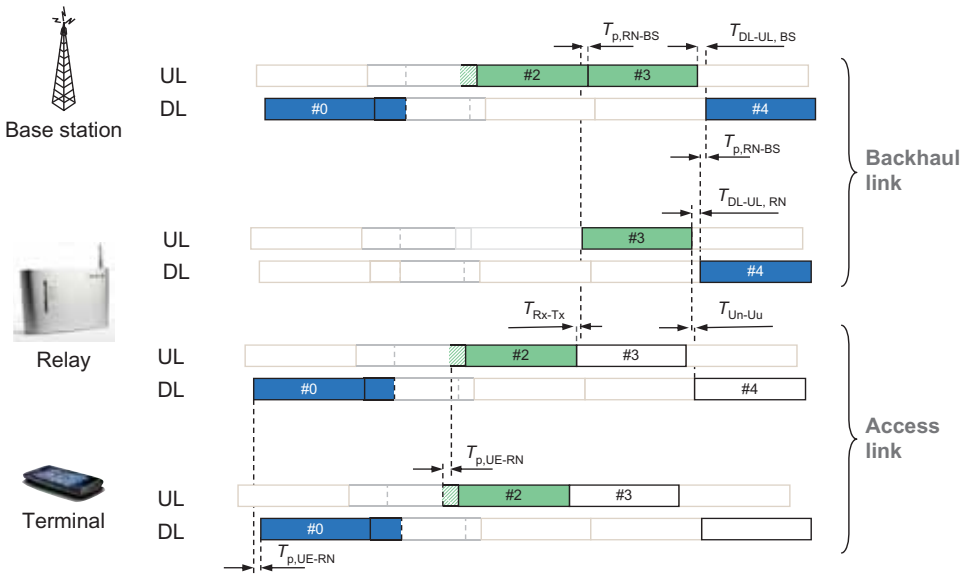


FIGURE 16.12

Example of uplink timing relation for TDD.

PDSCH transmissions intended for a relay can be semi-statically configured to start on the second, third, or fourth OFDM symbol to cater for different control region sizes in the donor cell and relay cells. The PDSCH transmission ends at the last or second last OFDM symbol, depending on which of the two timing cases above is used.

R-PDCCH transmissions intended for a relay always start at the fourth OFDM symbol. A fixed starting position was chosen to simplify the overall structure. Since the amount of resource blocks occupied by an R-PDCCH is relatively small compared to the PDSCH, the overhead reduction possible with a configurable starting positions is small and does not justify the additional specification and testing complexity.

CHAPTER

17 Spectrum and RF Characteristics

Spectrum flexibility is, as mentioned in Chapter 7, a key feature of LTE radio access and is set out in the LTE design targets [10]. It consists of several components, including deployment in different-sized spectrum allocations and deployment in diverse frequency ranges, both in paired and unpaired frequency bands.

There are a number of frequency bands identified for mobile use and specifically for IMT today. Most of these bands were already defined for operation with WCDMA/HSPA, and LTE is the next technology to be deployed in those bands. Both paired and unpaired bands are included in the LTE specifications. The additional challenge with LTE operation in some bands is the possibility of using channel bandwidths up to 20 MHz with a single carrier and even beyond that with aggregated carriers.

The use of OFDM in LTE gives flexibility both in terms of the size of the spectrum allocation needed and in the instantaneous transmission bandwidth used. The OFDM physical layer also enables frequency-domain scheduling, as briefly discussed in Chapter 7. Beyond the physical layer implications described in Chapters 10 and 11, these properties also impact the RF implementation in terms of filters, amplifiers, and all other RF components that are used to transmit and receive the signal. This means that the RF requirements for the receiver and transmitter will have to be expressed with flexibility in mind.

17.1 SPECTRUM FOR LTE

LTE can be deployed both in existing IMT bands and in future bands that may be identified. The possibility of operating radio-access technology in different frequency bands is, in itself, nothing new. For example, quad-band GSM terminals are common, capable of operating in the 850, 900, 1800, and 1900 MHz bands. From a radio-access functionality perspective, this has no or limited impact and the LTE physical-layer specifications [61–64] do not assume any specific frequency band. What may differ, in terms of specification, between different bands are mainly the more specific RF requirements, such as the allowed maximum transmit power, requirements/limits on out-of-band (OOB) emission, and so on. One reason for this is that external constraints, imposed by regulatory bodies, may differ between different frequency bands.

17.1.1 Spectrum Defined for IMT Systems by the ITU-R

The global designations of spectrum for different services and applications are done within the ITU-R. The *World Administrative Radio Congress* WARC-92 identified the bands 1885–2025 and

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 706
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

2110–2200 MHz as intended for implementation of IMT-2000. Of these 230 MHz of 3 G spectrum, 2 × 30 MHz were intended for the satellite component of IMT-2000 and the rest for the terrestrial component. Parts of the bands were used during the 1990s for deployment of 2 G cellular systems, especially in the Americas. The first deployment of 3 G in 2001–2002 by Japan and Europe were done in this band allocation, and for that reason it is often referred to as the IMT-2000 "core band".

Additional spectrum for IMT-2000 was identified at the World Radio-communication Conference WRC-2000, where it was considered that an additional need for 160 MHz of spectrum for IMT-2000 was forecasted by the ITU-R. The identification includes the bands used for 2 G mobile systems at 806–960 and 1710–1885 MHz, and "new" 3 G spectrum in the bands at 2500–2690 MHz. The identification of bands assigned for 2 G was also recognition of the evolution of existing 2 G mobile systems into 3 G. Additional spectrum was identified at WRC'07 for IMT, encompassing both IMT-2000 and IMT-Advanced. The bands added were 450–470, 698–806, 2300–2400, and 3400–3600 MHz, but the applicability of the bands varies on a regional and national basis.

The somewhat diverging arrangement between regions of the frequency bands assigned to 3 G means that there is not one single band that can be used for 3 G roaming worldwide. Large efforts have, however, been put into defining a minimum set of bands that can be used to provide roaming. In this way, multi-band devices can provide efficient worldwide roaming for 3 G.

17.1.2 Frequency Bands for LTE

The frequency bands where LTE will operate are in both paired and unpaired spectrum, requiring flexibility in the duplex arrangement. For this reason, LTE supports both FDD and TDD, as discussed in the previous chapters.

Release 8 of the 3GPP specifications for LTE includes 19 frequency bands for FDD and nine for TDD. The paired bands for FDD operation are numbered from 1 to 21 [76], as shown in Table 17.1, while the unpaired bands for TDD operation are numbered from 33 to 41, as shown in Table 17.2. Note that the frequency bands for UTRA FDD use the same numbers as the paired LTE bands, but are labeled with Roman numerals. All bands for LTE are summarized in Figures 17.1 and 17.2, which also show the corresponding frequency allocation defined by the ITU.

Some of the frequency bands are partly or fully overlapping. In most cases this is explained by regional differences in how the bands defined by the ITU are implemented. At the same time, a high degree of commonality between the bands is desired to enable global roaming. The set of bands have first been specified as bands for UTRA, with each band originating in global, regional, and local spectrum developments. The complete set of UTRA bands was then transferred to the LTE specifications in release 8 and additional ones have been added in later releases.

Bands 1, 33, and 34 are the same paired and unpaired bands that were defined first for UTRA in release 99 of the 3GPPP specifications, also called the 2 GHz "core band". *Band 2* was added later for operation in the US PCS1900 band and *Band 3* for 3 G operation in the GSM1800 band. The unpaired *Bands 35, 36, and 37* are also defined for the PCS1900 frequency ranges, but are not deployed anywhere today. *Band 39* is an extension of the unpaired Band 33 from 20 to 40 MHz for use in China.

Band 4 was introduced as a new band for the Americas following the addition of the 3 G bands at WRC-2000. Its downlink overlaps completely with the downlink of Band 1, which facilitates roaming and eases the design of dual Band 1 + 4 terminals. *Band 10* is an extension of Band 4 from 2 × 45 to 2 × 60 MHz.

Petitioners' Exhibit 1003, p. 707
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 17.1 Paired Frequency Bands Defined by 3GPP for LTE

Band	Uplink Range (MHz)	Downlink Range (MHz)	Main Region(s)
1	1920–1980	2110–2170	Europe, Asia
2	1850–1910	1930–1990	Americas (Asia)
3	1710–1785	1805–1880	Europe, Asia (Americas)
4	1710–1755	2110–2155	Americas
5	824–849	869–894	Americas
6	830–840	875–885	Japan (only for UTRA)
7	2500–2570	2620–2690	Europe, Asia
8	880–915	925–960	Europe, Asia
9	1749.9–1784.9	1844.9–1879.9	Japan
10	1710–1770	2110–2170	Americas
11	1427.9–1447.9	1475.9–1495.9	Japan
12	698–716	728–746	USA
13	777–787	746–756	USA
14	788–798	758–768	USA
17	704–716	734–746	USA
18	815–830	860–875	Japan
19	830–845	875–890	Japan
20	832–862	791–821	Europe
21	1447.9–1462.9	1495.9–1510.9	Japan

Table 17.2 Unpaired Frequency Bands Defined by 3GPP for LTE

Band	Frequency Range (MHz)	Main Region(s)
33	1900–1920	Europe, Asia (not Japan)
34	2010–2025	Europe, Asia
35	1850–1910	(Americas)
36	1930–1990	(Americas)
37	1910–1930	–
38	2570–2620	Europe
39	1880–1920	China
40	2300–2400	Europe, Asia
41	2496–2690	USA

Band 9 overlaps with Band 3, but is intended only for Japan. The specifications are drafted in such a way that implementation of roaming dual Band 3 + 9 terminals is possible. The 1500 MHz frequency band is also identified in 3GPP for Japan as *Bands 11* and *21*. It is allocated globally to mobile service on a co-primary basis and was previously used for 2 G in Japan.

Petitioners' Exhibit 1003, p. 708
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

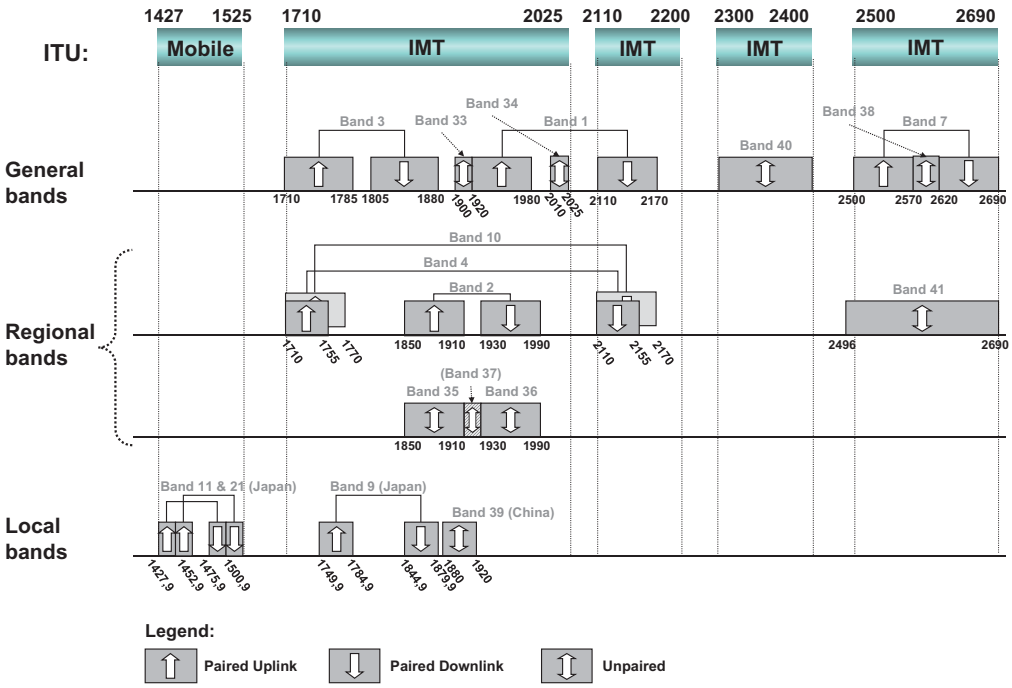


FIGURE 17.1

Operating bands specified for LTE in 3GPP above 1 GHz and the corresponding ITU allocation.

With WRC-2000, the band 2500–2690 MHz was identified for IMT-2000 and it is identified as *Band 7* in 3GPP for FDD and *Band 38* for TDD operation in the "center gap" of the FDD allocation. The band has a slightly different arrangement in North America, where a US-specific *Band 41* is defined. *Band 40* is an unpaired band specified for the new frequency range 2300–2400 MHz identified for IMT and has a widespread allocation globally.

WRC-2000 also identified the frequency range 806–960 MHz for IMT-2000, complemented by the frequency range 698–806 MHz in WRC'07. As shown in Figure 17.2, several bands are defined for FDD operation in this range. Band 8 uses the same band plan as GSM900. *Bands 5, 18, and 19* overlap, but are intended for different regions. Band 5 is based on the US cellular band, while Bands 18 and 19 are restricted to Japan in the specifications. 2 G systems in Japan had a very specific band plan and Bands 18 and 19 are a way of partly aligning the Japanese spectrum plan in the 810–960 MHz range to that in other parts of the world. Note that Band 6 was originally defined in this frequency range for Japan, but it is not used for LTE.

Bands 12, 13, 14, and 17 make up the first set of bands defined for what is called the *digital dividend* – that is, for spectrum previously used for broadcasting. This spectrum is partly migrated to be used by other wireless technologies, since TV broadcasting is migrating from analog to more spectrum-efficient digital technologies. Another regional band for the digital dividend is *Band 20* that is defined in Europe.

Petitioners' Exhibit 1003, p. 709
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

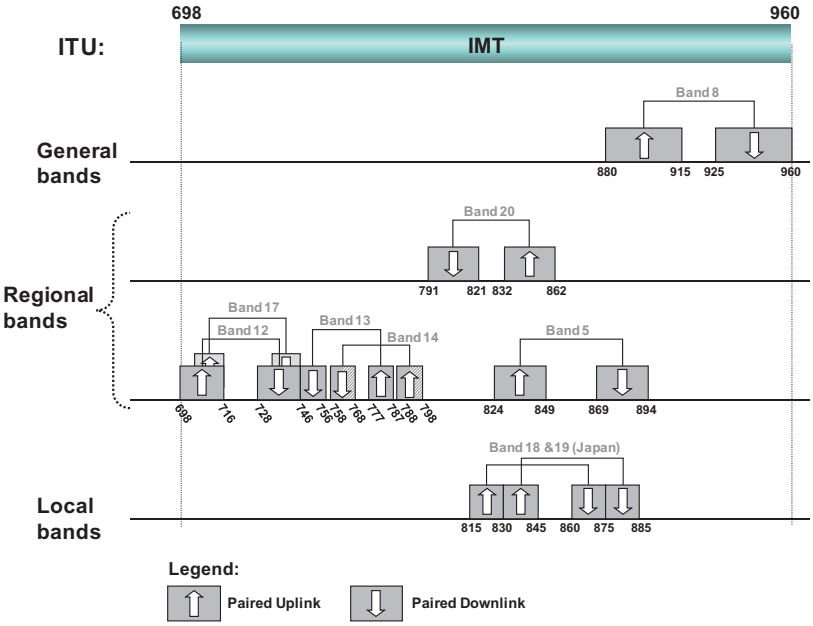


FIGURE 17.2

Operating bands specified for LTE in 3GPP below 1 GHz and the corresponding ITU allocation.

17.1.3 New Frequency Bands

Additional frequency bands are continuously specified for UTRA and LTE. WRC'07 identified additional frequency bands for IMT, which encompasses both IMT-2000 and IMT-Advanced. Several bands were defined by WRC'07 that will be available partly or fully for deployment on a global basis:

- *450–470 MHz* was identified for IMT globally. It is already allocated to mobile service globally, but it is only 20 MHz wide.
- *698–806 MHz* was allocated to mobile service and identified to IMT to some extent in all regions. Together with the band at 806–960 MHz identified at WRC-2000, it forms a wide frequency range from 698 to 960 MHz that is partly identified to IMT in all regions, with some variations.
- *2300–2400 MHz* was identified for IMT on a worldwide basis in all three regions.
- *3400–3600 MHz* was allocated to the mobile service on a primary basis in Europe and Asia and partly in some countries in the Americas. There is also satellite use in the bands today.

Additional bands for IMT are not on the agenda for WRC'12, but are likely to be treated at WRC'16. For the frequency ranges below 1 GHz identified at WRC-07, 3GPP has already specified several operating bands, as shown in Figure 17.2. The bands with the widest use are Bands 5 and 8, while most of the other bands have limited regional use. With the identification of bands down to 698 MHz for IMT use and the switchover from analog to digital TV broadcasting, Bands 12, 13, 14, and 17 are defined in the USA and Band 20 in Europe for the digital dividend. There is a

recent development in the Asia-Pacific area, where a harmonized band plan is agreed [77] for the digital dividend at 698–806 MHz, consisting either of a 2 × 45 MHz paired band or a ~100 MHz unpaired band.

Work in 3GPP is ongoing for the frequency band 3.4–3.8 GHz [78]. In Europe, a majority of countries already license the band at 3.4–3.6 GHz for both Fixed Wireless Access and mobile use. Licensing of 3.6–3.8 GHz for Wireless Access is more limited. There is a European spectrum decision for 3.4–3.8 GHz with "flexible usage modes" for deployment of fixed, nomadic, and mobile networks. Frequency arrangements considered in the decision include FDD use with 100 MHz block offset between paired blocks and/or TDD use. In Japan, not only 3.4–3.6 GHz but also 3.6–4.2 GHz will be available to terrestrial mobile services such as IMT to use after 2010. The band 3.4–3.6 GHz has also been licensed for wireless access in Latin America. 3GPP is specifying both LTE TDD and LTE FDD modes for the band.

Several Mobile Satellite Service (MSS) operators in the USA are planning to deploy an Ancillary Terrestrial Component (ATC) using LTE. For this purpose two new frequency bands are defined, one 2 × 20 MHz band for the S-band MSS operators at 2 GHz and one 2 × 34 MHz band for the L-band MSS operators at 1.5 GHz.

The US PCS1900 band will be extended with an additional 2 × 5 MHz block called the *G block*. In order to accommodate the new block, work is ongoing in 3GPP to create an extended PCS1900 band that will be 2 × 65 MHz, compared to the original Band 2, which is 2 × 60 MHz.

17.2 FLEXIBLE SPECTRUM USE

Most of the frequency bands identified above for deployment of LTE are existing IMT-2000 bands and some bands also have legacy systems deployed, including WCDMA/HSPA and GSM. Bands are also in some regions defined in a "technology neutral" manner, which means that coexistence between different technologies is a necessity.

The fundamental LTE requirement to operate in different frequency bands [79] does not, in itself, impose any specific requirements on the radio-interface design. There are, however, implications for the RF requirements and how those are defined, in order to support the following:

- *Coexistence between operators in the same geographical area in the band*. These other operators may deploy LTE or other IMT-2000 technologies, such as UMTS/HSPA or GSM/EDGE. There may also be non-IMT-2000 technologies. Such coexistence requirements are to a large extent developed within 3GPP, but there may also be regional requirements defined by regulatory bodies in some frequency bands.
- *Co-location of base station equipment between operators*. There are in many cases limitations to where base-station equipment can be deployed. Often, sites must be shared between operators or an operator will deploy multiple technologies in one site. This puts additional requirements on both base-station receivers and transmitters.
- *Coexistence with services in adjacent frequency bands and across country borders*. The use of the RF spectrum is regulated through complex international agreements, involving many interests. There will therefore be requirements for coordination between operators in different countries and for coexistence with services in adjacent frequency bands. Most of these are defined in different

regulatory bodies. Sometimes the regulators request that 3GPP includes such coexistence limits in the 3GPP specifications.

- *Coexistence between operators of TDD systems* in the same band is provided by inter-operator synchronization, in order to avoid interference between downlink and uplink transmissions of different operators. This means that all operators need to have the same downlink/uplink configurations and frame synchronization, not in itself an RF requirement, but it is implicitly assumed in the 3GPP specifications. RF requirements for unsynchronized systems become very strict.
- *Release-independent frequency-band principles*. Frequency bands are defined regionally and new bands are added continuously. This means that every new release of 3GPP specifications will have new bands added. Through the "release independence" principle, it is possible to design terminals based on an early release of 3GPP specifications that support a frequency band added in a later release.

17.3 FLEXIBLE CHANNEL BANDWIDTH OPERATION

The frequency allocations in Figures 17.1 and 17.2 are up to 2×75 MHz, but the spectrum available for a single operator may be from 2×20 MHz down to 2×5 MHz for FDD and down to 1×5 MHz for TDD. Furthermore, the migration to LTE in frequency bands currently used for other radio-access technologies must often take place gradually to ensure that a sufficient amount of spectrum remains to support the existing users. Thus, the amount of spectrum that can initially be migrated to LTE can be relatively small, but may then gradually increase, as shown in Figure 17.3. The variation of

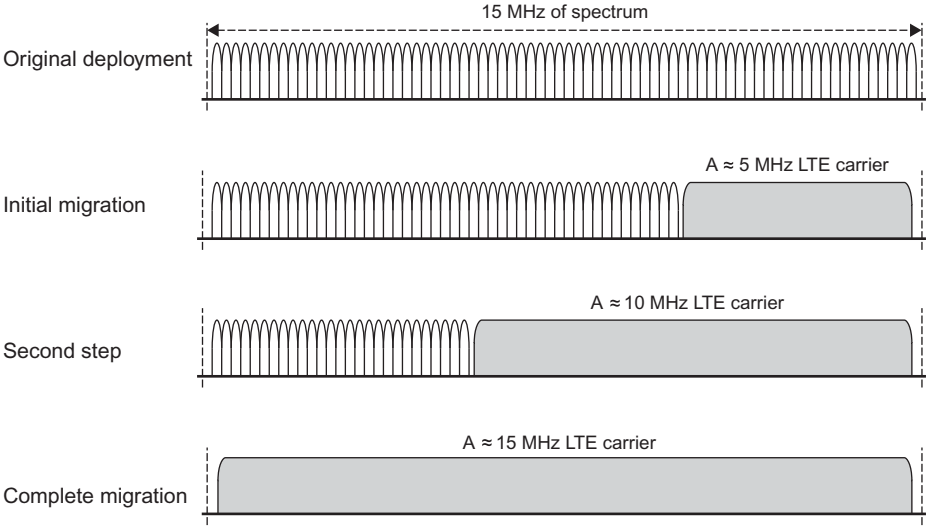


FIGURE 17.3

Example of how LTE can be migrated step-by-step into a spectrum allocation with an original GSM deployment.

Table 17.3 Channel Bandwidths Specified in LTE

Channel Bandwidth, $BW_{channel}$ (MHz)	Number of Resource Blocks (N_{RB})
1.4	6
3	15
5	25
10	50
15	75
20	100

possible spectrum scenarios implies a requirement for spectrum flexibility for LTE in terms of the transmission bandwidths supported.

The spectrum flexibility requirement points out the need for LTE to be scalable in the frequency domain. This flexibility requirement is stated in [10] as a list of LTE spectrum allocations from 1.25 to 20 MHz. Note that the final channel bandwidths selected differ slightly from this initial assumption.

As shown in Chapter 9, the frequency-domain structure of LTE is based on resource blocks consisting of 12 subcarriers with a total bandwidth of $12 \times 15\,\text{kHz} = 180\,\text{kHz}$. The basic radio-access specification including the physical-layer and protocol specifications enables *transmission bandwidth configurations* from six up to 110 resource blocks on one LTE RF carrier. This allows for channel bandwidths ranging from 1.4 MHz up to beyond 20 MHz in steps of 180 kHz and is fundamental to providing the required spectrum flexibility.

In order to limit implementation complexity, only a limited set of bandwidths are defined in the RF specifications. Based on the frequency bands available for LTE deployment today and in the future, as described above, and considering the known migration and deployment scenarios in those bands, a limited set of six channel bandwidths is specified. The RF requirements for the base station and UE are defined only for those six channel bandwidths. The channel bandwidths range from 1.4 to 20 MHz, as shown in Table 17.3. The lower bandwidths, 1.4 and 3 MHz, are chosen specifically to ease migration to LTE in spectrum where CDMA2000 is operated, and also to facilitate migration of GSM and TD-SCDMA to LTE. The specified bandwidths target relevant scenarios in different frequency bands. For this reason, the set of bandwidths available for a specific band is not necessarily the same as in other bands. At a later stage, if new frequency bands are made available that have other spectrum scenarios requiring additional channel bandwidths, the corresponding RF parameters and requirements can be added in the RF specifications, without actually having to update the physical-layer specifications. The process of adding new channel bandwidths in this way is similar to adding new frequency bands.

Figure 17.4 illustrates in principle the relationship between the channel bandwidth and the number of resource blocks N_{RB} for one RF carrier. Note that for all channel bandwidths except 1.4 MHz, the resource blocks in the transmission bandwidth configuration fill up 90% of the channel bandwidth. The spectrum emissions shown in Figure 17.4 are for a pure OFDM signal, while the actual transmitted emissions will also depend on the transmitter RF chain and other components. The emissions outside the channel bandwidth are called *unwanted emissions* and the requirements for those are discussed further below.

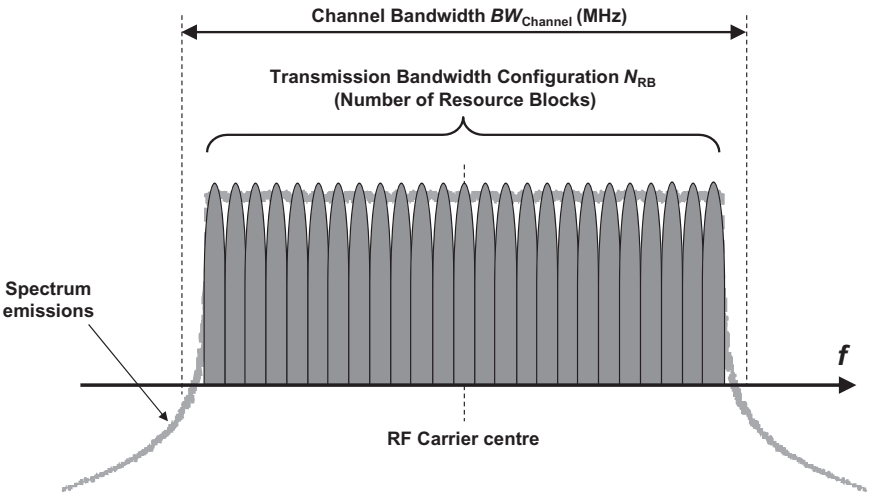


FIGURE 17.4

The channel bandwidth for one RF carrier and the corresponding transmission bandwidth configuration.

17.4 CARRIER AGGREGATION FOR LTE

The possibility in release 10 to aggregate two or more component carriers in order to support wider transmission bandwidths has several implications for the RF characteristics. The impact for the base station and UE RF characteristics are also quite different. Release 10 has some restrictions on carrier aggregation in the RF specification, compared to what has been specified for physical layer and signaling.

There is, from an RF point of view, a substantial difference between the two types of Carrier Aggregation (CA) defined for LTE (see also Section 7.3.1 for more details):

- *Intra-Band Carrier Aggregation* implies that two or more carriers within the same operating band are aggregated (see also the first two examples in Figure 7.4). RF requirements are restricted in release 10 to contiguous intra-band aggregation and a maximum of two carriers. Since aggregated carriers from an RF perspective have similar RF properties as a corresponding wider carrier being transmitted and received, there are many implications for the RF requirements. This is especially true for the UE. For the base station, it corresponds in practice to a multicarrier configuration (non-aggregated) already supported in earlier releases, which also means that the impact is less than for the UE.
- *Inter-Band Carrier Aggregation* implies that carriers in different operating bands are aggregated (see also the last example in Figure 7.4). Many RF properties within a band can, to a large extent, remain the same as for a single carrier case. There is, however, impact for the UE, due to the possibility for intermodulation and cross-modulation within the UE device when multiple transmitter and receiver chains are operated simultaneously. For the base station it has very little impact, since in practice it corresponds to a base station supporting multiple bands, which is a configuration not really treated in RF specifications.

Petitioners' Exhibit 1003, p. 714
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

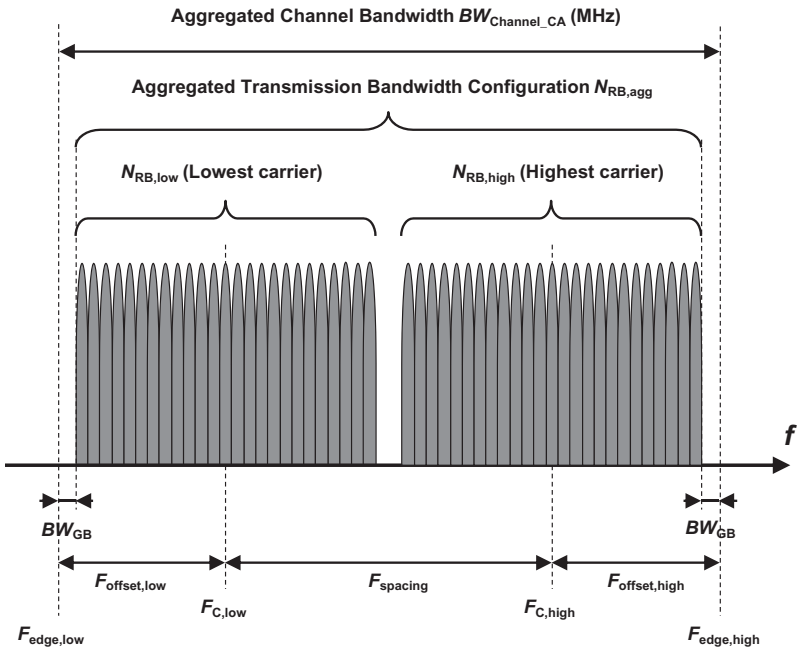


FIGURE 17.5

Definitions for Intra-Band Carrier Aggregation RF parameters, for an example with two aggregated carriers.

Intra-band carrier aggregation is limited to two component carriers and to one paired band (Band 1) and one unpaired (Band 40) band in release 10. Inter-band carrier aggregation is limited to the generic case of aggregating carriers between Bands 1 and 5. The next band pair for which a carrier aggregation capability is specified is a "European" scenario for Bands 3 and 7, which is planned for later inclusion in release 10. The band or set of bands over which carriers are aggregated is defined as a UE capability called *E-UTRA CA Band*. For the base station the band or set of bands defines what is called a *Carrier Aggregation Configuration* for the base station.

For intra-band carrier aggregation, the definitions of $BW_{channel}$ and N_{RB} shown in Figure 17.4 still apply for each component carrier, while new definitions are needed for the Aggregated Channel Bandwidth ($BW_{Channel\_CA}$) and the Aggregated Transmission bandwidth Configuration ($N_{RB,agg}$) shown in Figure 17.5. In connection with this, a new capability is defined for the UE called *Carrier Aggregation Bandwidth Class*. There are six classes, where each class corresponds to a range for $N_{RB,agg}$ and a maximum number of component carriers, as shown in Table 17.4. The classes corresponding to aggregation of more than two component carriers or consisting of more than 200 RBs are under study for later releases.

A fundamental parameter for intra-band CA is the channel spacing. A tighter channel spacing than the nominal spacing for any two single carriers could potentially lead to an increase in spectral efficiency, since there would be a smaller unused "gap" between carriers. On the other hand, there is also a requirement for the possibility to support legacy single-carrier terminals of earlier releases.

Table 17.4 UE Carrier Aggregation Bandwidth Classes

Channel Aggregation Bandwidth Classes	Aggregated Transmission BW Configuration	Number of Component Carriers
A	≤100	1
B	≤100	2
C	101–200	2
D, E, F	Under study (201–500)	Under study

An additional complication is that the component carriers should be on the same 15 kHz subcarrier raster in order to allow reception of multiple adjacent component carriers using a single FFT instead of an FFT per subcarrier.[1] As discussed in Section 9.4, this property, together with the fact that the frequency numbering scheme is on a 100 kHz raster, results in the spacing between two component carriers having to be a multiple of 300 kHz, which is the least common denominator of 15 and 100 kHz.

For the specification, RF requirements are based on a nominal channel spacing that is derived from the channel bandwidth of the two adjacent carriers $BW_{\text{Channel(1)}}$ and $BW_{\text{Channel(2)}}$ as follows:[2]

$$F_{\text{Spacing,Nominal}} = \left\lfloor \frac{BW_{\text{Channel(1)}} + BW_{\text{Channel(2)}} - 0.1\left|BW_{\text{Channel(1)}} - BW_{\text{Channel(2)}}\right|}{2 \cdot 0.3} \right\rfloor 0.3. \quad (17.1)$$

In order to allow for a tighter packing of component carriers, the value of F_{Spacing} can be adjusted to any multiple of 300 kHz that is smaller than the nominal spacing, as long as the carriers do not overlap.

RF requirements for LTE are normally defined relative to the channel bandwidth edges. For intra-band CA, this is generalized so that requirements are defined relative to the edges of the Aggregated Channel Bandwidth, identified in Figure 17.5 as $F_{\text{edge,low}}$ and $F_{\text{edge,high}}$. In this way many RF requirements can be reused, but with new reference points in the frequency domain. The aggregated channel bandwidth for both UE and base station is defined as:

$$BW_{\text{Channel\_CA}} = F_{\text{edge,high}} - F_{\text{edge,low}} \quad (17.2)$$

The location of the edges is defined relative to the carriers at the edges through a new parameter F_{offset} (see Figure 17.5) using the following relation to the carrier center positions F_C of the lowest and highest carriers:

$$F_{\text{edge,low}} = F_{\text{C,low}} - F_{\text{offset,low}} \quad (17.3)$$

$$F_{\text{edge,high}} = F_{\text{C,high}} + F_{\text{offset,high}} \quad (17.4)$$

[1] In case of independent frequency errors between component carriers, multiple FFTs and frequency-tracking functionality may be needed anyway.

[2] $\lfloor \ldots \rfloor$ denotes the "floor" operator, which rounds the number down.

The value of F_{offset} for the edge carriers and the corresponding location of the edges are, however, not defined in the same way for UE and base station.

For the base station, there are legacy scenarios where the base station receives and transmits adjacent independent carriers, supporting legacy terminals of earlier releases using single carriers. This scenario will also have to be supported for a configuration of aggregated carriers. In addition, for backward compatibility reasons, a fundamental parameter such as channel bandwidth and the corresponding reference points (the channel edge) for all RF requirements will have to remain the same. The implication is that the channel edges shown in Figure 17.4 for each component carrier will also remain as reference points when the carriers are aggregated. This results in the following base station definition of F_{offset}, for carrier aggregation, which is "inherited" from the single carrier scenario:

$$F_{\text{offset}} = \frac{BW_{\text{channel}}}{2} \quad \text{(for base station).} \tag{17.5}$$

Unlike the base station, the UE is not restricted by legacy operation, but rather from the nonlinear properties of the PA and the resulting unwanted emissions mask. At both edges of the aggregated channel bandwidth, a guard band BW_{GB} will be needed, in order for the emissions to reach a level where the out-of-band emissions limits in terms of an emission mask are applied. Whether a single wide carrier or multiple aggregated carriers of the same or different sizes are transmitted, the guard band needed will have to be the same at both edges, since the emission mask roll-off is the same. A problem with the backwards-compatible base station definition is that the resulting guard BW_{GB} is proportional to the channel BW and would therefore be *different* if carriers of different channel BW are aggregated.

For this reason, a different definition is used for the UE, based on a "symmetrical" guard band. For the edge carriers (low and high), F_{offset} is half of the transmission bandwidth configuration, plus a symmetrical guard band BW_{GB}:

$$F_{\text{offset}} = \frac{0.18\,\text{MHz} \cdot N_{\text{RB}}}{2} + BW_{\text{GB}} \quad \text{(for UE)}, \tag{17.6}$$

where 0.18 MHz is the bandwidth of one resource block and BW_{GB} is proportional to the channel BW of the largest component carrier. For the CA bandwidth classes defined in release 10 and where the edge carriers have the same channel bandwidth, F_{offset} will be the same for terminals and base stations and $BW_{\text{Channel\_CA}}$ will be the same.

It may look like an anomaly that the definitions may potentially lead to slightly different aggregated channel BW for the UE and the base station, but this is in fact not a problem. UE and base-station requirements are defined separately and do not have to cover the same frequency ranges. The aggregated channel BW for both UE and base station do, however, have to be within an operator's license block in the operating band.

Once the frequency reference point is set, the actual RF requirements are to a large extent the same as for a single carrier configuration. Which requirements are affected is explained for each requirement in the discussion later in this chapter.

Petitioners' Exhibit 1003, p. 717
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

17.5 MULTI-STANDARD RADIO BASE STATIONS

Traditionally the RF specifications have been developed separately for the different 3GPP radio-access technologies GSM/EDGE, UTRA, and E-UTRA (LTE). The rapid evolution of mobile radio and the need to deploy new technologies alongside the legacy deployments has, however, lead to implementation of different Radio-Access Technologies (RAT) at the same sites, often sharing antennas and other parts of the installation. A natural further step is then to also share the base-station equipment between multiple RATs. This requires multi-RAT base stations.

The evolution to multi-RAT base stations is also fostered by the evolution of technology. While multiple RATs have traditionally shared parts of the site installation, such as antennas, feeders, backhaul or power, the advance of both digital baseband and RF technologies enables a much tighter integration. A base station consisting of two separate implementations of both baseband and RF, together with a passive combiner/splitter before the antenna, could in theory be considered a multi-RAT base station. 3GPP has, however, made a narrower, but more forward-looking definition.

In a *Multi-Standard Radio* (MSR) base station, both the receiver and the transmitter are capable of simultaneously processing multiple carriers of different RATs in common *active* RF components. The reason for this stricter definition is that the true potential of multi-RAT base stations, and the challenge in terms of implementation complexity, comes from having a common RF. This principle is illustrated in Figure 17.6 with an example base station capable of both GSM/EDGE and LTE. Much of the GSM/EDGE and LTE baseband functionality may be separate in the base station, but is possibly implemented in the same hardware. The RF must, however, be implemented in the same active components as shown in the figure.

The main advantages of an MSR base station implementation are twofold:

- Migration between RATs in a deployment, for example from GSM/EDGE to LTE, is possible using the same base station hardware. In the example in Figure 17.6, a migration is performed in

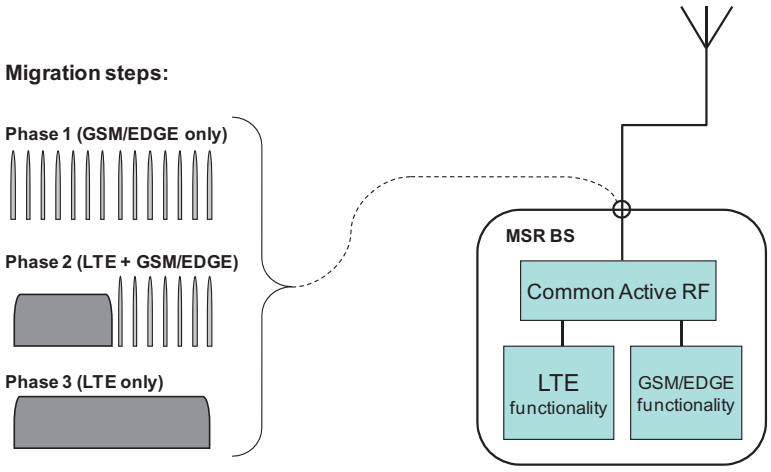


FIGURE 17.6

Example of migration from GSM to LTE using an MSR base station for all migration phases.

three phases using the same MSR base station. In the first phase, the base station is deployed in a network for GSM/EDGE-only operation. In the second phase, the operator migrates part of the spectrum to LTE. The same MSR base station will now operate one LTE carrier, but still supports the legacy GSM/EDGE users in half of the band available. In the third phase, when the GSM/EDGE users have migrated from the band, the operator can configure the MSR base station to LTE-only operation with double the channel bandwidth.

- A single base station designed as an MSR base station can be deployed in various environments for single-RAT operation for each RAT supported, as well as for multi-RAT operation where that is required by the deployment scenario. This is also in line with the recent technology trends seen in the market, with fewer and more generic base-station designs. Having fewer varieties of base station is an advantage both for the base-station vendor and for the operator, since a single solution can be developed and implemented for a variety of scenarios.

The single-RAT 3GPP radio-access standards, with requirements defined independently per RAT, do not support such migration scenarios with an implementation where common base-station RF hardware is shared between multiple access technologies, and hence a separate set of requirements for multi-standard radio equipment is needed.

An implication of a common RF for multiple RATs is that carriers are no longer received and transmitted independently of each other. For this reason, a common RF specification must be used to specify the MSR base station. 3GPP in release 9 has developed MSR specifications for the core RF requirements [80] and for test requirements [81]. Those specifications support GSM/EDGE,[3] UTRA and E-UTRA, and all combinations thereof. To support all possible RAT combinations, the MSR specifications have many generic requirements applicable regardless of RAT combination, together with specific single-access-technology-specific requirements to secure the integrity of the systems in single-RAT operation.

The MSR concept has a substantial impact for many requirements, while others remain completely unchanged. A fundamental concept introduced for MSR base stations is *RF bandwidth*, which is defined as the total bandwidth over the set of carriers transmitted and received. Many receiver and transmitter requirements for GSM/EDGE and UTRA are specified relative to the carrier center and for LTE in relation to the channel edges. For an MSR base station, they are instead specified relative to the *RF bandwidth edges*, in a way similar to carrier aggregation in release 10. In the same way as for carrier aggregation, a parameter F_{offset} is also introduced to define the location of the RF bandwidth edges relative to the edge carriers. For GSM/EDGE carriers, F_{offset} is set to 200 kHz, while it is in general half the channel bandwidth for UTRA and E-UTRA. By introducing the RF bandwidth concept and introducing generic limits, the requirements for MSR shift from being carrier centric towards being frequency block centric, thereby embracing technology neutrality by being independent of the access technology or operational mode.

While E-UTRA and UTRA carriers have quite similar RF properties in terms of bandwidth and power spectral density, GSM/EDGE carriers are quite different. The operating bands for which MSR base stations are defined are therefore divided into three *Band Categories* (BC):

- BC1 – All paired bands where UTRA FDD and E-UTRA FDD can be deployed.

[3]The MSR specifications are not applicable to single-RAT operation of GSM/EDGE.

- BC2 – All paired bands where in addition to UTRA FDD and E-UTRA FDD, GSM/EDGE can also be deployed.
- BC3 – All unpaired bands where UTRA TDD and E-UTRA TDD can be deployed.

Since the carriers of different RATs are not transmitted and received independently, it is necessary to perform parts of the testing with carriers of multiple RATs being activated. This is done through a set of multi-RAT *Test Configurations* defined in [81], specifically tailored to stress transmitter and receiver properties. These test configurations are of particular importance for the unwanted emission requirements for the transmitter and for testing of the receiver susceptibility to interfering signals (blocking, etc.). An advantage of the multi-RAT test configurations is that the RF performance of multiple RATs can be tested simultaneously, thereby avoiding repetition of test cases for each RAT. This is of particular importance for the very time-consuming tests of requirements outside the operating band over the complete frequency range up to 12.75 GHz.

The requirement with the largest impact from MSR is the spectrum mask, or the *operating band unwanted emissions* requirement, as it is called. The spectrum mask requirement for MSR base stations is applicable for multi-RAT operation where the carriers at the RF bandwidth edges are either GSM/EDGE, UTRA, or E-UTRA carriers of different channel bandwidths. The mask is generic and applicable to all cases and covers the complete operating band of the base station. There is an exception for the 150 kHz closest to the RF bandwidth edge, where the mask is aligned with the GSM/EDGE modulation spectrum for the case when a GSM/EDGE carrier or a 1.4/3 MHz E-UTRA carrier is transmitted adjacent to the edge.

An important aspect of MSR is the declaration by the base station vendor of the supported RF bandwidth, power levels, multicarrier capability, etc. All testing is based on the capability of the base station through a declaration of the supported *Capability Set* (CS), which defines all supported single RATs and multi-RAT combinations. There are currently six capability sets CS1–CS6 defined in the MSR test specification [81], allowing full flexibility for implementing and deploying base stations compliant to the MSR specification. For a large part of the base station RF requirements, multi-RAT testing is not necessary and the actual test limits are unchanged for the MSR base station. In these cases, both the requirements and the test cases are simply incorporated through direct references to the corresponding single-RAT specifications.

Carrier aggregation as described above in Section 17.4 is also applicable to MSR base stations. Since the MSR specification already has most of the concepts and definitions in place for defining multi-carrier RF requirements, whether aggregated or not, the changes of the MSR requirements compared to non-aggregated carriers are very minor.

17.6 OVERVIEW OF RF REQUIREMENTS FOR LTE

The RF requirements define the receiver and transmitter RF characteristics of a base station or UE. The base station is the physical node that transmits and receives RF signals on one or more antenna connectors. Note that a base station is not the same thing as an eNodeB, which is the corresponding logical node in the LTE Radio-Access Network. The terminal is denoted UE in the description below, as it is in all RF specifications.

The set of RF requirements defined for LTE is fundamentally the same as those defined for UTRA or any other radio system. Some requirements are also based on regulatory requirements and are more

concerned with the frequency band of operation and/or the place where the system is deployed, than with the type of system.

What is particular to LTE is the flexible bandwidth and the related multiple channel bandwidths of the system, which makes some requirements more complex to define. These properties have special implications for the transmitter requirements on unwanted emissions, where the definition of the limits in international regulation depends on the channel bandwidth. Such limits are harder to define for a system where the base station may operate with multiple channel bandwidths and where the UE may vary its channel bandwidth of operation. The properties of the flexible OFDM-based physical layer also have implications for specifying the transmitter modulation quality and how to define the receiver selectivity and blocking requirements.

The type of transmitter requirements defined for the UE is very similar to what is defined for the base station, and the definitions of the requirements are often similar. The output power levels are, however, considerably lower for a UE, while the restrictions on the UE implementation are much higher. There is tight pressure on cost and complexity for all telecommunications equipment, but this is much more pronounced for terminals, due to the scale of the total market, which is more than one *billion* devices per year. In cases where there are differences in how requirements are defined between UE and base station, they are treated separately in this chapter.

The detailed background of the RF requirements for LTE is described in [82,83], with further details of the additional requirements in release 10 (for LTE-Advanced) in [84,85]. The RF requirements for the base station are specified in [86] and for the UE in [76]. The RF requirements are divided into transmitter and receiver characteristics. There are also *performance characteristics* for base station and UE that define the receiver baseband performance for all physical channels under different propagation conditions. These are not strictly RF requirements, though the performance will also depend on the RF to some extent.

Each RF requirement has a corresponding test defined in the LTE test specifications for the base station [87] and the UE [74]. These specifications define the test setup, test procedure, test signals, test tolerances, etc. needed to show compliance with the RF and performance requirements.

17.6.1 Transmitter Characteristics

The transmitter characteristics define RF requirements for the wanted signal transmitted from the UE and base station, but also for the unavoidable unwanted emissions outside the transmitted carrier(s). The requirements are fundamentally specified in three parts:

- *Output power level* requirements set limits for the maximum allowed transmitted power, for the dynamic variation of the power level and in some cases for the transmitter OFF state.
- *Transmitted signal quality* requirements define the "purity" of the transmitted signal and also the relation between multiple transmitter branches.
- *Unwanted emissions* requirements set limits to all emissions outside the transmitted carrier(s) and are tightly coupled to regulatory requirements and coexistence with other systems.

A list of the UE and base-station transmitter characteristics arranged according to the three parts defined above is shown in Table 17.5. A more detailed description of the requirements can be found later in this chapter.

Petitioners' Exhibit 1003, p. 721
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 17.5 Overview of LTE Transmitter Characteristics

	Base-Station Requirement	UE Requirement
Output power level	Maximum output power	Transmit power
	Output power dynamics	Output power dynamics
	On/Off power (TDD only)	Power control
Transmitted signal quality	Frequency error	Frequency error
	Error Vector Magnitude (EVM)	Transmit modulation quality
	Time alignment between transmitter branches	
Unwanted emissions	Operating band unwanted emissions	Spectrum emission mask
	Adjacent Channel Leakage Ratio (ACLR)	Adjacent Channel Leakage Ratio (ACLR)
	Spurious emissions	Spurious emissions
	Occupied bandwidth	Occupied bandwidth
	Transmitter intermodulation	Transmit intermodulation

17.6.2 Receiver Characteristics

The set of receiver requirements for LTE is quite similar to what is defined for other systems such as UTRA, but many of them are defined differently, due to the flexible bandwidth properties. The receiver characteristics are fundamentally specified in three parts:

- *Sensitivity and dynamic range* requirements for receiving the wanted signal.
- *Receiver susceptibility to interfering signals* defines receivers' susceptibility to different types of interfering signals at different frequency offsets.
- *Unwanted emissions* limits are also defined for the receiver.

A list of the UE and base-station receiver characteristics arranged according to the three parts defined above is shown in Table 17.6. A more detailed description of each requirement can be found later in this chapter.

17.6.3 Regional Requirements

There are a number of regional variations to the RF requirements and their application. The variations originate in different regional and local regulations of spectrum and its use. The most obvious regional variation is the different frequency bands and their use, as discussed above. Many of the regional RF requirements are also tied to specific frequency bands.

When there is a regional requirement on, for example, spurious emissions, this requirement should be reflected in the 3GPP specifications. For the base station it is entered as an optional requirement and is marked as "regional". For the UE, the same procedure is not possible, since a UE may roam between different regions and will therefore have to fulfill all regional requirements that are tied to an operating band in the regions where the band is used. For LTE, this becomes more complex than for UTRA, since there is an additional variation in the transmitter (and receiver) bandwidth used, making some regional requirements difficult to meet as a mandatory requirement. The concept of *network*

Table 17.6 Overview of LTE Receiver Characteristics

	Base-Station Requirement	UE Requirement
Sensitivity and dynamic range	Reference sensitivity	Reference sensitivity power level
	Dynamic range	Maximum input level
	In-channel selectivity	
Receiver susceptibility to interfering signals	Out-of-band blocking	Out-of-band blocking
		Spurious response
	In-band blocking	In-band blocking
	Narrowband blocking	Narrowband blocking
	Adjacent channel selectivity	Adjacent channel selectivity
	Receiver intermodulation	Intermodulation characteristics
Unwanted emissions from the receiver	Receiver spurious emissions	Receiver spurious emissions

signaling of RF requirements is therefore introduced for LTE, where a UE can be informed at call setup of whether some specific RF requirements apply when the UE is connected to a network.

17.6.4 Band-Specific UE Requirements Through Network Signaling

For the UE, the channel bandwidths supported are a function of the LTE operating band, and also have a relation to the transmitter and receiver RF requirements. The reason is that some RF requirements may be difficult to meet under conditions with a combination of maximum power and high number of transmitted and/or received resource blocks.

Some additional RF requirements apply for the UE when a specific Network Signaling Value (NS_x) is signaled to the UE as part of the cell handover or broadcast message. For implementation reasons, these requirements are associated with restrictions and variations to RF parameters such as UE output power, maximum channel bandwidth, and number of transmitted resource blocks. The variations of the requirements are defined together with the Network Signaling Value (NS_x) in the UE RF specification [76], where each value corresponds to a specific condition. The default value for all bands is NS_01. All NS_x values are connected to an allowed power reduction called *Additional Maximum Power Reduction* (A-MPR) and apply for transmission using a certain minimum number of resource blocks, depending also on the channel bandwidth. The following are examples of UE requirements that have a related Network Signaling Value for some bands:

- *NS_03, NS_04, or NS_06* is signaled when specific FCC requirements [88] on UE unwanted emissions apply for operation in a number of US bands.
- *NS_05* is signaled for protection of the PHS band in Japan when UE operates in the 2 GHz band (Band 1).

In some bands the NS_x signaling is also applied for testing of receiver sensitivity, since the active transmitted signal can affect the receiver performance.

17.6.5 Base-Station Classes

In the base-station specifications, there is one set of RF requirements that is generic, applicable to what is called "general purpose" base stations. This is the original set of requirements developed in 3GPP release 8. It has no restrictions on base-station output power and can be used for any deployment scenario. When the RF requirements were derived, however, the scenarios used were macro scenarios [89]. For this reason, in release 9 additional base-station classes were introduced that were intended for pico-cell and femto-cell scenarios. It is then also clarified from release 9 that the original set of RF parameters is for macro-cell scenarios. The terms macro, pico, and femto are not used in 3GPP to identify the base-station classes, instead the following terminology is used:

- *Wide Area base stations*. This type of base station is intended for macro-cell scenarios, defined with a minimum coupling loss between BS and UE of 70 dB.
- *Local Area base stations*. This type of base station is intended for pico-cell scenarios, defined with a minimum coupling loss between BS and UE of 45 dB. Typical deployments are indoor offices and indoor/outdoor hotspots, with the BS mounted on walls or ceilings.
- *Home base stations*. This type of base station is intended for femto-cell scenarios, which are not explicitly defined. Minimum coupling loss between BS and UE of 45 dB is also assumed here. Home BS can be used both for open access and in closed subscriber groups.

The Local Area and Home base station classes have modifications to a number of requirements compared to Wide Area base stations, mainly due to the assumption of a lower minimum coupling loss:

- Maximum base station power is limited to 24 dBm output power for Local Area base stations and to 20 dBm for Home base stations, counting the power over all antennas (up to four). There is no maximum base station power defined for Wide Area base stations.
- Home base stations have an additional requirement for protecting systems operating on adjacent channels. The reason is that a UE connected to a base station belonging to another operator on the adjacent channel may be in close proximity to the Home base station. To avoid an interference situation where the adjacent UE is blocked, the Home base station must make measurements on the adjacent channel to detect adjacent base-station operations. If an adjacent base-station transmission (UTRA or LTE) is detected under certain conditions, the maximum allowed Home base-station output power is reduced in proportion to how weak the adjacent base-station signal is, in order to avoid interference to the adjacent base station.
- The spectrum mask (operating band unwanted emissions) has lower limits for Local Area and Home base stations, in line with the lower maximum power levels.
- Unwanted emission limits for protecting Home base-station operation (from other Home base stations) are lower, since a stricter through-the-wall indoor interference scenario is assumed. Limits for co-location for Local Area are, however, less strict, corresponding to the relaxed reference sensitivity for the base station.
- Receiver reference sensitivity limits are higher (more relaxed) for Local Area and Home base stations. Receiver dynamic range and in-channel selectivity are also adjusted accordingly.
- All Local Area and Home base-station limits for receiver susceptibility to interfering signals are adjusted to take the higher receiver sensitivity limit and the lower assumed minimum coupling loss (base station-to-UE) into account.

Petitioners' Exhibit 1003, p. 724
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

17.7 OUTPUT POWER LEVEL REQUIREMENTS

17.7.1 Base-Station Output Power and Dynamic Range

There is no general maximum output power requirement for base stations. As mentioned in the discussion of base-station classes above, there is, however, a maximum power limit of 24 dBm output power for Local Area base stations and of 20 dBm for Home base stations, counting the power over all antennas. In addition to this there is a tolerance specified, defining how much the actual maximum power may deviate from the power level declared by the manufacturer.

The base station also has a specification of the total power control dynamic range for a resource element, defining the power range over which it should be possible to configure. There is also a dynamic range requirement for the Total base-station power.

For TDD operation, a power mask is defined for the base-station output power, defining the Off power level during the uplink subframes and the maximum time for the *transmitter transient period* between the transmitter On and Off states.

17.7.2 UE Output Power and Dynamic Range

The UE output power level is defined in three steps:

- *UE power class* defines a *nominal* maximum output power for QPSK modulation. It may be different in different operating bands, but the main UE power class is today set at 23 dBm for all bands.
- *Maximum Power Reduction (MPR)* defines an allowed reduction of maximum power level for certain combinations of modulation used and the number of resource blocks that are assigned.
- *Additional Maximum Power Reduction (A-MPR)* may be applied in some regions and is usually connected to specific transmitter requirements such as regional emission limits. For each such set of requirement, there is an associated network signaling value NS_x that identifies the allowed A-MPR and the associated conditions, as explained above.

The UE has a definition of the transmitter Off power level, applicable to conditions when the UE is not allowed to transmit. There is also a general On/Off time mask specified, plus specific time masks for PRACH, SRS, subframe boundary and PUCCH/PUSCH/SRS.

The UE transmit power control is specified through requirements for the *absolute power tolerance* for the initial power setting, the *relative power tolerance* between two subframes, and the *aggregated power tolerance* for a sequence of power-control commands.

17.8 TRANSMITTED SIGNAL QUALITY

The requirements for transmitted signal quality specify how much the transmitted base station or UE signal deviates from an "ideal" modulated signal in the signal and the frequency domains. Impairments on the transmitted signal are introduced by the transmitter RF parts, with the nonlinear properties of the power amplifier being a major contributor. The signal quality is measured for base station and UE through *EVM* and *frequency error*. An additional UE requirement is UE in-band emissions.

Petitioners' Exhibit 1003, p. 725
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

17.8.1 EVM and Frequency Error

While the theoretical definitions of the signal quality measures are quite straightforward, the actual assessment is a very elaborate procedure, described in great detail in the 3GPP specification. The reason is that it becomes a multidimensional optimization problem, where the best match for the timing, the frequency, and the signal constellation are found.

The *Error Vector Magnitude* (EVM) is a measure of the error in the modulated signal constellation, taken as the root mean square of the error vectors over the active subcarriers, considering all symbols of the modulation scheme. It is expressed as a percentage value in relation to the power of the ideal signal. The EVM fundamentally defines the maximum SINR that can be achieved at the receiver, if there are no additional impairments to the signal between transmitter and receiver.

Since a receiver can remove some impairments of the transmitted signal such as time dispersion, the EVM is assessed after cyclic prefix removal and equalization. In this way, the EVM evaluation includes a standardized model of the receiver. The frequency offset resulting from the EVM evaluation is averaged and used as a measure of the *frequency error* of the transmitted signal.

17.8.2 UE In-Band Emissions

In-band emissions are emissions within the channel bandwidth. The requirement limits how much a UE can transmit into non-allocated resource blocks within the channel bandwidth. Unlike the out-of-band emissions, the in-band emissions are measured after cyclic prefix removal and FFT, since this is how a UE transmitter affects a real base-station receiver.

17.8.3 Base-Station Time Alignment

Several LTE features require the base station to transmit from two ore more antennas, such as transmitter diversity and MIMO. For carrier aggregation, the carriers may also be transmitted from different antennas. In order for the UE to properly receive the signals from multiple antennas, the timing relation between any two transmitter branches is specified in terms of a maximum time alignment error between transmitter branches. The maximum allowed error depends on the feature or combination of features in the transmitter branches.

17.9 UNWANTED EMISSIONS REQUIREMENTS

Unwanted emissions from the transmitter are divided into *out-of-band (OOB) emission* and *spurious emissions* in ITU-R recommendations [90]. OOB emissions are defined as emissions on a frequency close to the RF carrier, which results from the modulation process. Spurious emissions are emissions outside the RF carrier that may be reduced without affecting the corresponding transmission of information. Examples of spurious emissions are harmonic emissions, intermodulation products, and frequency conversion products. The frequency range where OOB emissions are normally defined is called the *OOB domain*, whereas spurious emission limits are normally defined in the *spurious domain*.

ITU-R also defines the boundary between the OOB and spurious domains at a frequency separation from the carrier center of 2.5 times the necessary bandwidth, which corresponds to 2.5 times the

channel bandwidth for LTE. This division of the requirements is easily applied for systems that have a fixed channel bandwidth. It does, however, become more difficult for LTE, which is a flexible bandwidth system, implying that the frequency range where requirements apply would then vary with the channel bandwidth. The approach taken for defining the boundary in 3GPP is slightly different for base-station and UE requirements.

With the recommended boundary between OOB emissions and spurious emissions set at 2.5 times the channel bandwidth, third- and fifth-order intermodulation products from the carrier will fall inside the OOB domain, which will have a bandwidth of twice the channel bandwidth. For the OOB domain, two overlapping requirements are defined for both base station and UE: *Spectrum Emission Mask* (SEM) and *Adjacent Channel Leakage Ratio* (ACLR). The details of these are further explained below.

17.9.1 Implementation Aspects

As shown in Chapter 3, the spectrum of an OFDM signal decays rather slowly outside of the transmission bandwidth configuration. Since the transmitted signal for LTE occupies 90% of the channel bandwidth, it is not possible to directly meet the unwanted emission limits directly outside the channel bandwidth with a "pure" OFDM signal. The techniques used for achieving the transmitter requirements are, however, not specified or mandated in LTE specifications. Time-domain windowing is one method commonly used in OFDM-based transmission systems to control spectrum emissions. Filtering is always used, both time-domain digital filtering of the baseband signal and analog filtering of the RF signal.

The nonlinear characteristics of the *Power Amplifier* (PA) used to amplify the RF signal must also be taken into account, since it is the source of intermodulation products outside the channel bandwidth. Power back-off to give a more linear operation of the PA can be used, but at the cost of a lower power efficiency. The power back-off should therefore be kept to a minimum. For this reason, additional linearization schemes can be employed. These are especially important for the base station, where there are fewer restrictions on implementation complexity and use of advanced linearization schemes is an essential part of controlling spectrum emissions. Examples of such techniques are feedforward, feedback, predistortion and postdistortion.

17.9.2 Spectrum Emission Mask

The spectrum emission mask defines the permissible out-of-band spectrum emissions outside the necessary bandwidth. As explained above, how to take the flexible channel bandwidth into account when defining the frequency boundary between OOB emissions and spurious domains is done differently for the LTE base station and UE. Consequently, the spectrum emission masks are also based on different principles.

17.9.2.1 Base-Station Operating Band Unwanted Emission Limits

For the LTE base station, the problem of the implicit variation of the boundary between OOB and spurious domain with the varying channel bandwidth is handled by not defining an explicit boundary. The solution is a unified concept of *operating band unwanted emissions* for the LTE base station instead of the spectrum mask usually defined for OOB emissions. The operating band unwanted emissions requirement applies over the whole base station transmitter operating band, plus an

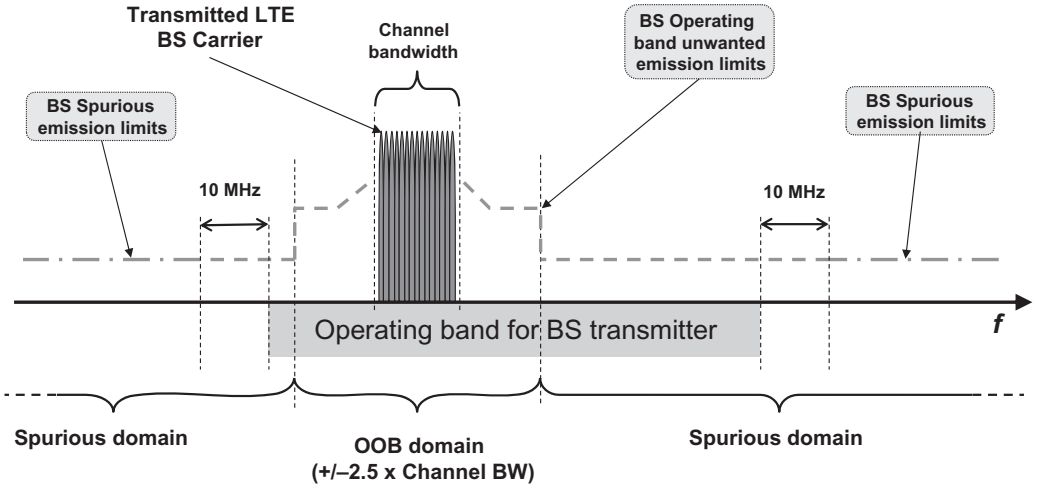


FIGURE 17.7

Frequency ranges for operating band unwanted emissions and spurious emissions applicable to an LTE base station.

additional 10 MHz on each side, as shown in Figure 17.7. All requirements outside of that range are set by the regulatory spurious emission limits, based on the ITU-R recommendations [90]. As seen in the figure, a large part of the operating band unwanted emissions are defined over a frequency range that for smaller channel bandwidths can be both in spurious and OOB domains. This means that the limits for the frequency ranges that may be in the spurious domain also have to align with the regulatory limits from the ITU-R. The shape of the mask is generic for all channel bandwidth from 5 to 20 MHz, with a mask that consequently has to align with the ITU-R limits starting 10 MHz from the channel edges. Special masks are defined for the smaller 1.4 and 3 MHz channel bandwidths. The operating band unwanted emissions are defined with a 100 kHz measurement bandwidth.

There are also special limits defined to meet a specific regulation set by the FCC [88] for the operating bands used in the USA and by the ECC for some European bands. These are specified as separate limits in addition to the operating band unwanted emission limits.

17.9.2.2 UE Spectrum Emission Mask

For implementation reasons, it is not possible to define a generic UE spectrum mask that does not vary with the channel bandwidth, so the frequency ranges for OOB limits and spurious emissions limits do not follow the same principle as for the base station. The SEM extends out to a separation Δf_{OOB} from the channel edges, as illustrated in Figure 17.8. For 5 MHz channel bandwidth, this point corresponds to 250% of the necessary bandwidth as recommended by the ITU-R, but for higher channel bandwidths it is set closer than 250%.

The SEM is defined as a general mask and a set of additional masks that can be applied to reflect different regional requirements. Each additional regional mask is associated with a specific network signaling value NS_x.

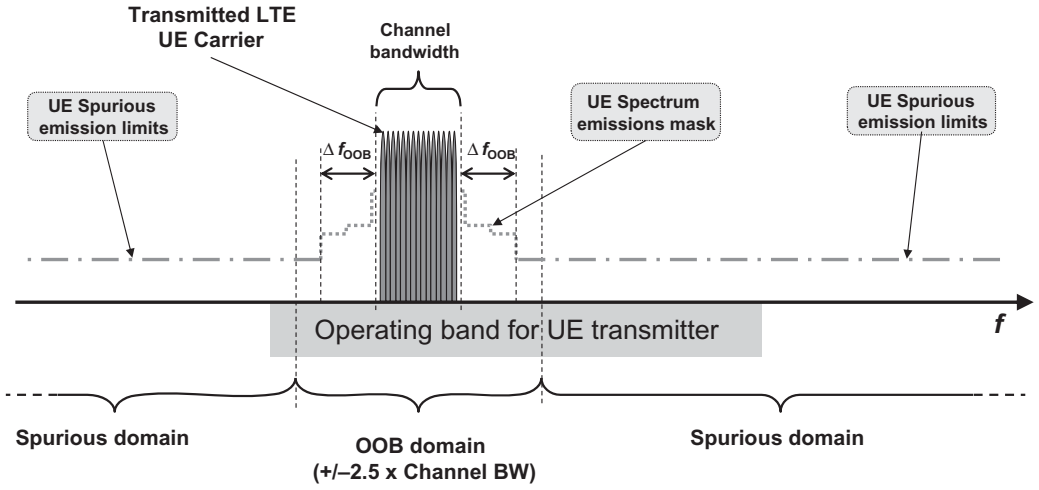


FIGURE 17.8

Frequency ranges for spectrum emission mask and spurious emissions applicable to an LTE UE.

17.9.3 Adjacent Channel Leakage Ratio

In addition to a spectrum emissions mask, the OOB emissions are defined by an *Adjacent Channel Leakage Ratio* (ACLR) requirement. The ACLR concept is very useful for analysis of coexistence between two systems that operate on adjacent frequencies. The ACLR defines the ratio of the power transmitted within the assigned channel bandwidth to the power of the unwanted emissions transmitted on an adjacent channel. There is a corresponding receiver requirement called *Adjacent Channel Selectivity* (ACS), which defines a receiver's ability to suppress a signal on an adjacent channel.

The definitions of ACLR and ACS are illustrated in Figure 17.9 for a wanted and an interfering signal received in adjacent channels. The interfering signal's leakage of unwanted emissions at the wanted signal receiver is given by the ACLR and the ability of the receiver of the wanted signal to suppress the interfering signal in the adjacent channel is defined by the ACS. The two parameters when combined define the total leakage between two transmissions on adjacent channels. That ratio is called the *Adjacent Channel Interference Ratio* (ACIR) and is defined as the ratio of the power transmitted on one channel to the total interference received by a receiver on the adjacent channel, due to both transmitter (ACLR) and receiver (ACS) imperfections.

This relation between the adjacent channel parameters is [91]:

$$\text{ACIR} = \frac{1}{\frac{1}{\text{ACLR}} + \frac{1}{\text{ACS}}}. \tag{17.7}$$

ACLR and ACS can be defined with different channel bandwidths for the two adjacent channels, which is the case for some requirements set for LTE due to the bandwidth flexibility. The equation

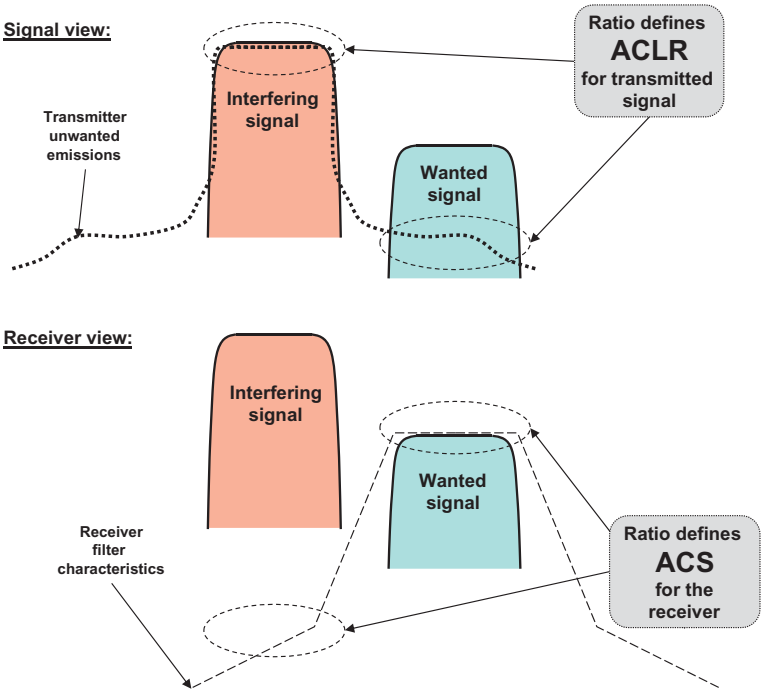


FIGURE 17.9

Illustration of ACLR and ACS, with example characteristics for an "aggressor" interferer and a receiver for a "victim" wanted signal.

above will also apply for different channel bandwidths, but only if the same two channel bandwidths are used for defining all three parameters ACIR, ACLR, and ACS used in the equation.

The ACLR limits for LTE UE and base station are derived based on extensive analysis [89] of LTE coexistence with LTE or other systems on adjacent carriers.

The LTE base-station requirements on ACLR and operating band unwanted emissions both cover the OOB domain, but the operating band unwanted emission limits are set slightly more relaxed compared to the ACLR, since they are defined in a much narrower measurement bandwidth of 100 kHz. This allows for some variations in the unwanted emissions due to intermodulation products from varying power allocation between resource blocks within the channel. For an LTE base station, there are ACLR requirements both for an adjacent channel with a UTRA receiver and with an LTE receiver of the same channel bandwidth.

ACLR limits for the UE are set both with assumed UTRA and LTE receivers on the adjacent channel. As for the base station, the limits are also set stricter than the corresponding SEM, thereby accounting for variations in the spectrum emissions resulting from variations in resource-block allocations.

Petitioners' Exhibit 1003, p. 730
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

17.9.4 Spurious Emissions

The limits for base station spurious emissions are taken from international recommendations [90], but are only defined in the region outside the frequency range of operating band unwanted emissions limits as illustrated in Figure 17.7 – that is, at frequencies that are separated from the base-station transmitter operating band by at least 10 MHz. There are also additional regional or optional limits for protection of other systems that LTE may coexist with or even be co-located with. Examples of other systems considered in those additional spurious emissions requirements are GSM, UTRA FDD/TDD, CDMA2000, and PHS.

UE spurious emission limits are defined for all frequency ranges outside the frequency range covered by the SEM. The limits are generally based on international regulations [90], but there are also additional requirements for coexistence with other bands when the mobile is roaming. The additional spurious emission limits can have an associated network signaling value.

In addition, there are base-station and UE emission limits defined for the receiver. Since receiver emissions are dominated by the transmitted signal, the receiver spurious emission limits are only applicable when the transmitter is Off, and also when the transmitter is On for an LTE FDD base station that has a separate receiver antenna connector.

17.9.5 Occupied Bandwidth

Occupied bandwidth is a regulatory requirement that is specified for equipment in some regions, such as Japan and the USA. It is originally defined by the ITU-R as a maximum bandwidth, outside of which emissions do not exceed a certain percentage of the total emissions. The occupied bandwidth is for LTE equal to the channel bandwidth, outside of which a maximum of 1% of the emissions are allowed (0.5% on each side).

In the case of carrier aggregation, the occupied bandwidth is equal to the aggregated channel bandwidth.

17.9.6 Transmitter Intermodulation

An additional implementation aspect of an RF transmitter is the possibility of intermodulation between the transmitted signal and another strong signal transmitted in the proximity of the base station or UE. For this reason there is a requirement for *transmitter intermodulation*.

For the base station, the requirement is based on a stationary scenario with a co-located other base-station transmitter, with its transmitted signal appearing at the antenna connector of the base station being specified, but attenuated by 30 dB. Since it is a stationary scenario, there are no additional unwanted emissions allowed, implying that all unwanted emission limits also have to be met with the interferer present.

For the UE, there is a similar requirement based on a scenario with another UE transmitted signal appearing at the antenna connector of the UE being specified, but attenuated by 40 dB. The requriement specifies the minimum attenuation of the resulting intermodulation product below the transmitted signal.

Petitioners' Exhibit 1003, p. 731
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

17.10 SENSITIVITY AND DYNAMIC RANGE

The primary purpose of the *reference sensitivity requirement* is to verify the receiver *Noise Figure*, which is a measure of how much the receiver's RF signal chain degrades the SNR of the received signal. For this reason, a low-SNR transmission scheme using QPSK is chosen as reference channel for the reference sensitivity test. The reference sensitivity is defined at a receiver input level where the throughput is 95% of the maximum throughput for the reference channel.

For the base station, reference sensitivity could potentially be defined for a single resource block up to a group covering all resource blocks. For reasons of complexity, a maximum granularity of 25 resource blocks has been chosen, which means that for channel bandwidths larger than 5 MHz, sensitivity is verified over multiple adjacent 5 MHz blocks, while it is only defined over the full channel for smaller channel bandwidths.

For the UE, reference sensitivity is defined for the full channel bandwidth signals and with all resource blocks allocated for the wanted signal. For the higher channel bandwidths ($>$5 MHz) in some operating bands, the nominal reference sensitivity needs to be met with a minimum number of allocated resource blocks. For larger allocation, a certain relaxation is allowed.

The intention of the *dynamic range requirement* is to ensure that the receiver can also operate at received signal levels considerably higher than the reference sensitivity. The scenario assumed for base-station dynamic range is the presence of increased interference and corresponding higher wanted signal levels, thereby testing the effects of different receiver impairments. In order to stress the receiver, a higher SNR transmission scheme using 16QAM is applied for the test. In order to further stress the receiver to higher signal levels, an interfering AWGN signal at a level 20 dB above the assumed noise floor is added to the received signal. The dynamic range requirement for the UE is specified as a *maximum signal level* at which the throughput requirement is met.

17.11 RECEIVER SUSCEPTIBILITY TO INTERFERING SIGNALS

There is a set of requirements for base station and UE, defining the receiver's ability to receive a wanted signal in the presence of a stronger interfering signal. The reason for the multiple requirements is that, depending on the frequency offset of the interferer from the wanted signal, the interference scenario may look very different and different types of receiver impairments will affect the performance. The intention of the different combinations of interfering signals is to model as far as possible the range of possible scenarios with interfering signals of different bandwidths that may be encountered inside and outside the base-station and UE receiver operating band. While the types of requierments are very similar between base station and UE, the signal levels are different, since the interference scenarios for the base station and UE are very different. There is also no UE requirement corresponding to the base-station *In-Channel Selectivity* (ICS) requirement.

The following requirements are defined for LTE base station and UE, starting from interferers with large frequency separation and going close in (see also Figure 17.10). In all cases where the interfering signal is an LTE signal, it has the same bandwidth as the wanted signal, but at most 5 MHz.

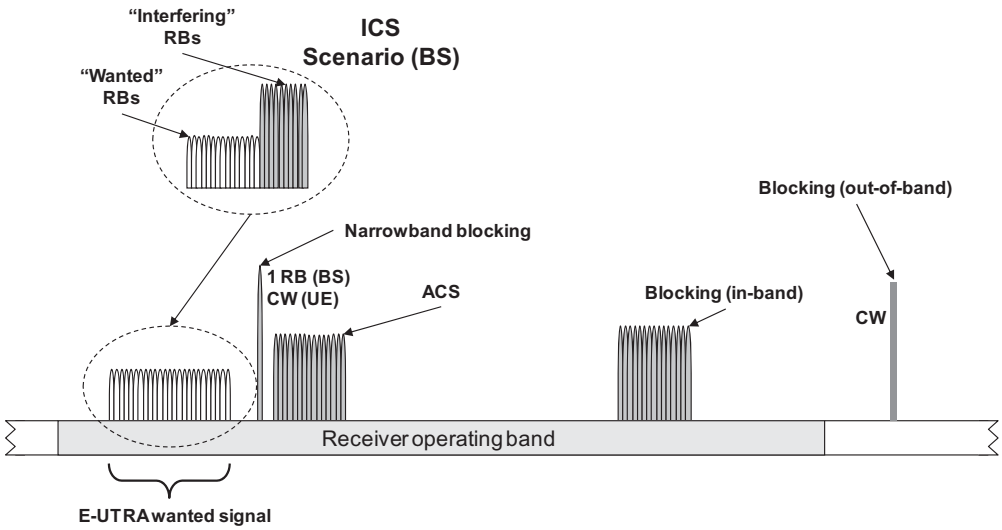


FIGURE 17.10

Base-station and UE requirements for receiver susceptibility to interfering signals in terms of blocking, ACS, narrowband blocking, and in-channel selectivity (BS only).

- *Blocking*. This corresponds to the scenario with strong interfering signals received outside the operating band (out-of-band blocking) or inside the operating band (in-band blocking), but not adjacent to the wanted signal. In-band blocking includes interferers in the first 20 MHz outside the band for the base station and the first 15 MHz for the UE. The scenarios are modeled with a *Continuous Wave* (CW) signal for the out-of-band case and an LTE signal for the in-band case. There are additional (optional) base-station blocking requirements for the scenario when the base station is co-sited with another base station in a different operating band. For the UE, a fixed number of *exceptions* are allowed from the out-of-band blocking requirement, for each assigned frequency channel and at the respective *spurious response frequencies*. At those frequencies, the UE must comply with the more relaxed spurious response requirement.
- *Adjacent channel selectivity*. The ACS scenario is a strong signal in the channel adjacent to the wanted signal and is closely related to the corresponding ACLR requirement (see also the discussion in Section 17.9.3). The adjacent interferer is an LTE signal. For the UE, the ACS is specified for two cases with a lower and a higher signal level.
- *Narrowband blocking*. The scenario is an adjacent strong narrowband interferer, which in the requirement is modeled as a single resource block LTE signal for the base station and a CW signal for the UE.
- *In-channel selectivity* (ICS). The scenario is multiple received signals of different received power levels inside the channel bandwidth, where the performance of the weaker "wanted" signal is verified in the presence of the stronger "interfering" signal. ICS is only specified for the base station.
- *Receiver intermodulation*. The scenario is *two* interfering signals near to the wanted signal, where the interferers are one CW and one LTE signal (not shown in Figure 17.10). The interferers are

placed in frequency in such a way that the main intermodulation product falls inside the wanted signal's channel bandwidth. There is also a *narrowband intermodulation* requirement for the base station where the CW signal is very close to the wanted signal and the LTE interferer is a single RB signal.

For all requirements except in-channel selectivity, the wanted signal uses the same reference channel as in the corresponding reference sensitivity requirement. With the interference added, the same 95% relative throughput is met as for the reference channel, but at a "desensitized" higher wanted signal level.

Petitioners' Exhibit 1003, p. 734
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CHAPTER

Performance 18

18.1 PERFORMANCE ASSESSMENT

Computer simulation of mobile systems is a very powerful tool to assess the system performance. The "real-life" performance can, of course, be measured and evaluated in the field for an already deployed system and such values represent a valid example of performance for a certain system configuration. But there are several advantages with computer simulations:

- Evaluation can be made of system concepts that are not deployed or still under development.
- There is full control of the environment, including propagation parameters, traffic, system layout, etc., and full traceability of all parameters affecting the result.
- Well-controlled "experiments" comparing similar system concepts or parts of concepts can be done under repeatable conditions.

In spite of the advantages, simulation results obviously do not give a full picture of the performance of a system. It is impossible to model all aspects of the mobile environment and to properly model the behavior of all components in a system. Still, a very good picture of system performance can be obtained and it can often be used to find the potential limits for performance. Because of the difficulty in modeling all relevant aspects, relative capacity measures for introducing features will be more accurate than absolute capacity numbers, if a good model is introduced of the feature in question.

The capacity of a system is difficult to assess without comparisons, since a system performance number in itself does not provide very much information. It is when set in relation to how other systems can perform that the number becomes interesting. Since making comparisons is an important component in assessing performance, it also makes performance numbers a highly contentious issue. One always has to watch out for "apples and oranges" comparisons, since the system performance depends on so many parameters. If parameters are not properly selected to give comparable conditions for two systems, the performance numbers will not be comparable either.

In this context, it is also essential to take into account that system performance and capacity will be feature dependent. Many features such as MIMO and advanced antenna techniques that have been introduced in 3G (HSPA) and 4G (LTE) systems are very similar between systems. If a certain feature is a viable option for several systems that are evaluated in parallel, the feature should be included in the evaluation for all systems.

Any simulated performance number should be viewed in the context that real radio network performance will depend on many parameters that are difficult to control or model, including:

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 736
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- The mobile environment, including channel conditions, angular spreads, clutter type, terminal speeds, indoor/outdoor usage, and coverage holes.
- User-related behavior, such as voice activity, traffic distribution, and service distribution.
- System tuning of service quality and network quality.
- Deployment aspects such as site types, antenna heights and types, and frequency planning.
- A number of additional parameters that are usually not modeled, such as signaling capacity and performance, and measurement quality.

There is no single universal measure of performance for a telecommunications system. Indeed, end-users (subscribers) and system operators define good performance quite differently. On the one hand, end-users want to experience the highest possible level of quality. On the other hand, operators want to derive maximum revenue, for example by squeezing as many users as possible into the system. Performance-enhancing features can improve perceived quality of service (end-user viewpoint) or system performance (operator viewpoint). The good news, however, is that LTE and its evolution has the potential to do both. Compared to 3G systems, LTE yield better data rates and shorter delay. That is, LTE and its evolution can greatly improve both the service experience (end-user viewpoint) and the system capacity (operator viewpoint).

18.1.1 End-User Perspective of Performance

Users of circuit-switched services are assured of a fixed data rate. The quality of service in the context of speech or video telephony services is defined by perceived speech or video quality. Superior-quality services have fewer bit errors in the received signal.

By contrast, users who download a web page or movie clip via packet data describe quality of service in terms of the delay they experience from the time they start the download until the web page or movie clip is displayed. Best-effort services do not guarantee a fixed data rate. Instead, users are allocated whatever data rate is available under present conditions. This is a general property of packet-switched networks – that is, network resources are not reserved for each user. Given that the delay increases with the size of the object to be downloaded, absolute delay is not a fair measure of quality of service.

Performance of a packet data service in cellular systems can be characterized by several different measures depending on the perspective taken (see Figure 18.1). A single user in a radio network experiencing good radio conditions may enjoy the *peak data rate* of the radio interface. A user will, however, normally share radio resources with other users. If radio conditions are less than optimal or there is interference from other users, the radio-interface data rate will be less than the peak data rate. In addition, some data packets might be lost, in which case the missing data must be retransmitted, further reducing the effective data rate as seen from higher protocol layers. Furthermore, the effective data rate diminishes even further as the distance from the cell increases (due to poorer radio conditions at cell edges). The data rate experienced above the MAC layer, after sharing the channel with other users, is denoted *user throughput*.

The *Transmission Control Protocol* (TCP) – the protocol at the transport layer – is commonly used together with IP traffic. However, due to the so-called slow-start algorithm, which is sensitive to latency in the network, it is especially prone to cause delay for small files. The slow-start algorithm is meant to ensure that the packet transmission rate from the source does not exceed the capability of network nodes and interfaces.

Petitioners' Exhibit 1003, p. 737
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

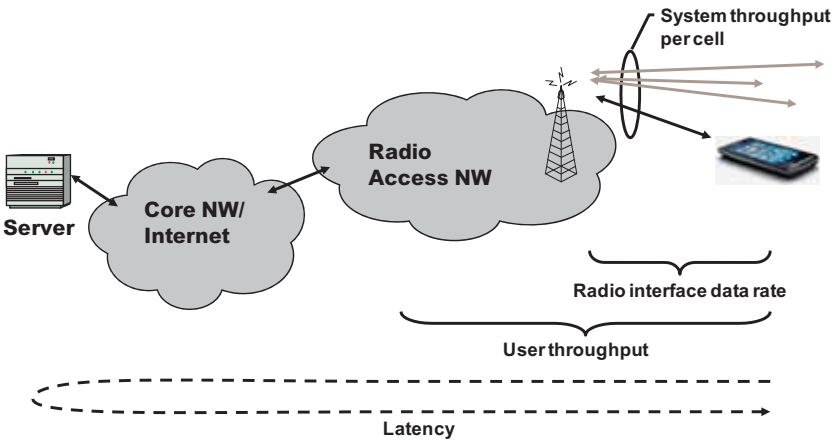


FIGURE 18.1

Definitions of data rates for performance.

Network *latency*, which in principle is a measure of the time it takes for a packet to travel from a client to a server and back again, has a direct impact on performance with TCP. Therefore, an important design objective for LTE has been to reduce network latency. One other quality-related criterion (end-user viewpoint) relates to the setup time for initiating, for example, a web-browsing session.

18.1.2 Operator Perspective

Radio resources need to be shared when multiple users are in the network. As a result, all data must be queued before it can be transmitted, which restricts the effective data rate to each user. Notwithstanding this fact, by scheduling radio resources, operators can improve system throughput or the total number of bits per second transmitted over the radio interface. A common measure of system performance is "spectral efficiency", which is the system throughput per MHz of spectrum in each cell of the system.

LTE employs intelligent scheduling methods to optimize performance, from both end-user and operator viewpoints.

An important performance measure for operators is the number of active users who can be connected simultaneously. Given that system resources are limited, there will thus be a trade-off between number of active users and perceived quality of service in terms of user throughput.

18.2 PERFORMANCE IN TERMS OF PEAK DATA RATES AND LATENCY

As described in Chapter 1, LTE has been developed in a process where design targets for performance parameters play an important role. One target is for the peak data rate over the radio interface. The original design targets for the first release of LTE are documented in 3GPP TR 25.913 [10]. The target capability when operating in a 20 MHz spectrum allocation is a peak data rate of 100 Mbit/s in

Table 18.1 LTE Peak Spectral Efficiency [92]

Peak Spectral Efficiency	ITU Requirement (bit/s/Hz)	LTE Fulfillment			
		Release 8		Release 10	
		FDD	TDD	FDD	TDD
Downlink	15	15.3	15.0	30.6	30.0
Uplink	6.75	4.2	4.0	16.8	16.0

the downlink and 50 Mbit/s in the uplink. The numbers assume two receive antennas in the terminal for the downlink capability and one transmit antenna for the uplink capability. These target numbers are exceeded by a good margin by the peak data rate capability of the specified LTE standard. LTE release 8 supports peak data rates of 300 Mbit/s in the downlink and 75 Mbit/s in the uplink by using spatial multiplexing of four layers (4 × 4 MIMO) in the downlink and 64QAM in both downlink and uplink. With the assumptions in the design targets – that is, spatial multiplexing of two layers – the downlink peak data rate is 150 Mbit/s, which is still significantly higher than the target.

The design targets for LTE release 10 ("LTE-Advanced") are documented in 3GPP TR 36.913 [10], based on the targets set by ITU-R [65]. There is no absolute peak data rate target expressed for LTE release 10; it is instead expressed relative to the channel bandwidth as a peak spectral efficiency, with targets of 15 bit/s/Hz for downlink and 6.75 bit/s/MHz for uplink [65]. LTE release 10 exceeds those numbers by a good margin, as shown in Table 18.1. The assumptions for deriving the peak spectral efficiency numbers is a deployment with 20 MHz channel bandwidth, 8 × 8 MIMO in the downlink, and 4 × 4 MIMO in the uplink.

The ITU-R requirement for downlink peak spectral efficiency is in fact fulfilled already by LTE release 8, assuming 4 × 4 MIMO in the downlink [92].

The ITU-R target for *latency* in [65] is set with a different definition than in Figure 18.1. Instead of a two-way *latency*, there is a 10 ms target for the *one-way latency* in both downlink and uplink. The one-way latency is defined as the one-way transit time between a packet being available at the IP layer in the user base station and the availability of this packet at the IP layer in the user terminal, and vice versa. This is achieved with a good margin for LTE, where the latency achieved is 4 ms for LTE FDD and 4.9 ms for LTE TDD.

18.3 PERFORMANCE EVALUATION OF LTE-ADVANCED

An essential part of the submission of LTE release 10 to ITU-R as a candidate for IMT-Advanced was the performance evaluation of the spectral efficiency. The technical requirements are set by ITU-R Report M.2134 [65] and the detailed evaluation methodology is described in ITU-R Report M.2135 [93].

For the work on LTE release 10, 3GPP performed a large simulation campaign with input from several 3GPP members. The resulting performance numbers formed an essential part of the submission of LTE-Advanced as a candidate for IMT-Advanced and is reported in detail in 3GPP TR 36.912 [92]. In addition to the ITU-R evaluation criteria, an additional test environment with higher

Petitioners' Exhibit 1003, p. 739
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 18.2 Test Environment and Deployment Parameters for the Evaluation

	Test Environment			
	Indoor	**Microcellular**	**Base Coverage, Urban**	**High Speed**
Deployment scenario	Indoor hotspot	Urban micro	Urban macro	Rural macro
Channel model	InH	UMi	UMa	RMa
Carrier frequency (GHz)	3.4	2.5	2.0	0.8
Inter-site distance (m)	60	200	500	1732
Terminal speed (km/h)	3	3	30	120
User distribution	100% indoor	50% indoor, 50% outdoor	100% outdoor	100% outdoor
BS antenna height (m)	6	10	25	35
BS antenna gain (dBi)	0	17	17	17
BS output power (dBm/20 MHz)	21	44	49	49
UE output power (dBm)	21	24	24	24

performance targets than the ones set by ITU-R was defined in 3GPP. Performance numbers for this additional environment are also reported in [92].

An evaluation based on the ITU-R methodology and assumptions is presented in [94] and is also outlined below. The evaluation is based on time-dynamic system simulations, where users are dropped independently with uniform distribution over a simulated LTE system with a large number of cells. The simulations include overhead for control channels and time-dynamic models of feedback channels. Further details are given below. With the level of details applied to model the protocols and the simulation assumptions used for the evaluation described below, the technology potential of LTE release 10 is demonstrated, in addition to showing that the IMT-Advanced performance requirements are exceeded.

Detailed evaluations of LTE release 8 in comparison to earlier 3GPP releases of HSPA can be found in [95,96].

18.3.1 Models and Assumptions

This section presents the models and assumptions used for the evaluation in [94]. A summary of the test environments is given in Table 18.2 and the assumptions for the LTE-Advanced system characteristics are given in Table 18.3.

The evaluation is performed in four deployment scenarios, each corresponding to a different test environment defined by ITU-R [93]:

- *Indoor Hotspot*. Deployment scenario for the *indoor* environment, having isolated office cells or hotspots for stationary or pedestrian users, with high user density and high user throughput.
- *Urban Micro*. Deployment scenario for the *microcellular* environment, having small cells with outdoor and outdoor-to-indoor coverage for pedestrian and slow vehicular users, provided by

Table 18.3 LTE-Advanced System Characteristics for the evaluation in [94]

General Characteristics	
Duplex method assumptions	FDD
	TDD: Configuration 1, DwPTS/GP/UpPTS length set to 12/1/1 OFDM symbols (see Chapter 9)
Spectrum allocation	10 MHz DL + 10 MHz UL for FDD,
	10 MHz for TDD
	Double bandwidth for InH case
Antenna configuration at base station (BS)	Vertically co-polarized
	Antennas with 4 (InH) or 0.5 (UMi, UMa, RMa) wavelengths separation
Antenna configuration at terminal (UE)	Vertically co-polarized
	0.5 wavelengths separation
Network synchronization	Synchronized, not explicitly utilized other than for avoiding UE–UE and BS–BS interference for TDD
Detailed Radio-Interface Characteristics and Models	
Scheduler	DL: Proportional fair in time and frequency
	UL: Quality-based frequency-domain multiplexing
Downlink transmission scheme	InH: Transmission mode 4; closed-loop codebook-based precoded adaptive rank spatial multiplexing
	UMi, UMa, RMa: Transmission mode 5; coordinated beam-forming (within site) with MU-MIMO
Uplink transmission scheme	1 Tx, 4Rx antennas, no MU-MIMO
Receiver type	Minimum Mean Squared Error (MMSE) in DL and UL
Uplink power control	Open loop with fractional path-loss compensation, parameters chosen according to the deployment scenario. Effective noise rise below 10 dB
Hybrid-ARQ scheme	Incremental redundancy, synchronous, adaptive
Link adaptation	Non-ideal, based on delayed feedback
Channel estimation	Non-ideal channel estimation
	Non-ideal channel-state reports in downlink; CQI error per resource block is N(0,1) dB, error-free feedback of the reports, 6 ms reporting delay, 5 ms reporting periodicity
	Uplink quality estimated from PUSCH, 6 ms delay, 20 ms sounding period
Feedback channel errors	Error-free, but quantized and delayed
Control channel overhead	DL: 3 OFDM symbols per subframe
	UL: 4 resource blocks
	Overhead for common control channels (synchronization, broadcast and random access; ~1% for 10 MHz) has not been deducted

Petitioners' Exhibit 1003, p. 741
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

below rooftop outdoor base stations. It has high traffic per unit area and will be interference limited.

- *Urban Macro*. Deployment scenario for the *base coverage urban* environment, having large cells and continuous coverage for pedestrians up to fast vehicular users, provided by above rooftop outdoor base stations. It will be interference limited and has mostly non-line-of-sight propagation conditions.
- *Rural Macro*. Deployment scenario for the *high speed* environment, having large cells and continuous coverage for high-speed vehicular and train users. It will be noise and/or interference limited.

Each deployment scenario described in [93] corresponds to a set of deployment parameters, including detailed propagation models for line-of-sight, non-line-of-sight, and/or outdoor-to-indoor propagation. The channel model is based on the so-called WINNER II channel model [97], which is a Spatial Channel Model (SCM) applicable for MIMO simulations [98]. Further details of the test environments and deployment parameters are given in Table 18.2.

The simulation methodology is "time dynamic", where a system of base stations and terminals is simulated over a limited time frame (20–100 seconds). This is repeated to create a number of samples to reach sufficient statistical confidence. For each simulation, terminals are randomly positioned over a model of a radio network and the radio channel between each base station and terminal antenna pair is simulated according to the propagation and fading models. A full buffer traffic model with an average of 10 users per cell is assumed. This results in the system operating at the maximum 100% system load.

Based on the channel realizations and the active interferers, a *signal-to-interference-and-noise ratio* (SINR) is calculated for each terminal (or base-station) receive antenna. The SINR values are then mapped to *block error probability* for the modulation and coding scheme employed for each user. MIMO and the modulation-and-coding scheme according to the LTE standard are selected based on delayed feedback. Retransmissions are explicitly modeled and the user throughput for each active user i will be the number of correctly received bits χ_i (above the MAC layer) divided by the simulated time T. The distribution of user throughput between users is used as a basis for assessing end-user quality. The served traffic per cell is calculated from the total number of received bits χ_i for all users, averaged over all cells and divided by the simulated time T. Statistics are collected from each simulation run and then new terminals are randomly positioned for the next sample.

18.3.2 Evaluation Criteria

ITU-R defines two requirements related to the efficiency of the radio interface for evaluating the performance of the IMT-Advanced candidate radio-interface technologies (RITs) [65]. The first is *cell spectral efficiency*, defining the operator perspective, and the second is *cell-edge spectral efficiency*, defining the end-user perspective.

The *cell spectral efficiency* is the aggregated throughput over all users, averaged over all cells and divided by the channel bandwidth. The measure relates to the system throughput in Figure 18.1 and is a measure of the maximum total "capacity" available in the system to be shared between users; it is measured in bits/s/Hz/cell.

The cell spectral efficiency η is defined as:

$$\eta = \frac{\sum_{i=1}^{N} \chi_i}{T \cdot \omega \cdot M}, \tag{18.1}$$

Petitioners' Exhibit 1003, p. 742
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 18.4 ITU-R Requirements for IMT-Advanced Spectral Efficiency

Test Environment and Corresponding Deployment Scenario	Cell Spectral Efficiency (bit/s/Hz/cell)		Cell-Edge User Spectral Efficiency (bit/s/Hz)	
	Downlink	Uplink	Downlink	Uplink
Indoor (InH)	3	2.25	0.1	0.07
Microcellular (UMi)	2.6	1.8	0.075	0.05
Base coverage, urban (UMa)	2.2	1.4	0.06	0.03
High speed (RMa)	1.1	0.7	0.4	0.015

where χ_i denotes the number of correctly received bits for user i in a system with N users and M cells, ω is the channel bandwidth, and T is the time over which the data bits are received.

The *cell-edge user spectral efficiency* is based on the distribution between users of the *normalized user throughput* (see also Figure 18.1), which is defined as the average user throughput over a certain period of time divided by the channel bandwidth, and is measured in bit/s/Hz. The cell-edge user spectral efficiency is defined as the 5% point of the cumulative distribution function (CDF) of the normalized user throughput. It is thus a measure of the end-user perceived "quality of service" for the 5% of the users with the lowest user throughput.

The normalized user throughput for user i is defined as:

$$\gamma_i = \frac{\chi_i}{T_i \cdot \omega}, \tag{18.2}$$

where T_i is the active session time for user i.

The requirements defined by ITU-R [65] for cell spectral efficiency and cell-edge user spectral efficiency are listed in Table 18.4. The requirement levels are shown as dashed lines together with the simulated performance values in Figures 18.2 and 18.5.

18.3.3 Performance Numbers for FDD

Simulations for FDD and TDD and for all test environments were submitted for the ITU-R evaluation and are also presented here. The numbers here, however, are not identical to the numbers put forward to ITU-R in [92], but will be seen as one sample of results from the evaluation in [94].

For FDD, the cell spectral efficiency and cell-edge spectral efficiency are shown in Figure 18.2. All results exceed the ITU-R performance requirements in Table 18.4, in some cases by a very good margin. For the indoor scenario and the downlink, this is achieved using an uncorrelated antenna configuration together with single-user MIMO. For the other scenarios, a correlated antenna setup and intra-site coordinated beam-forming (CBF) with MU-MIMO are used in the downlink. A quite basic uplink configuration not utilizing MIMO is used for all environments. It should be noted that the cell-edge spectral efficiency is highly dependent on the system load and that the ITU-R simulations are performed with maximum load and a full buffer model. An example of LTE performance numbers including lower and varying loads can be found in [96].

Petitioners' Exhibit 1003, p. 743
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

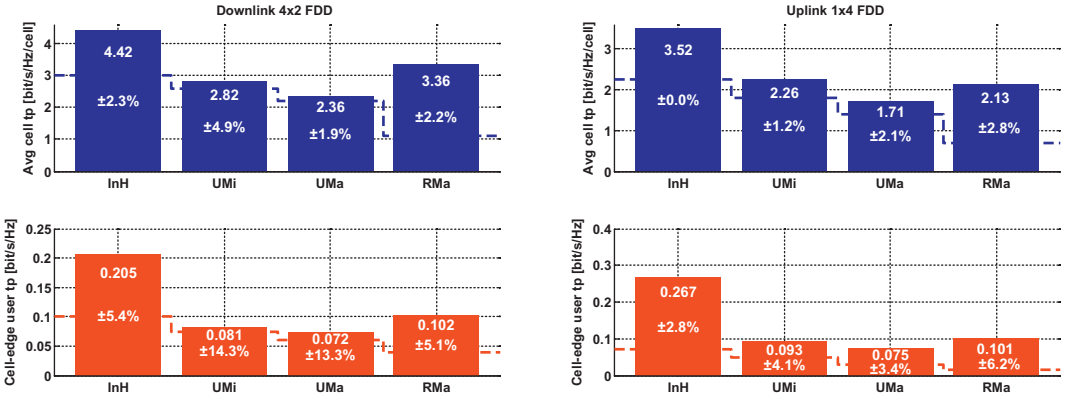


FIGURE 18.2

FDD cell spectral efficiency and cell-edge user spectral efficiency, compared with ITU-R requirements (downlink and uplink).

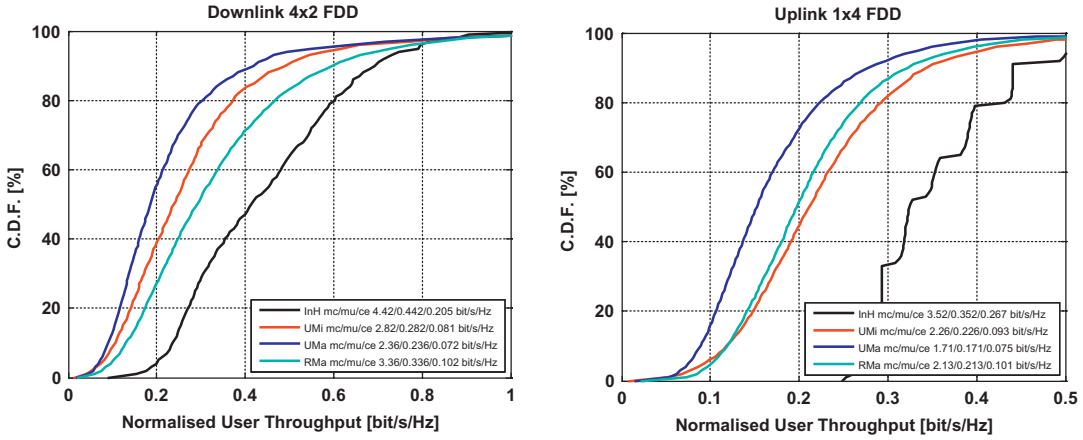


FIGURE 18.3

FDD normalized user throughput distributions (downlink and uplink).

The normalized user throughput distributions are given in Figure 18.3 and Signal-to-Noise-and-Interference Ratio (SINR) distributions are shown in Figure 18.4. The figures demonstrate the impact of the very advantageous SINR distributions achieved in the indoor hotspot scenario and to some extent also for rural macro, resulting in higher spectral efficiency numbers in those environments.

18.3.4 Performance Numbers for TDD

For TDD, the cell spectral efficiency and cell-edge spectral efficiency are shown in Figure 18.5, while normalized user throughput distributions are illustrated in Figure 18.6. There is a small drop in the

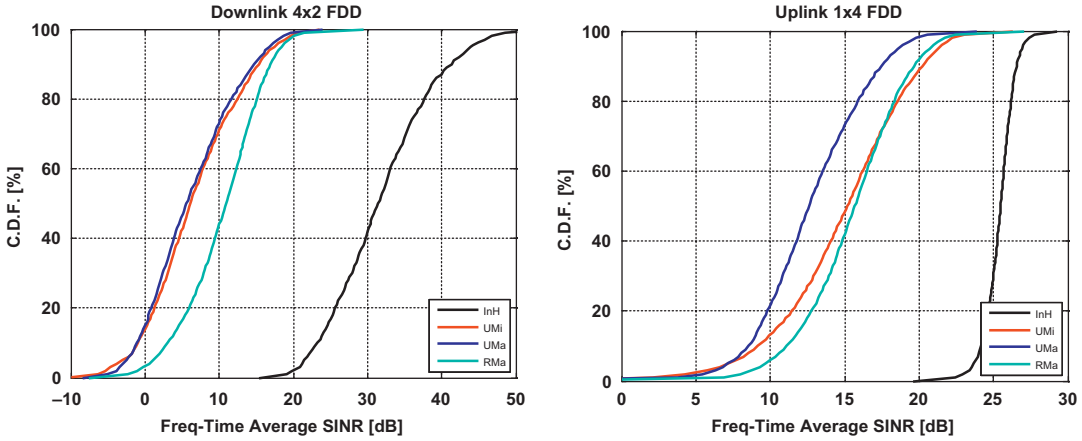


FIGURE 18.4

FDD SINR distributions (downlink and uplink).

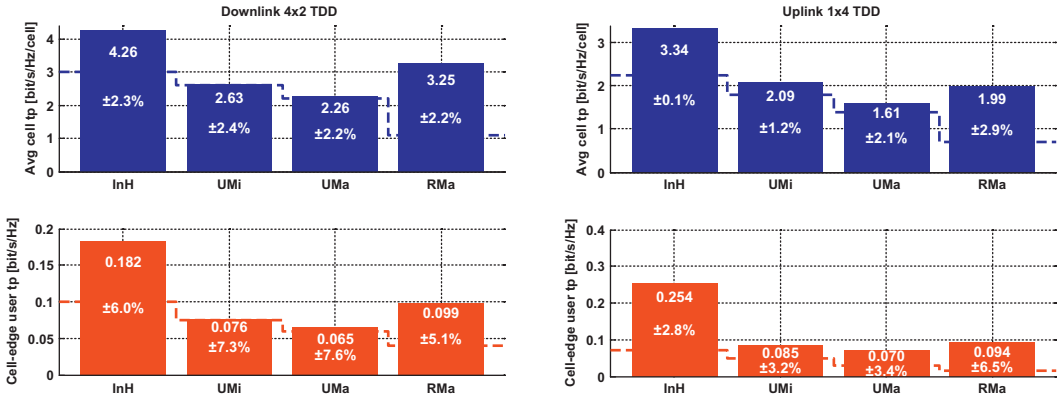


FIGURE 18.5

TDD cell spectral efficiency and cell-edge user spectral efficiency, compared with ITU-R requirements (downlink and uplink).

spectral efficiency numbers compared to FDD, but all results exceed the ITU-R performance requirements. The difference compared to FDD is due to a higher overhead from the guard period between uplink and downlink. The average delay between making measurements in the terminal and receiving the measurement result at the base station is also increased compared to FDD, due to the TDD time-domain structure. This has some impact on the performance of scheduling and link adaptation. The channel reciprocity is not utilized in the simulated TDD scheme.

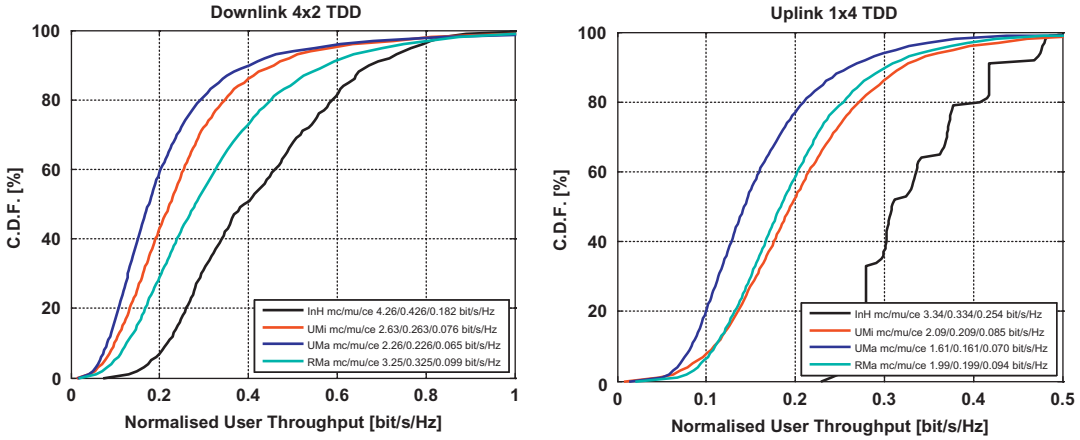


FIGURE 18.6

TDD normalized user throughput distributions (downlink and uplink).

18.4 CONCLUSION

The simulation results presented in this chapter demonstrate the high potential of LTE/LTE-Advanced in terms of both overall spectral efficiency to the benefit of operators and high cell-edge performance to the benefit of the end-user. The performance is assessed in four different test environments. The results for FDD and TDD in downlink and uplink all exceed the requirements set up by ITU-R for the evaluation of IMT-Advanced candidates. In addition, the peak radio-interface data rates and the latency achieved by LTE meet the ITU-R requirements.

Petitioners' Exhibit 1003, p. 746
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CHAPTER

Other Wireless Communications Systems

19

Most mobile and cellular systems go through a continuous development of the underlying technology and of the features, services, and performance supported. The direction of development is from the baseline "narrowband" systems of the 1990s supporting mainly voice services to today's "wideband" systems that target a much wider set of services, including broadband wireless data.

The fundamental technologies introduced in the systems to support new and better performing services all fall within the scope of Chapters 2–6 of this book. When the problems to solve are fundamentally the same, the solutions engineered tend to be quite similar. Wideband transmission, higher-order modulation, fast scheduling, advanced receivers, multi-carrier, OFDM, MIMO, etc. have been added as continuous developments and, at other times, as more revolutionary steps for the different technologies.

The application of these different technical solutions to LTE has been discussed in the previous chapters of this book. A similar development is occurring for the other technologies in the IMT-2000 family. This chapter gives a brief overview of HSPA and GSM, developed in 3GPP, 1xEV-DO, developed in 3GPP2, and 806.16 m/WiMAX, developed in IEEE in conjunction with WiMAX forum.

19.1 HSPA

Wideband Code-Division Multiple Access (WCDMA), also known as *Universal Terrestrial Radio Access* (UTRA), is the dominant third-generation cellular technology, developed by 3GPP with the first version of the specifications released in 1999. WCDMA is based on code-division multiple access using a chip rate of 3.84 Mchip/s, is originally designed for 5 MHz of spectrum allocation, and provides wide-area coverage of data rates[1] up to 384 kbit/s in both uplink and downlink. Circuit-switched as well as packet-switched services are supported.

High-Speed Packet Access (HSPA) is an evolution of the WCDMA radio interface, adding significantly enhanced support for packet data by applying technologies such as shared-channel transmission, channel-dependent scheduling, link adaptation, and hybrid ARQ with soft combining. The first version of HSPA appeared in release 5 of the WCDMA standard in 2002, but the specifications have

[1]The specifications support peak data rates of up to 2 Mbit/s in both uplink and downlink, but practical implementations typically support up to 384 kbit/s only.

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 748
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

been updated following a similar release scheme as the LTE specifications. Later versions of HSPA include features such as spatial multiplexing, carrier aggregation, and broadcast support. Figure 19.1 outlines the evolutionary steps of HSPA, which are also summarized below:

- Release 5 was the first release of HSPA, introducing the basic set of features (shared-channel transmission, channel-dependent scheduling, link adaptation, and hybrid ARQ with soft combining) in the downlink. Peak data rates up to 14 Mbit/s in the downlink were supported.
- Release 6 provided the basic set of features for uplink transmissions, resulting in an uplink peak data rate of 5.7 Mbit/s.
- Release 7 brought spatial multiplexing of two layers to the downlink, as well as downlink 64QAM and uplink 16QAM, to HSPA. Other enhancements in release 7 included continuous packet connectivity to provide better DRX/DTX capabilities and enhanced CELL_FACH to reduce the latency associated with state switching.
- Release 8 supports simultaneous usage of spatial multiplexing and 64QAM modulation in the downlink.
- Release 9 introduced carrier aggregation in a similar way as later done for LTE, thereby increasing the HSPA bandwidth to 10 MHz.
- Release 10 further increased the bandwidth supported by HSPA to 20 MHz by using four carriers in the downlink. The downlink peak data rate is 168 Mbit/s using roughly 20 MHz of spectrum.

As seen from the list above, the performance of HSPA has increased considerably in less than 10 years since its first incarnation in release 5. The fact that HSPA is an *evolution* and builds upon the basic WCDMA structure sets some constraints on what it is possible to introduce compared to a clean-slate design such as LTE, but also provides the possibility to gradually improve the performance of an already deployed network. This is an important aspect from an operator's perspective. The evolution is still ongoing and HSPA can, in many aspects, provide performance similar to that of LTE.

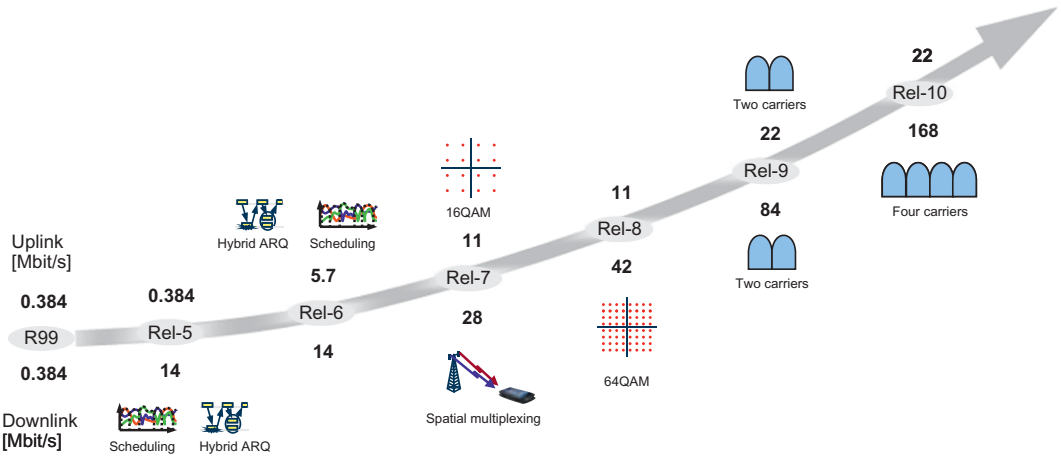


FIGURE 19.1

Evolution of HSPA.

HSPA exists in both FDD and TDD versions but, unlike LTE, the two duplex schemes are designed more or less independently of each other, resulting in significant differences in the physical-layer design. In the following, a brief overview of the most important technology components in the FDD version of HSPA is provided, as well as a short summary of the TDD version. For a more detailed description of HSPA, see [96].

19.1.1 Architecture

The WCDMA radio-access network architecture, upon which HSPA builds, is different from LTE, with the main difference being the existence of a *Radio Network Controller* (RNC), motivated by the support of macro diversity in WCDMA. The functional split between the RNC and the NodeB[2] is such that the NodeB handles most of the physical-layer processing, while the RNC handles the higher-layer protocols and all the radio-resource management. The WCDMA/HSPA radio-access network architecture is illustrated in Figure 19.2.

HSPA to a large extent relies on the same basic features as LTE, such as channel-dependent scheduling, hybrid ARQ with soft combining, rate adaptation, etc. These features to a large extent rely on rapid adaptation to the instantaneous radio conditions and hence need to be located in the NodeB, while the higher-layer protocols reside in the RNC. At the same time, an important design objective of HSPA was, as far as possible, to retain the original WCDMA functional split between layers and nodes. Minimization of the architectural changes is desirable as it simplifies introduction of HSPA in already deployed networks and also secures operation in environments where not all cells have been upgraded with HSPA functionality. Therefore, HSPA introduced new MAC sublayers in the NodeB, to handle scheduling, rate adaptation, and hybrid-ARQ retransmissions.

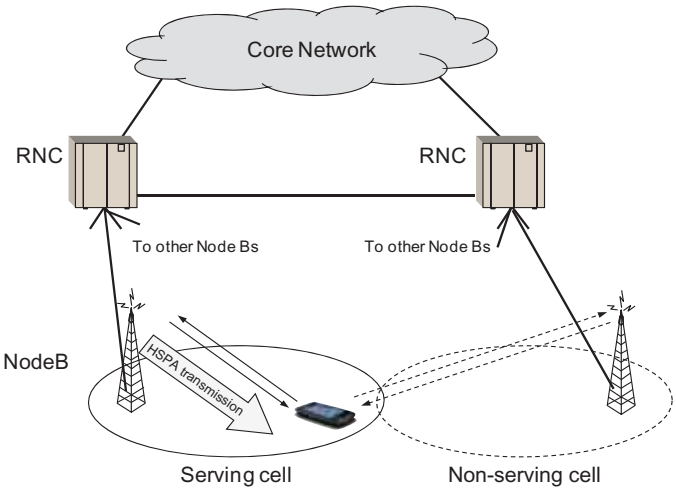


FIGURE 19.2

WCDMA/HSPA architecture.

[2]In WCDMA/HSPA, the term NodeB is used instead of eNodeB.

Each terminal using HSPA will receive data from one cell, the *serving cell*, which is also the cell responsible for scheduling. Unlike LTE, uplink soft handover is explicitly supported, in which case the uplink data transmission will be received in multiple cells and the terminal will receive power control commands from multiple cells.

19.1.2 Channel-Dependent Scheduling

Channel-dependent scheduling is used in HSPA for similar reasons as in LTE, namely to rapidly adapt to varying traffic and radio-channel conditions. The basic operation is similar to LTE, with scheduling decisions taken by the NodeB once per 2 ms TTI, but the difference in the uplink multiple-access scheme between HSPA and LTE has particularly affected the scheduling design.

The downlink transmission scheme in HSPA is based on reserving a certain fraction of the total downlink radio resources available within a cell, channelization codes and transmission power in the case of WCDMA/HSPA, and dynamically scheduling these resources across the users. The shared resource, illustrated in Figure 19.3, consists of a set of channelization codes of spreading factor 16. The dynamic allocation of the code resource for transmission to a specific user is done on a 2 ms TTI basis (see lower part of Figure 19.3). The reasons for a short TTI are similar as for LTE, namely to follow fast channel variations and to reduce the overall latency. From a scheduling perspective, using a set of orthogonal codes is similar to using a set of orthogonal frequency resources in LTE, and hence the downlink scheduling strategy for HSPA is similar to that of LTE. Channelization codes not used for HSPA data transmission are used for other downlink channels, for example control signaling and non-HSPA services.

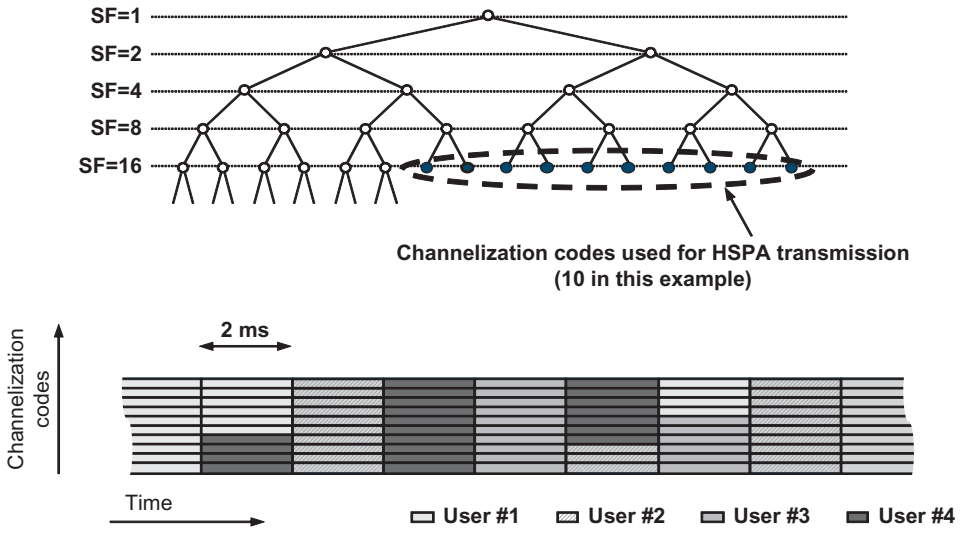


FIGURE 19.3

Shared resource in HSPA downlink – channelization codes.

The uplink transmission scheme, on the other hand, is inherently non-orthogonal and this motivates a different scheduling mechanism than the one used for the orthogonal LTE uplink. The higher the data rate a terminal is using, the higher the received power at the NodeB must be to maintain the E_b/N_0 required for successful demodulation. By increasing the transmission power, the terminal can transmit at a higher data rate. However, due to the non-orthogonal uplink, the received power from one terminal represents interference when receiving from other terminals due to the use of non-orthogonal spreading codes in the uplink. Hence, the shared resource in the uplink is basically the amount of tolerable interference in the cell. If the interference level is too high, some transmissions in the cell, most notably control channels and non-scheduled uplink transmissions, may not be received properly. On the other hand, an interference level that is too low may indicate that terminals are artificially throttled and the full system capacity is not being exploited. Therefore, the task of the uplink scheduler is to give users with data to transmit permission to use as high a data rate as possible without exceeding the maximum tolerable interference level in the cell.

The uplink scheduling framework for HSPA is based on *scheduling grants* sent by the NodeB scheduler to control the terminal transmission activity and *scheduling requests* sent by the terminals to request resources. The scheduling grants essentially control the maximum allowed transmission power the terminal may use; a larger grant implies the terminal may use a higher data rate but also contributes more to the interference level in the cell. Both multi-bit absolute grants, directly setting the grant level in the terminal to the desired level, as well as single-bit relative grants increasing/decreasing the grant level in the terminal are supported. Within the limits set by the scheduling grants, the terminals are allowed to autonomously select the data rate to use. A terminal not utilizing all its granted resources will transmit at a lower power, thereby reducing the intra-cell interference. Hence, shared resources not utilized by one mobile terminal can be exploited by another mobile terminal through statistical multiplexing.

For very high data rates, a non-orthogonal transmission scheme may result in relatively large amounts of interference from high-rate transmissions to low-rate transmissions. HSPA therefore makes it possible to also separate data transmissions in the time domain in the uplink, where terminals are allowed to transmit in certain 2 ms TTIs only. By separating high-rate and low-rate terminals in the time domain, the interference problem can be alleviated.

The fact that HSPA supports uplink macro diversity also has an impact on the scheduling framework. Although the scheduling grants are provided to the terminal by the serving cell only, there is the chance that neighboring cells may affect the grant level in the terminal. In essence, this is an overload indicator, common to multiple terminals, which a cell can set in order to ask terminals in the soft handover region to lower their data rates, thereby reducing the interference level in the non-serving cell.

Different data rates in the uplink as well as in the downlink are supported in a similar way as in LTE by supporting different modulation orders, up to 16QAM in the uplink and up to 64QAM in the downlink, in combination with rate matching to adjust the coding rate. For historical reasons, a 10 ms TTI is supported in the uplink in addition to the 2 ms TTI.

19.1.3 Hybrid ARQ with Soft Combining

Fast hybrid ARQ with soft combining in HSPA uses the same structure with multiple, parallel hybrid-ARQ processes as in LTE. Retransmissions typically take place 12 ms after the initial transmission in the downlink. For the uplink, the corresponding figure is 16 ms for a 2 ms TTI (40 ms for a 10 ms TTI).

Petitioners' Exhibit 1003, p. 752
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Since the RLC is located in the RNC, while the hybrid-ARQ functionality is located in the NodeB, a separate reordering mechanism is located in the NodeB to ensure in-sequence delivery of received transport blocks to the RLC (in LTE, reordering is an integral part of the RLC).

19.1.4 Control-Plane Latency Reductions

Starting in release 7, mechanisms to reduce the overall latency were introduced in HSPA, more specifically *Continuous Packet Connectivity* (CPC) and *Enhanced CELL_FACH*, to match the bursty nature of packet-data traffic.

In WCDMA/HSPA, a terminal can be in one of four different states, URA_PCH, CELL_PCH, CELL_FACH, and CELL_DCH, ranging from low activity, low power consumption, to high activity and higher power consumption. Thus, from a delay perspective it is preferable to keep the terminal in CELL_DCH, while from an interference and power-consumption perspective, one of the paging states is preferred. RRC signaling, originating from the RNC, is used to move the terminal between the different states.

To improve the packet-data support in HSPA, a set of features known as *Continuous Packet Connectivity* (CPC) was introduced in release 7. CPC consists of three building blocks:

1. *Discontinuous transmission* (DTX), to reduce the uplink interference and thereby increase the uplink capacity, as well as to save battery power. Without DTX, the terminal is constantly transmitting on a control channel in the uplink while being in the CELL_DCH state.
2. *Discontinuous reception* (DRX), to allow the terminal to periodically switch off the receiver circuitry and save battery power.
3. *HS-SCCH-less operation*, to reduce the downlink control signaling overhead for small amounts of data, as will be the case for services such as voice-over IP.

The intention with these features is to provide an "always-on" experience for the end-user by keeping the terminal in CELL_DCH for a longer time and avoiding frequent state changes to the low-activity states, as well as improving the capacity for services such as voice-over IP (Figure 19.4).

The purpose of CPC is, as discussed above, to provide an "always-on" user experience by keeping the terminal in the active state CELL_DCH while still providing mechanisms for reduced power consumption. However, eventually the terminal will be switched to CELL_FACH if there has been no transmission activity for a certain period of time. Once the terminal is in CELL_FACH, signaling on the *Forward Access Channel* (FACH), a low-rate common downlink transport channel, is required to

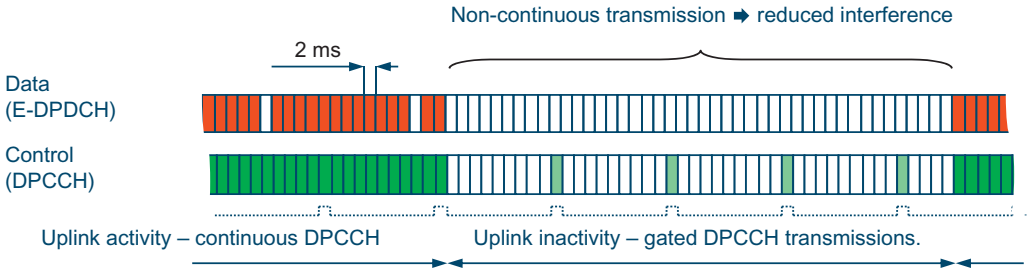


FIGURE 19.4

Simplified illustration of DTX in continuous packet connectivity.

move the terminal to CELL_DCH prior to any data exchange using the HSPA features taking place. The physical resources to which the FACH is mapped is semi-statically configured by the RNC and, to maximize the resources available for HS-DSCH and other downlink channels, the amount of resources (and thus the FACH data rate) is typically kept small, of the order of a few tens of kbit/s.

To reduce the latency associated with state changes, release 7 improved the performance by allowing HSPA to be used also in the CELL_FACH state. This is often referred to as *Enhanced CELL_FACH Operation*. Using the high-rate HSPA transmission scheme also in CELL_FACH allows for a significant reduction in the delays associated with switching to the CELL_DCH state. Instead of using a low-rate semi-statically allocated control channel, the signaling from the network to the terminal can be carried using high-rate HSPA channels. This can result in a significant reduction in call-setup delay and a corresponding improvement in user perception. In release 8, this is further improved by also supporting HSPA functionality in the uplink when being in the CELL_FACH state.

19.1.5 Spatial Multiplexing

Spatial multiplexing in HSPA supports up to two layers in the downlink. Two transport blocks, one per layer, are used in multi-stream transmission and HSPA-MIMO is thus a multi-codeword scheme (see Chapter 5 for a discussion on single- vs. multi-codeword schemes), allowing for a successive-interference-cancellation receiver in the terminal.

Similar to LTE, precoding is used prior to transmitting the two layers. Using precoding is beneficial for several reasons, especially in the case of single-stream transmission. In this case, precoding provides both *diversity gain* and *array gain* as both transmit antennas are used and the weights are selected such that the signals from the two antennas add coherently at the receiver. This results in a higher received carrier-to-interference ratio than in the absence of precoding, thus increasing the coverage for a certain data rate. Furthermore, if a separate power amplifier is used for each physical antenna, precoding ensures that both of them are also used in the case of single-layer transmissions, thereby increasing the total transmit power.

19.1.6 Carrier Aggregation

In later releases of HSPA, carrier aggregation is supported with up to four carriers in the downlink and two carriers in the uplink. A similar structure as for LTE has been adopted, where each carrier in principle is independently processed.

19.1.7 UTRA TDD

In parallel to the development of WCDMA and its evolution to HSPA, 3GPP also works on UTRA TDD. Although the higher layers are virtually identical between FDD and TDD, the physical-layer design is, for historical reasons, quite different. Furthermore, there are three versions of the TDD specifications, with the chip rate being one distinguishing factor.

Initially, TDD supported 3.84 Mchip/s only, but later 1.28 and 7.68 Mchip/s versions were added. The 3.84 and 7.68 versions share many features, while the 1.28 version, also known as *Time-Division-Synchronous CDMA* (TD-SCDMA), is substantially different from the other two. Of the three versions, TD-SCDMA is the only version deployed on a larger scale, mainly in China, with the other two versions being limited to niche applications.

Petitioners' Exhibit 1003, p. 754
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

TD-SCDMA was primarily developed in China as an industry standard within CCSA. In release 4, TD-SCDMA was introduced into 3GPP as an alternative to the 3.84 Mchip/s TDD version. The main differences from WCDMA/HSPA are, apart from the use of TDD instead of FDD, the lower chip rate and resulting (approximate) 1.6 MHz carrier bandwidth, the optional 8PSK higher-order modulation, a different 5 ms time-slot structure, and beam-forming support with eight antennas.

The HSPA enhancements to TD-SCDMA are similar to those applied to FDD, such as the use of 16QAM higher-order modulation and the use of hybrid ARQ. Some main differences are that, due to the TDD frame structure, timing relations are very different and a TTI of 5 ms is used. In general, UTRA TDD development is completed at a later stage in the 3GPP standardization process compared to FDD.

Some features found in TD-SCDMA originate from the work within the CCSA [99], including:

- *Multi-frequency operation*. In this mode, multiple 1.28 Mchip/s carriers are supported in one cell, but BCH is only sent on one carrier called *primary frequency*, in order to decrease inter-cell interference. The carrier on the primary frequency contains all common channels while traffic channels can be on both primary and secondary carriers. Each terminal still operates on a single 1.6 MHz carrier.
- *Beam-forming improvement*. Angle-of-arrival parameters for beam-forming can be signaled in the RACH and FACH data frames.
- *Multi-carrier HSPA*. In a cell using multi-carrier HSPA, data can be transmitted to a terminal on more than one carrier. There is a UE capability defined for receiving up to six carriers.

As discussed in Chapter 9, the LTE TDD mode has been designed to ease coexistence with and migration from TD-SCDMA.

19.2 GSM/EDGE

Worldwide GSM deployment started in 1992 and GSM quickly became the most widely deployed cellular standard in the world, with more than 2.5 billion subscribers today. A major evolutionary step for GSM was initiated in late 1996, at the same time as UTRA development started in ETSI. This step sprung out of the study of higher-order modulation for a 3G TDMA system that was performed within the European FRAMES project (see also Chapter 1).

The enhancement of GSM is called EDGE (*Enhanced Data Rates for GSM Evolution*). The EDGE development was initially focused on higher end-user data rates by introducing higher-order modulation in GSM, both for circuit-switched services and the GPRS packet-switched services. During the continued work, focus moved to the enhancement of GPRS (EGPRS), where other advanced radio-interface components were added, including link adaptation, hybrid ARQ with soft combining, and advanced scheduling techniques, as described in Chapter 6 of this book. In this way GSM became the first cellular standard to add such enhancements,[3] later followed by WCDMA/HSPA, CDMA2000, and other technologies. GSM/EDGE is, however, a more narrowband technology than WCDMA/HSPA and CDMA2000, implying that the peak data rates achievable are not as high. HSPA and CDMA2000 have,

[3]The first cellular technology to deploy higher-order modulation was iDEN, which uses "M-16QAM". It is, however, a proprietary technology and as such is not standardized.

however, added a time-division structure to make full use of advanced scheduling techniques for high-rate data services. Being a TDMA system, EDGE already has a time-division structure.

19.2.1 Objectives for GSM/EDGE Evolution

An evolved GSM/EDGE standard is developed in 3GPP based on a feasibility study for an "Evolved GSM/EDGE Radio Access Network (GERAN)" [100]. The objective is to improve service performance for GERAN for a range of services, including interactive best-effort services as well as conversational services including *voice-over IP*.

The Evolved GERAN is compatible with the existing GSM/EDGE in terms of frequency planning and coexistence with legacy terminals. It also reuses the existing network architecture (Figure 19.5) and has minimum impact on the BTS, BSC, and core network hardware. For the standardization of Evolved GERAN, a number of performance targets were set [100]:

- *Improved spectrum efficiency*. The target is a 50% increase in an interference-limited scenario (measured in kbit/s/MHz/cell for data or Erlang/MHz/cell for voice).
- *Increased peak data rates*. The target is a 100% increase in both downlink and uplink.
- *Improved coverage for voice and data*. The target is a sensitivity increase of 3 dB in downlink (noise-limited scenario).
- *Improved service availability*. The target is a 50% increase in mean data rate for uplink and downlink at cell edges (when cells are planned for voice).
- *Reduced latency*. The target is a *round-trip time* (RTT) of less than 450 ms for initial access and less than 100 ms after initial access (in non-ideal radio conditions, counting from the terminal to the GGSN and back, as shown in Figure 19.5).

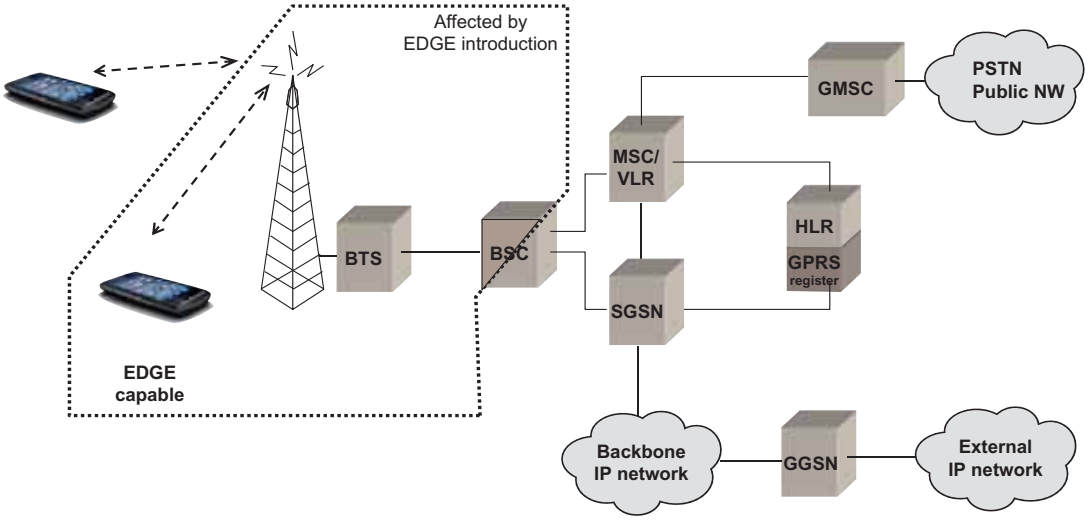


FIGURE 19.5

GSM/EDGE network structure.

A number of alternative solutions were studied in 3GPP to achieve the performance and compatibility targets listed above. These are not fundamentally different from the solutions selected for LTE or other technologies and are all described in a more general context in Chapters 2–6 of this book. The technologies chosen for standardization in 3GPP for GERAN Evolution were:

- Dual-antenna terminals
- Multi-carrier EDGE
- Reduced TTI and fast feedback
- Improved modulation and coding
- Higher symbol rates.

The specific application of these technologies to GERAN is discussed below. The solutions are included in release 7 of the GSM/EDGE specifications.

19.2.2 Dual-Antenna Terminals

As was shown in Chapter 5, multiple receiver antennas are an effective means against multipath fading and to provide an improved signal-to-noise ratio through "energy gain" when combining the antenna signals. There will thus be improvements for both interference-limited and noise-limited scenarios. There are also possibilities for interference cancellation through multiple antennas. While multiple antennas have an implementation impact for the terminal, there is no impact on the base-station hardware or software.

For GSM/EDGE, a dual-antenna solution called *Mobile Station Receive Diversity* (MSRD) is standardized. Analysis shows that a dual-antenna solution in GSM terminals can give a substantial coverage improvement of up to 6 dB. In addition, the dual-antenna terminals could potentially handle almost 10 dB more interference [79,101].

19.2.3 Multi-Carrier EDGE

The GSM radio interface is based on a TDMA structure with eight time slots and 200 kHz carrier bandwidth. To increase data rates, today's GPRS and EDGE terminals can use multiple time slots for transmission, reception, or both. Using 8PSK modulation (Figure 19.6) and assigning the maximum of eight time slots, the GSM/EDGE standard gives a theoretical peak data rate of close to 480 kbit/s. However, from a design and complexity point of view, it is best to avoid simultaneous transmission and reception. Today's terminals typically receive on a maximum of five time slots because they must also transmit (on at least one time slot) as well as measure the signal strength of neighboring cells.

To increase data rates further, multiple carriers for the downlink and the uplink can be introduced, similar to what is discussed in Chapter 2. This straightforward enhancement increases peak and mean data rates in proportion to the number of carriers employed. For example, given two carriers with eight time slots each, the peak data rate will be close to 1 Mbit/s. Using dual carriers can be seen as a straightforward extension of the multi-slot principle, allowing a multi-slot configuration to span more than one carrier. The limiting factor in this case is the complexity and cost of the terminal, which must have either multiple transmitters and receivers or a wideband transmitter and receiver. The use of multiple carriers has only a minor impact on base transceiver stations. A dual-carrier downlink solution is standardized in release 7 of the GSM/EDGE standard.

Petitioners' Exhibit 1003, p. 757
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

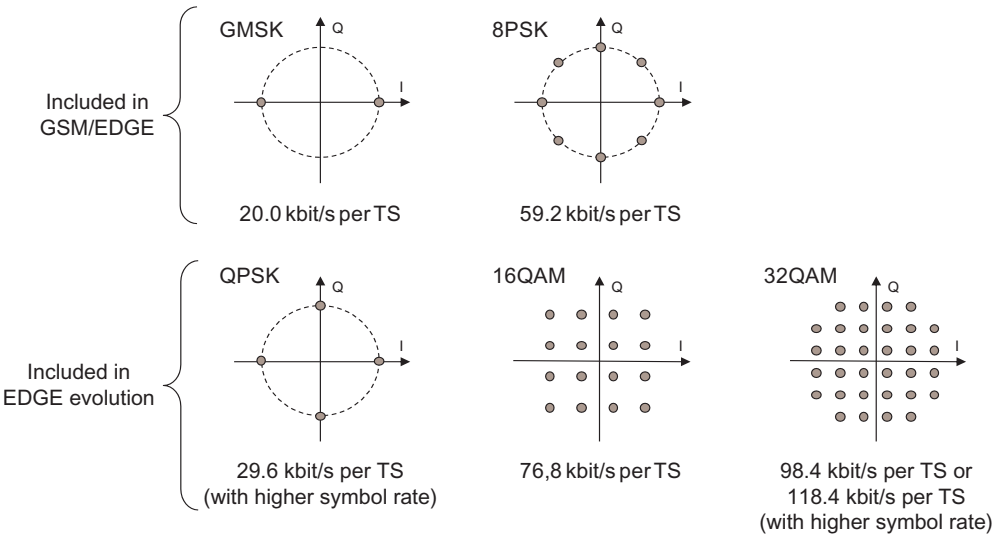


FIGURE 19.6

Existing and new modulation schemes for GSM/EDGE. The highest specified radio-interface data rate using GPRS is shown for each scheme [101]. Note that the view of the nonlinear binary GMSK scheme is simplified in the figure.

19.2.4 Reduced TTI and Fast Feedback

Latency is usually defined as the round-trip time over the radio-access network. It has a major influence on user experience, and conversational services such as voice and video telephony especially require low latency, but services such as web browsing and e-mail download are also improved considerably. A major parameter in the radio interface that has an impact on latency is the *Transmission Time Interval* (TTI), as discussed for LTE in Chapter 8. It is difficult to substantially improve latency without reducing the TTI.

The *round-trip time* (RTT) in GSM/EDGE networks can be 150 ms [101], including network delays but not retransmissions over the radio interface. Radio blocks are transmitted interleaved over four consecutive bursts on one assigned time slot over 20 ms. In GSM/EDGE evolution, a reduced TTI with radio blocks interleaved over four consecutive bursts assigned on *two time slots* in 10 ms is introduced. This reduction of the TTI from 20 to 10 ms can reduce the round-trip time from 150 to less than 100 ms [101]. Multiplexing of users with the two different interleaving schemes is also possible on the same RF carrier.

Faster responses to incorrectly received radio blocks speed up the retransmission of radio blocks and can also help in reducing the latency. In GSM/EDGE evolution, a fast ACK/NACK reporting mechanism is introduced to reduce time for the network to realize that a block is lost. ACK/NACK reports can also "piggy-back" on user data, which reduces the overhead. Combined with the shorter TTI, the total time to retransmit lost radio blocks is thus reduced significantly and the throughput is increased.

Petitioners' Exhibit 1003, p. 758
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

19.2.5 Improved Modulation and Coding

The main evolutionary step taken for GSM when EDGE was introduced was the higher-order modulation to enhance the data rates over the radio interface – Enhanced Data Rates for GSM Evolution. 16QAM was considered for EDGE, but 8PSK was finally chosen as a smooth evolutionary step that gives three bits per modulated symbol instead of one. This increases the peak data rate from approximately 20 to 60 kbit/s per time slot.

Figure 19.6 shows the further steps that are standardized for Evolved EDGE, giving 4 bits/symbol for 16QAM and 5 bits/symbol for 32QAM. Since the signal points in the new schemes move more closely together, they are more susceptible to interference. With more bits per symbol, however, the higher data rates allow for more robust channel coding, which can more than compensate for the increased susceptibility to interference. QPSK modulation with 2 bits/symbol is also included in Evolved GSM/EDGE, but used only with the higher symbol rate described below.

Both GSM and EDGE use convolutional codes, while Turbo codes are also standardized for Evolved EDGE. Decoding Turbo codes is more complex than regular convolutional codes. However, since Turbo codes are already used today for WCDMA and HSPA, and many terminals support both GSM/EDGE and WCDMA/HSPA, the decoding circuitry for Turbo codes already exists in the terminals and can be reused for EDGE.

Turbo codes perform well for large code-block sizes, making them better suited for higher data rate EDGE channels using 8PSK or higher-order modulation. It is estimated that, compared to the existing EDGE scheme with 8PSK modulation, the combination of Turbo codes and 16QAM improves the user data rates 30–40% for the median user in a system [100]. Turbo codes are standardized for the downlink in release 7 of GSM/EDGE.

19.2.6 Higher Symbol Rates

The modulation can also be improved by simply increasing the modulation symbol rate. As a part of GERAN Evolution in 3GPP, the combination of higher-order modulation and a 20% increase in symbol rate has been standardized [102]. For both uplink and downlink, two "levels" of terminal capabilities are defined, called Levels A and B. Each level defines a set of modulation schemes, where Level B also applies the higher symbol rate for some modulation schemes. Table 19.1 shows the combinations that are defined.

The higher symbol rate of 325 ksymbol/s will operate with the same nominal carrier bandwidth and carrier raster as legacy GERAN having 271 ksymbols/s, which puts some requirements on the

Table 19.1 Combinations of Modulation Schemes and Symbol Rates in GSM/EDGE Evolution

Terminal Capability	Symbol Rate (ksymbols/s)	Modulation Schemes
Uplink Level A	271	GMSK, 8PSK, 16QAM
Uplink Level B	271	GMSK
	325	QPSK, 16QAM, 32QAM
Downlink Level A	271	GMSK, 8PSK, 16QAM, 32QAM
Downlink Level B	271	GMSK
	325	QPSK, 16QAM, 32QAM

transmitter filter. The amount of transmitter filtering has to be weighed against the receiver complexity and performance, and the amount of interference in adjacent channels. An alternative wider Tx filter has been standardized for the uplink. A wider Tx filter is also studied for the downlink.

19.2.7 Voice Service over Adaptive Multi-User Channels

The focus of GSM/EDGE evolution has been improvements of the data services through higher spectral efficiency and increased peak data rates. At the same time, voice is still a predominant service for many operators and an improvement of voice performance is also desirable. Earlier improvements of voice capacity have mainly been in the voice coding area, where half-rate voice coding was a major step taken in earlier releases. There are eight time slots in the GSM TDMA frame structure, with one full-rate or two half-rate users occupying each slot.

For release 9 of the GERAN specification, multi-user channels on each time slot were investigated and a new mode called *Voice services over Adaptive Multi-user channels* (VAMOS) was introduced [103]. In VAMOS mode, *two* users are multiplexed on the same physical resource – that is, on the same frequency and TDMA time slot. The two users form a *VAMOS pair*, each user being mapped on one *VAMOS subchannel*. In the uplink, each subchannel is modulated with GSMK. In the downlink, a new *Adaptive Quadrature Phase-Shift Keying* (AQPSK) modulation scheme is used jointly for the two subchannels. The two subchannels in a VAMOS pair have different training sequences to facilitate joint demodulation of the two subchannels.

The AQPSK modulation scheme shown in Figure 19.7 is used in the downlink when both subchannels in a VAMOS pair have a burst scheduled for transmission. The bits from one subchannel in the VAMOS pair are mapped on the first bit that forms the QPSK constellation (corresponding to I) and the bits from the second user subchannel are mapped on the second bit (corresponding to Q). Depending on the choice of the parameter α, the power ratio between the two subchannels mapped on I and Q can be controlled, thereby providing partially independent power control of the two subchannels.

Use of the VAMOS mode was studied in detail by GERAN [103], with the conclusion that there is no harmful degradation of voice services for legacy users.

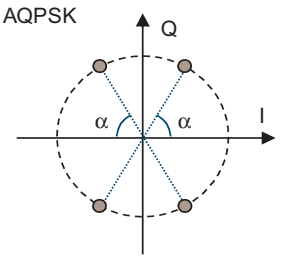


FIGURE 19.7

The AQPSK modulation scheme used in the downlink for two users forming a VAMOS pair.

19.3 CDMA2000 AND HRPD/1x EV-DO

CDMA2000 evolved as a cellular standard under the name IS-95 and later became a part of the IMT-2000 family of technologies described in Chapter 1. When it became a more global IMT-2000 technology, the name was changed to CDMA2000 and the specification work was moved from the *US Telecommunications Industry Association* (TIA) to 3GPP2. Being a sister organization to 3GPP, 3GPP2 is responsible for CDMA2000 specifications.

The CDMA2000 standard is going through an evolution similar to that of WCDMA/HSPA. In the different evolutionary steps, the same gradual shift of focus from voice and circuit-switched data to best-effort data and broadband data can be seen as for WCDMA/HSPA. The basic principles used are also very similar to those found in HSPA.

The evolutionary steps of CDMA2000 are shown in Figure 19.8. After the CDMA2000 1x standard was formed as an input to ITU for IMT-2000, two parallel evolutionary tracks were initiated for better support of data services. The first one was EV-DO (*Evolution-Data Only*),[4] which has continued to be the main track, as further described below. It is also called HRPD (*High-Rate Packet Data*). A parallel track was EV-DV (*Evolution for integrated Data and Voice*), developed to give parallel support of data and circuit-switched services on the same carrier. It is not used at the moment and has not been developed further within 3GPP2.

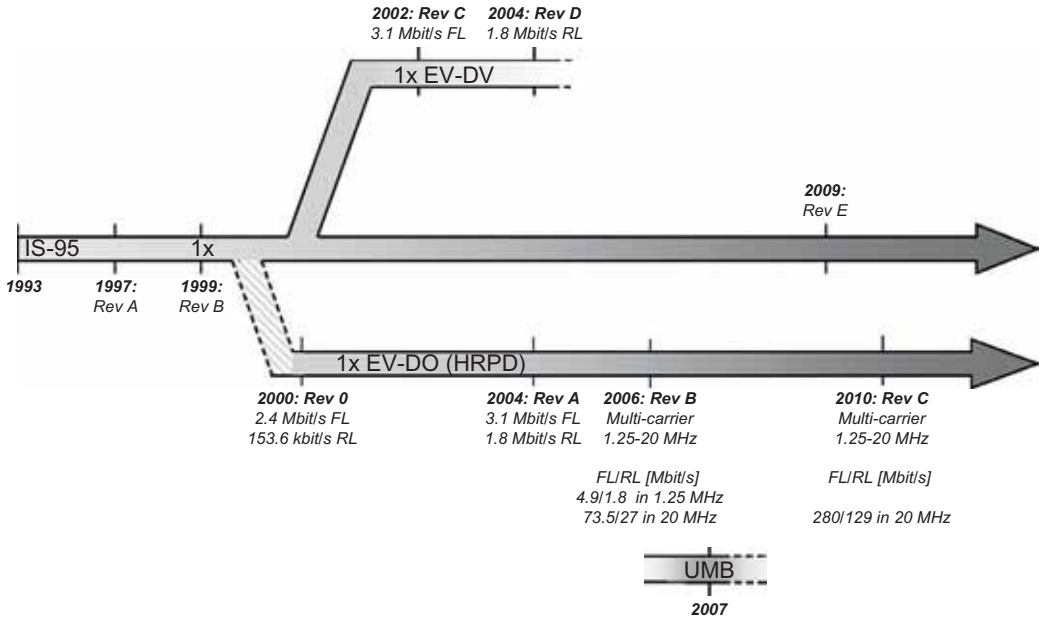


FIGURE 19.8

The evolution from IS-95 to CDMA2000 1x and 1x EV-DO.

[4]The abbreviation "DO" is also interpreted as "Data Optimized", since the EV-DO carrier targets data services.

The figure also illustrates UMB (*Ultra Mobile Broadband*), an OFDM-based standard including support for multi-antenna transmission and channel bandwidths up to 20 MHz. It is similar to LTE in terms of the technologies and features used, with one main difference that UMB uses OFDM in the uplink while LTE uses single-carrier modulation. UMB is not backwards compatible with CDMA2000. At the moment UMB is not used, and has not been developed further within 3GPP2, but some features from UMB, most notably the OFDM-based multi-antenna schemes, have subsequently been the basis for the corresponding features in EV-DO Rev C.

19.3.1 CDMA2000 1x

The CDMA2000 standard, which originally supported both a single-carrier (1x) and a multi-carrier (3x) mode, was adopted by ITU-R under the name IMT-2000 CDMA *Multi-Carrier* (MC) [2]. It offers several improvements over the earlier versions of IS-95 that give better spectral efficiency and higher data rates. The most important aspect from a 3G evolution perspective, however, is that 1x has been a platform for further evolution of packet-data modes, as shown in Figure 19.8. While 1x EV-DV is not undergoing any new development, 1x EV-DO is deployed today and is going through several new evolutionary steps in Rev 0, Rev A, Rev B, and Rev C that are described further below. While all steps up to Rev A are fundamentally based on direct sequence spread spectrum and a 1.25 MHz carrier bandwidth, Rev B and Rev C diverge from this by including wider carrier bandwidths and for Rev C also OFDM operation.

The 3x mode of CDMA2000 was never deployed in its original form, but was still an essential component of the submission of CDMA2000 to the ITU-R. However, multi-carrier CDMA is today once again included in the CDMA2000 evolution through EV-DO Rev B.

The 1x version of CDMA2000 (that is, not the EV-DO/HRPD track in Figure 19.8) has evolved into Rev E (the letters C and D were used for the EV-DV versions). Compared to Rev B, several small enhancements have been introduced in order to increase the voice capacity. Receiver requirements have also been defined to facilitate terminals simultaneously receiving circuit-switched voice call on one CDMA2000 carrier and packet data on EV-DO carriers.

19.3.2 1x EV-DO Rev 0

EV-DO Rev 0 defines a new uplink and downlink structure for CDMA2000 1x, where DO originally implied "*Data Only*". The reason is that an EV-DO carrier has a structure optimized for data that does not support the voice and circuit-switched data services of a CDMA2000 1x carrier. In this way, the whole carrier works as a shared downlink resource for data transmission. An operator would deploy an additional carrier for EV-DO, thereby separating circuit-switched and packet-switched connections on different carriers. A drawback is reduced flexibility in that there cannot be a simultaneous packet-data and legacy circuit-switched service (such as voice) to the same user on one carrier. 1x EV-DO has later also been named HRPD (*High-Rate Packet Data*).

With EV-DO Rev 0, a peak data rate of 2.4 Mbit/s is supported in the downlink on a 1.25 MHz carrier. There are several components in EV-DO Rev 0, several of which have similarities with the HSPA evolution described in Section 19.1:

- *Shared-channel transmission*. EV-DO Rev 0 has a *Time-Division Multiplexing* (TDM) downlink, with transmission to only one user at the time with the full power of the Base Station (BS). This makes the downlink a resource that is shared between the users in the time domain only. This is

Petitioners' Exhibit 1003, p. 762
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

similar to the "shared-channel transmission" for HSPA, with the difference that HSPA can also share the downlink in the code domain, primarily with non-HSPA users.

- *Channel-dependent scheduling*. The adaptive data scheduler of EV-DO Rev 0 takes into account fairness, queue sizes, and measures of the channel state. It thereby exploits multi-user diversity in fading channels in a way similar to the channel-dependent scheduling used in HSPA.
- *Short TTI*. The TTI is reduced from 20 ms in CDMA2000 to 1.67 ms in EV-DO Rev 0. This is important to enable fast channel-dependent scheduling and rapid retransmissions, also resulting in lower latency. The TTI for EV-DO Rev 0 is thereby of the same order as the 2 ms TTI used for HSPA.
- *Rate control*. EV-DO Rev 0 employs rate control through adaptive modulation and coding, thereby maximizing the throughput for a given channel condition. This is similar to HSPA, but an EV-DO base station follows the rate request from the mobile, while in HSPA the feedback is a recommendation and the NodeB takes the final decision.
- *Higher-order modulation*. EV-DO Rev 0 supports 16QAM modulation in the downlink, which is similar to the first HSPA release.
- *Hybrid ARQ*. The EV-DO Hybrid-ARQ scheme is similar to the scheme used for HSPA.
- *Virtual SOHO*. EV-DO Rev 0 does not use soft handover in the downlink like CDMA2000. Instead, the terminal supports "virtual soft handover" via adaptive server selection initiated by the terminal, which can be seen as fast cell selection within the "active set" of base stations. These server changes may result in some packet transmission delays [104].
- *Receive diversity in the mobile*. EV-DO Rev 0 has terminal performance numbers specified assuming receive diversity, similar to performance requirements specified for HSPA advanced receivers.

19.3.3 1x EV-DO Rev A

The next step in the evolution of CDMA2000 is 1x EV-DO Rev A. The focus is on an uplink improvement similar to the enhanced uplink of HSPA, but it also includes an updated downlink, a more advanced quality-of-service handling, and an add-on multicast mode [104].

The downlink of EV-DO Rev A is based on the EV-DO Rev 0 downlink, with the following differences:

- *Higher peak rates*. EV-DO Rev A downlink supports 3.1 Mbit/s as compared to the 2.4 Mbit/s of EV-DO Rev 0. Rev A also offers a finer quantization of data rates.
- *Shorter packets*. New transmission formats for EV-DO Rev A enable 128-, 256-, and 512-bit packets. This, together with new multi-user packets, where data to multiple terminals share the same packet in the downlink, improves support for lower-rate, delay-sensitive services.

The major enhancements in EV-DO Rev A compared to Rev 0 are in the uplink. This results in a more packet-oriented uplink with higher capacity and data rates. Peak uplink data rates of up to 1.8 Mbit/s are supported:

- *Higher-order modulation*. In addition to BPSK modulation in EV-DO Rev 0, the uplink physical layer of Rev A supports QPSK and optionally 8PSK modulation.
- *Hybrid ARQ*. Improved performance is achieved through an uplink hybrid ARQ scheme, similar to HSPA.
- *Reduced latency*. The use of smaller packet sizes and a shorter TTI enables a reduced latency of up to 50% compared to EV-DO Rev 0 [105].

Petitioners' Exhibit 1003, p. 763
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- *Capacity/latency trade-off*. Each packet can be transmitted in one of two possible transmission modes: *LoLat* gives low latency through a higher power level, ensuring that the packet is received within the latency target, while *HiCap* gives higher total capacity by allowing for more retransmissions and lower transmit power levels. A similar effect can be obtained in HSPA through different HARQ profiles [96].

19.3.4 1x EV-DO Rev B

The next step for the 1x EV-DO series of standards is Rev B, which enables higher data rates by aggregation of multiple carriers. This fundamental way of increasing the data rate is also discussed in Chapter 2. Rev B permits up to sixteen 1.25 MHz carriers to be aggregated, forming a 20 MHz wide system [106], and giving a theoretical peak data rate of up to 46.5 Mbit/s in the downlink. For reasons of cost, size, and battery life, Rev B devices will most likely support up to three carriers [105], giving a peak downlink data rate of 9.3 Mbit/s.

The lower layers of the radio interface are similar to and compatible with those in Rev A, making it possible for both single-carrier Rev 0 and Rev A terminals to function on a Rev B network that supports multi-carrier operation.

Carriers do not have to be symmetrically allocated in the uplink and the downlink. For asymmetric applications such as file downloads, a larger number of carriers can be set up for downlink than for uplink. This reduces the amount of overhead for the uplink transmission. One uplink channel can carry feedback information for multiple forward link channels operating on multiple downlink carriers to a single terminal in asymmetric mode.

19.3.5 1x EV-DO Rev C

The latest step in the evolution of 1x EV-DO is Rev C, which introduces both smaller software-based enhancements as well as larger enhancements requiring hardware modifications.

The major new features in Rev C are inclusion of OFDM and support for spatial multiplexing. OFDM is supported in the forward link only. A subcarrier spacing of 6.8 kHz is used, resulting in an OFDM symbol duration of 162.76 μs including a cyclic prefix of 16.28 μs. OFDM- and CDMA-based transmissions are time multiplexed to support Rev C and legacy terminals on the same carrier.

Spatial multiplexing supports up to four transmission layers in the forward link. Forward-link spatial multiplexing is only supported in conjunction with OFDM. In the reverse link, which only supports CDMA-based transmission, up to two layers are supported together with codebook-based precoding under control of the base station. Higher-order modulation in the reverse link has been increased to 64QAM.

19.4 IEEE 802.16E, MOBILE WiMAX AND 802.16m

The IEEE 802.16 family of radio-access technologies is developed by IEEE, initially targeting fixed wireless access applications but later being extended to also support mobility, thus providing a radio-access technology that can be used to offer mobile-data/broadband services.

The initial 802.16 specification was designed for line-of-sight operation in the 10–60 GHz frequency range. The next revision, 802.16a, introduced support for non-line-of-sight operation with focus on the 2–11 GHz frequency range, but still targeting the fixed-wireless-access application. Support for mobility was introduced as part of IEEE 802.16e, finalized in December 2005. 802.16e

Petitioners' Exhibit 1003, p. 764
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

is the basis for all currently commercial mobile-data networks based on the 802.16 technology. Part of 802.16e has also, at a relatively late stage (2007), been approved by the ITU as an additional IMT-2000 technology in parallel with WCDMA/HSPA, TD-SCDMA, and CDMA2000/1xEV-DO. The 802.16e-based IMT-2000 technology is only supporting TDD operation and is, in the ITU, referred to as *IMT-2000 OFDMA TDD WAN*.

The latest step taken within the IEEE 802.16 community is the development of the 16 m version of the specification (IEEE 802.16 m), a key goal of which was to ensure compliance with the ITU requirements on IMT-Advanced [65]. In October 2010, 802.16 m was approved by the ITU as a second IMT-Advanced-compliant technology under the name *WirelessMAN-Advanced*, in parallel with LTE/LTE-Advanced.

The IEEE 802.16 specifications cover only the physical and MAC layers of the overall protocol stack, with no definition of higher layers. Furthermore, the 802.16 specifications contain an extremely large set of different features, often serving essentially the same purpose but doing it in different ways, including even multiple alternatives for the basic physical-layer transmission scheme. Including all these options and alternative features in a mobile terminal is not feasible. Thus, it is generally accepted that the 802.16 specifications in themselves do not provide a complete and implementable specification for a mobile-communication system.

The *WiMAX forum* is an industry-led, non-profit cooperation formed to promote and certify compatibility and interoperability of 802.16-based products. As part of this, the WiMAX forum selects the set of features, from the full set of features specified by the IEEE, that should be included in any equipment that conforms to the different *WiMAX System Profiles*. The first such profile, System Profile Release 1.0, was published in 2007, with the second profile, System Profile Release 1.5, finalized in 2009. System Profile Release 2.0 corresponds to the 802.16 m specifications currently under development.

The system profiles for 802.16e developed by the WiMAX forum are also, jointly, often referred to as Mobile WiMAX or just WiMAX.

19.4.1 IEEE 802.16e and Mobile WiMAX

Although IEEE 802.16 includes several alternatives for the basic physical-layer transmission scheme, including both OFDM and single-carrier transmission, Mobile WiMAX is based on OFDM transmission supporting different bandwidths for both uplink and downlink. In contrast to LTE, which is based on a single numerology for all transmission bandwidths, different bandwidths of 802.16e may correspond to partly different numerology, including different subcarrier spacing. However, the main focus of Mobile WiMAX has been on the 5 and 10 MHz bandwidths,[5] both corresponding to a subcarrier spacing $\Delta f \approx 10.94$ kHz and only differing in the number of subcarriers within the transmission bandwidth. Note that, although wider bandwidths are supported by the 802.16e specifications, 10 MHz is the maximum transmission bandwidth supported by the current Mobile WiMAX profiles.

802.16e includes support for both TDD and FDD operation, including the possibility for half-duplex FDD (see Chapter 9 for a discussion on half-duplex FDD in the context of LTE). However, WiMAX has mainly focused on the TDD mode of operation. In particular, TDD was the only duplex operation supported by the first WiMAX release (1.0). Also, as already mentioned, the WiMAX/802.16e-based

[5] There are additional bandwidths supported by Mobile WiMAX, more specifically 3.5, 7.5, and 8.75 MHz.

Petitioners' Exhibit 1003, p. 765
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

IMT-2000 standard only supports TDD operation. This overview will therefore focus on the TDD mode of operation for Mobile WiMAX.

As illustrated in Figure 19.9, in the time domain, a 5 ms frame[6] is divided into two parts, a downlink part and an uplink part, together consisting of 48 OFDM symbols.[7] With one symbol used as preamble, there is a maximum of 47 symbols available for downlink and uplink transmission. These symbols can be assigned for downlink and uplink transmission respectively, by means of a number of defined downlink/uplink configurations, ranging from 32:12 (35 downlink symbols and 12 uplink symbols) to 26:21 (26 downlink symbols and 21 uplink symbols). This only leaves a very small time available for downlink/uplink switching. If additional switching time is needed, for example to handle large cells, one can simply discard a number of symbols at the end of the downlink part of the frame.

Downlink control signaling for scheduling and hybrid-ARQ operation is transmitted at the beginning of the downlink part. Hence, unlike LTE, where such control signaling can be provided in each downlink subframe, in 802.16e such control signaling can be provided once per 5 ms frame only. Hybrid ARQ with soft combining is also supported both in 802.16 and by Mobile WiMAX. However, in contrast to HSPA and LTE, the first Mobile WiMAX releases only support Chase combining and not incremental redundancy.

Similar to LTE, 802.16e and Mobile WiMAX supports QPSK, 16QAM, and 64QAM[8] data modulation, providing spectral efficiency up to 6 bit/s/symbol. Also similar to LTE, adaptive modulation and coding ("link adaptation") can be used to adjust the modulation scheme and coding rate, and thus the data rate, to match the instantaneous channel conditions. The 802.16e specifications support a range of channel coding schemes, including both Turbo codes, similar to HSPA and LTE, and so-called LDPC codes [53]. However, LDPC codes are not supported in current Mobile WiMAX releases.

802.16e allows for mapping of data to the basic OFDM time–frequency grid in different ways to achieve diversity either by means of resource allocations that spread the coded information in the frequency domain, or optimization for channel-dependent scheduling and link adaptation by concentrating the transmission in the frequency domain. The different resource assignment schemes can be used

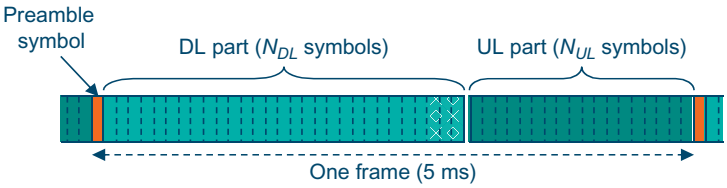


FIGURE 19.9

Basic frame structure for IEEE802.16e/Mobile WiMAX (N_{DL}:N_{UL} = 29:18).

[6]Additional frame lengths are specified in 802.16e. However, 5 ms is the only frame length included in the Mobile WiMAX profiles.

[7]This assumes a cyclic-prefix length of approximately 11.4 μs. The 802.16e specifications include both larger and smaller cyclic-prefix lengths, corresponding to somewhat less/more OFDM symbols within a 5 ms frame. However, these cyclic-prefix lengths are not part of the Mobile WiMAX system profiles.

[8]64QAM for the uplink is not supported/mandatory in the first Mobile WiMAX releases.

within the same subframe by dividing the subframe into different time-domain regions or "zones". Uplink channel-dependent scheduling was not part of the first release of Mobile WiMAX but was added in later releases.

A wide range of multi-antenna transmission schemes are included in 802.16e. Already since the first release (1.0), Mobile WiMAX has included a subset of these, more specifically open-loop spatial multiplexing. Later releases have introduced additional multi-antenna transmission techniques for both downlink and uplink.

19.4.2 IEEE 802.16m – WiMAX for IMT-Advanced

The work on 802.16m was initiated with the aim to extend the family of 802.16 radio-access technologies and ensure fulfillment of the IMT-Advanced requirements defined by the ITU.

In contrast to LTE-Advanced being an evolution of LTE release 8/9, 802.16m is not a direct evolution of 802.16e, adding new complementary features to extend the performance and capabilities of the radio-access technology. Rather, 802.16m is, in many respects, a new radio-access technology although retaining several of the basic characteristics of 802.16e, including the basic OFDM numerology. This also implies that 802.16e and 802.16m can coexist on the same carrier by means of time multiplexing the two radio-access technologies within the 802.16e 5 ms frame structure. In contrast, earlier releases of LTE are included as integrated parts of LTE release 10, providing a more straightforward backwards compatibility and support of legacy terminals, for example.

Technology wise, 802.16m introduces many features similar to LTE release 10, including the use of multi-carrier transmission (carrier aggregation) for bandwidths beyond 20 MHz and support for relaying functionality.

802.16m also introduces substantially shorter subframes of length roughly 0.6 ms to reduce hybrid-ARQ round-trip time and, in general, allow for reduced latency over the radio interface.

Regarding the resource assignment, 802.16m does not support the resource mapping schemes specified for 802.16e.[9] Rather, 802.16m introduces *physical resource units* consisting of a number of frequency-contiguous subcarriers during one subframe, very similar to the LTE resource blocks. Actually, the number of subcarriers in a resource unit equals 18 which, together with the subcarrier spacing of 10.94 kHz, results in a resource unit with a bandwidth that is very similar to the LTE resource-block bandwidth of 180 kHz. Above the physical resource units are *logical resource units* that can be distributed or localized, where distributed resource units are used for cases when frequency diversity is used. Once again, this is very similar to LTE localized and distributed resource mapping, as described in Chapter 10.

Taking into account the many similarities between LTE and 802.16m, it is not surprising that performance evaluations indicate similar performance of the two radio-interface technologies. Thus, similar to LTE, 802.16m also fulfils all the requirements for IMT-Advanced as defined by the ITU.

As already mentioned, 802.16m was approved by the ITU in October 2010, as a second IMT-Advanced-compliant technology under the name WirelessMAN-Advanced. Thus, similar to LTE, IEEE 802.16m can also be seen as a fully compliant 4G technology.

[9] They can, of course, be supported on a 802.16m carrier as part of 802.16e/802.16m time multiplexing.

Petitioners' Exhibit 1003, p. 767
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

19.5 SUMMARY

The IMT-2000 technologies and the other technologies introduced above are developed in different standardization bodies, but all show many commonalities. The reason is that they target the same type of application and operate under similar conditions and scenarios. The fundamental constraints for achieving high data rates, good quality of service, and system performance will require that a set of efficient tools are applied to reach those targets.

The technologies described in Chapters 2–6 of this book form a set of such tools and it turns out that many of these are applied across most of the technologies discussed here. To cater for high data rates, different ways to transmit over wider bandwidth is employed, such as single- and multi-carrier transmission including OFDM, often with the addition of higher-order modulation. Multi-antenna techniques are employed to exploit the "spatial domain", using techniques such as receive and transmit diversity, beam-forming, and multi-layer transmission. Most of the schemes also employ dynamic link adaptation and scheduling to exploit variations in channel conditions. In addition, coding schemes such as Turbo codes are combined with advanced retransmission schemes such as hybrid ARQ.

As mentioned above, one reason that solutions become similar between systems is that they target similar problems for the systems. It is also true to some extent that some technologies and their corresponding abbreviations go in and out of "fashion". Most 2G systems were developed using TDMA, while many 3G systems are based on CDMA and the evolution towards 4G is based on OFDM. Another reason for this stepwise shift of technologies is of course that as technology develops, more complex implementations are made possible. A closer look at many of the evolved wireless communication systems of today also shows that they often combine multiple techniques from previous steps, and are built on a mix of TDMA, OFDM, and spread spectrum components.

Petitioners' Exhibit 1003, p. 768
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CHAPTER

Final Thoughts 20

The focus of this book has been on the LTE radio-access technology, from the first version in release 8, via release 9 to release 10. LTE release 10 is the latest version of the LTE radio-access specifications, sometimes also referred to as *LTE-Advanced* and approved by the ITU as the first *IMT-Advanced* technology.

The basic technologies described in Chapters 2–6 served as a foundation for the detailed discussion and explanation of the LTE radio-access technology in the subsequent chapters, providing information about the LTE radio-network architecture, the basic transmission structure, and all the protocols and procedures needed for a complete radio-access network.

The capabilities and system performance of LTE were illustrated in Chapter 18 and it was shown that all the requirements defined by the ITU for IMT-Advanced were fulfilled, in many cases by a significant margin.

At the same time as ITU-R is completing the work on the formal IMT-Advanced recommendations, activities are initiated to look at what will come beyond IMT-Advanced in the 2012–2020 time frame. Several regional workshops on "*IMT for the 2010–2020 Decade"* are planned for 2011 and a new report looking at global broadband wireless services and marketplace for IMT has been initiated within ITU-R WP5D. The basis for the continued work is that future mobile broadband consumers will expect similar user experience and access to similar services and applications in the mobile environment as for fixed broadband, with the added convenience of mobility. Studies within ITU-R will include long-term market forecasts and take into account new user behavior, specifically considering personal computers and smart phones.

20.1 WHERE TO GO IN THE FUTURE?

The evolution of LTE does not end with LTE release 10. Rather LTE will continue to evolve into release 11, release 12, and so on, with each new release bringing additional capabilities and further enhanced system performance into the LTE radio-access technology. Not only will the additional capabilities provide better performance in existing applications, they may also open up for, or even be motivated by, new application areas. Examples hereof are home automation, smart transportation, security, and e-books, but the list is continuously growing as additional applications benefiting from mobile connectivity are emerging. Similarly, new ways of deploying cellular networks, for example more extensive use of massive beam-forming or ubiquitous access to optical fibers in the backhaul, may call for enhancements in the radio interface.

4G LTE/LTE-Advanced for Mobile Broadband.
© 2011 Erik Dahlman, Stefan Parkvall & Johan Sköld. Published by Elsevier Ltd. All rights reserved.

Petitioners' Exhibit 1003, p. 770
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Initial 3GPP discussions on release 11 have already started, with actual work expected to be initiated in early 2011, aiming for completion of this release in mid-2012. In the following, some possible areas for the future evolution of LTE will be briefly discussed. Some of these areas may happen in release 11 or 12, while others may be more futuristic.

20.1.1 Advanced Multi-Cell Coordination

Coordinated Multi-Point transmission and reception (CoMP) refers to a wide range of different techniques with the common denominator being the dynamic coordination of transmission and/or reception at multiple geographically separated sites with the aim to enhance system performance and end-user service quality. Many different coordination schemes of very different characteristics fall under the joint umbrella of CoMP, ranging from dynamic inter-cell scheduling coordination to joint transmission/reception at multiple sites. In the former case, CoMP can, to a large extent, be seen as an extension of the inter-cell interference coordination that is already part of LTE, discussed in Chapter 13.

Joint reception means that the signals received at multiple sites are jointly processed for enhanced reception performance. Maximum-ratio combining and interference-rejection combining are examples of schemes that can be used to combine the uplink transmission received at multiple points. This is, in many respects, similar to softer handover used within a site, for example in WCDMA/HSPA-based systems, but extended to multiple sites.

Joint transmission implies that data is transmitted to a mobile terminal jointly from several sites, thereby not only reducing the interference but also increasing the received power. The transmission from the sites can also take the instantaneous channel conditions at the different terminals into account to enhance the received signal strength, while at the same time reducing the interference between different transmissions.

In general, both joint reception and transmission pose high requirements on low latency in the communication between the network node involved in the joint processing and the different antennas involved in the reception/transmission. Hence, in practice, it can be expected that the different sites may be connected in the form of a *centralized RAN* (C-RAN) deployment for example, as briefly discussed in Chapter 13.

20.1.2 Network Energy Efficiency

Low energy consumption for mobile terminals has been an important requirement ever since the emergence of hand-held terminals roughly 20 years ago. The driving force has been the reduction in battery size and improved battery time. Today, reduced energy consumption *also in the radio-access network* is receiving increased attention for several reasons:

- The cost of energy is a far from negligible part of the overall operational cost for the operator. Thus, reduced energy consumption is one component in the everlasting quest for reduced operating costs for network operators.
- In some rural areas, it may not even be possible to connect the base station to the electrical grid. With sufficiently low energy consumption, reasonably sized solar panels could be used as power source, instead of the diesel generators commonly used today.

Petitioners' Exhibit 1003, p. 771
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- In today's world, where energy consumption and the related climate impact is seen as one of the great challenges for the future, the mobile industry should lead the way for reduced energy consumption.

Regarding the third point, it is important to bear in mind though that the entire ICT (*Information and Communication Technologies*) sector today (2010) contributes roughly 2% of the overall world energy consumption and the contribution of the mobile-communication sector is just a fraction of that. At the same time, the emergence of mobile broadband communication opens up tremendous opportunities for reducing the global energy consumption in general by, for example, virtual meetings replacing traveling to physical meetings.

Still, low energy consumption in mobile networks is important. In particular, taking into account large future traffic increases, where traffic growth of several hundred times up to perhaps 1000 times can be expected in a longer-term perspective, low energy consumption of the mobile networks will most likely be as important a performance metric as capacity, data rates and latency, and must be treated as such.

Reducing the energy consumption of mobile networks is, to a large extent, an implementation issue. However, it is important to ensure that the basic principles of the radio-access technology allows for low energy consumption. One key characteristic is that the energy consumption should scale with the use of the radio resources, not only on average but also on a short-term basis. That is, during points in time where there is no traffic, the energy consumption should be reduced to an absolute minimum, for example by avoiding all but absolutely necessary transmissions. LTE already provides several tools that can be used for this. Nevertheless, the future evolution of LTE should further strive for minimizing transmission of signals strictly not needed.

This will be even more important as the network becomes more and more dense with more and more network nodes. In such network deployments, which may typically be heterogeneous networks as discussed in Chapter 13, pico cells may often be deployed to provide high data rates, rather then being needed for capacity reasons. Thus, the load per cell may be relatively low and each pico cell may often be more or less "empty", further stressing the importance of very low energy consumption when idle.

20.1.3 Machine-Type Communication

Similar to earlier mobile-communication systems, LTE has been designed with data services in mind and much effort has been put into developing techniques for providing high data rates and low latencies for services such as file downloading and web browsing. However, with the increased availability of mobile broadband, connectivity has also become a realistic option for machine-type communication. Machine-type communication spans a wide range of applications, from massive deployment of low-cost battery-powered sensors to remote-controlled utility meters, to surveillance cameras. Many of these applications can be handled by LTE already; communicating with a surveillance camera, for example, is not significantly different from uploading a file, in which case high data rates are paramount. However, other applications may not require transmission of large amounts of data or low latency, but rather pose challenges in terms of a vast amount of devices connecting to the network.

Petitioners' Exhibit 1003, p. 772
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

According to some sources [107], 50 billion connections, most of them machine-type communications, can be expected in the year 2020. Handling such a large number of devices is likely to be a challenge mainly for the core network, but improvements in the area of connection setup and power-efficient handling of control signaling in the radio-access network may be of interest.

20.1.4 New ways of Using Spectrum

Spectrum has been, is, and will continue to be a scarce resource for the mobile-communication industry. In particular, in light of the continuous increase in the data rates requested and the corresponding need for wider bandwidths, it is expected that spectrum will remain a scarce resource.

Historically, up until now, the mobile industry has relied on spectrum dedicated for mobile communication and licensed to a certain operator. This will also clearly be the main track for the future. However, in situations where licensed spectrum is not available, other possibilities for increasing the spectrum availability are of interest. This could include the use of unlicensed spectrum, or secondary spectrum primarily used for other communication services, as a complement to operation in the licensed spectrum. Broadcast spectrum not used (in some areas) is often referred to as "white space" [108]. Related to this is the concept of *cognitive radio* [109,110] – that is, radio-access-related functionality related to "smart" selection of spectrum usage. However, the applicability of cognitive radio to cellular communication is a relatively new area and further studies are required to assess the feasibility and impact of such usage.

20.1.5 Direct Device-to-Device Communication

One possible longer-term evolution path would be to extend the LTE radio-access technology with support for direct device-to-device communication – that is, make it possible for two mobile terminals to communicate directly with each other without going via the network. This has been studied in academia for some years, for example as part of the European research project WINNER [111]. Scenarios where the possibility for direct device-to-device communication could be of interest include situations where no network infrastructure is available, for example national security and public safety (NSPS), and situations where network infrastructure is available but when communication directly between the terminals could be more efficient, either in terms of requiring a smaller amount of radio resources for the same communication quality or allowing for improved communication quality. In the latter case, one could envision different degrees of network interaction in the device-to-device communication. However, this area is still in its infancy and scenarios where device-to-device communication offers benefits and how to interact with infrastructure-based communication need to be better understood.

Related to device-to-device communication is the possibility to also use LTE as a radio-access technology in the home, for example a digital camera connecting to the TV. Although such connectivity is possible to some extent today by using (semi-proprietary) technology, basing this type of communication on LTE could be attractive. When outside the home, the devices can communicate with the cellular LTE network, but while at home they can seamlessly connect to the local LTE network covering the home. Furthermore, for devices that are to be used at home only, operation without a SIM card and interaction with an external core network should be possible. Adding this type of functionality to LTE is most likely a relatively simple task.

Petitioners' Exhibit 1003, p. 773
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

20.2 CONCLUDING REMARKS

The list of technology areas above should be seen as examples. Some of these technologies will most likely be part of future releases of LTE, while others may not happen at all. There may also be other technologies, not listed above and maybe yet to be discovered, that could be of interest for LTE evolution. What is clear though is that LTE is a very flexible platform that can evolve in different directions to meet the future needs of wireless communication. Given the size of the LTE ecosystem, such evolution is a very attractive path for future wireless communication.

Petitioners' Exhibit 1003, p. 774
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

References

[1] ITU-R, International mobile telecommunications-2000 (IMT-2000), Recommendation ITU-R M.687-2, February 1997.

[2] ITU-R, Detailed specifications of the radio interfaces of international mobile telecommunications-2000 (IMT-2000), Recommendation ITU-R M.1457-9, May 2010.

[3] ITU-R, Principles for the process of development of IMT-advanced, Resolution ITU-R 57, October 2007.

[4] ITU-R, Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000, Recommendation ITU-R M.1645, June 2003.

[5] ITU-R, Invitation for submission of proposals for candidate radio interface technologies for the terrestrial components of the radio interface(s) for IMT-advanced and invitation to participate in their subsequent evaluation, ITU-R SG5, Circular Letter 5/LCCE/2, March 2008.

[6] ITU-R, ITU paves way for next-generation 4G mobile technologies; ITU-R IMT-advanced 4G standards to usher new era of mobile broadband communications, ITU Press Release, 21 October 2010.

[7] ITU-R, Working document towards a preliminary draft new recommendation ITU-R M.[IMT. RSPEC] ITU-R WP5D, Contribution 870, Attachment 5.11.

[8] ITU-R, Frequency arrangements for implementation of the terrestrial component of international mobile telecommunications-2000 (IMT-2000) in the bands 806–960 MHz, 1710–2025 MHz, 2110–2200 MHz and 2500–2690 MHz, Recommendation ITU-R M.1036-3, July 2007.

[9] M. Olsson, S. Sultana, S. Rommer, L. Frid, C. Mulligan, SAE and the Evolved Packet Core – Driving the Mobile Broadband Revolution, Academic Press, 2009.

[10] 3GPP, 3rd generation partnership project; Technical specification group radio access network; Requirements for Evolved UTRA (E-UTRA) and Evolved UTRAN (E-UTRAN) (Release 7), 3GPP TR 25.913.

[11] C.E. Shannon, A mathematical theory of communication, Bell System Tech. J. 27 (July and October 1948) 379–423, 623–656.

[12] J.G. Proakis, Digital Communications, McGraw-Hill, New York, 2001.

[13] G. Bottomley, T. Ottosson, Y.-P. Eric Wang, A generalized RAKE receiver for interference suppression, IEEE J. Sel. Area Comm. 18 (8) (August 2000) 1536–1545.

[14] WiMAX Forum, Mobile WiMAX – Part I: A technical overview and performance evaluation, White Paper, August 2006.

[15] ETSI, Digital video broadcasting (DVB): Framing structure, channel coding and modulation for digital terrestrial television, ETS EN 300 744 v. 1.1.2.

[16] NTT DoCoMo et al., Views on OFDM parameter set for evolved UTRA downlink, Tdoc R1-050386, 3GPP TSG-RAN WG 1, Athens, Greece, 9–13 May 2005.

[17] L. Hanzo, M. Munster, B.J. Choi, and T. Keller, OFDM and MC-CDMA for broadband multi-user communications, WLANs, and broadcasting, Wiley-IEEE Press, Chichester, UK, ISBN 0-48085879.

Petitioners' Exhibit 1003, p. 776
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

[18] R. van Nee, R. Prasad, OFDM for Wireless Multimedia Communications, Artech House Publishers, London, January 2000.
[19] J. Tellado and J.M. Cioffi, PAR reduction in multi-carrier transmission systems, ANSI T1E1.4/97-367.
[20] P.V. Etvalt, Peak to average power reduction for OFDM schemes by selective scrambling, Electron. Lett. 32 (21) (October 1996) 1963–1964.
[21] W. Zirwas, Single frequency network concepts for cellular OFDM radio systems, International OFDM Workshop, Hamburg, Germany, September 2000.
[22] A. Oppenheim, R.W. Schafer, Digital Signal Processing, Prentice-Hall International, ISBN 0-13-214107-8 01.
[23] S. Haykin, Adaptive Filter Theory, Prentice-Hall International, NJ, USA, 1986. ISBN 0-13-004052-5 025.
[24] D. Falconer, S.L. Ariyavisitakul, A. Benyamin-Seeyar, B. Eidson, Frequency domain equalization for single-carrier broadband wireless systems, IEEE Commun. Mag. 40 (4) (April 2002) 58–66.
[25] G. Forney, Maximum likelihood sequence estimation of digital sequences in the presence of intersymbol interference, IEEE T. Inform. Theory IT-18 (May 1972) 363–378.
[26] G. Forney, The viterbi algorithm, Proceedings of the IEEE, Piscataway, NJ, USA, Vol. 61, No. 3, March, 1973, 268–278.
[27] Motorola, Comparison of PAR and Cubic Metric for Power De-rating, Tdoc R1-040642, 3GPP TSG-RAN WG1, May 2004.
[28] U. Sorger, I. De Broeck, M. Schnell, IFDMA – A new spread-spectrum multiple-access scheme, Proceedings of the ICC'98, Atlanta, GA, USA, June 1998, pp. 1267–1272.
[29] W. Lee, Mobile Communications Engineering, McGraw-Hill, New York, USA, ISBN 0-07-037039-7.
[30] J. Karlsson, J. Heinegard, Interference rejection combining for GSM, Proceedings of the 5th IEEE International Conference on Universal Personal Communications, Cambridge, MA, USA, 1996, pp. 433–437.
[31] L.C. Godara, Applications of antenna arrays to mobile communications, Part I: Beam-forming and direction-of-arrival considerations, Proceedings of the IEEE, Vol. 85, No. 7, July, 1997, 1029–1030.
[32] L.C. Godara, Applications of antenna arrays to mobile communications, Part II: beam-forming and direction-of-arrival considerations, Proceedings of the IEEE, Piscataway, Vol. 85, No. 7, July, 1997, 1031–1060.
[33] A. Huebner, F. Schuehlein, M. Bossert, E. Costa, H. Haas, A simple space–frequency coding scheme with cyclic delay diversity for OFDM, Proceedings of the 5th European Personal Mobile Communications Conference, Glasgow, Scotland, April 2000, pp. 106–110.
[34] 3GPP, 3rd generation partnership project; technical specification group radio access network; Physical Channels and Mapping of Transport Channels onto Physical Channels (FDD), 3GP TS 25.211.
[35] V. Tarokh, N. Seshadri, A. Calderbank, Space–time block codes from orthogonal design, IEEE T. Inform. Theory 45 (5) (July 1999) 1456–1467.
[36] A. Hottinen, O. Tirkkonen, and R. Wichman, Multi-Antenna Transceiver Techniques for 3G and Beyond, John Wiley, Chichester, UK, ISBN 0470 84542 2.
[37] C. Kambiz, L. Krasny, Capacity-achieving transmitter and receiver pairs for dispersive MISO channels, IEEE T. Commun. 42 (April 1994) 1431–1440.

Petitioners' Exhibit 1003, p. 777
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

[38] R. Horn and C. Johnson, Matrix analysis, Proceedings of the 36th Asilomar Conference on Signals, Systems and Computers, Pacific Grove, CA, USA, November 2002.
[39] K.J. Kim, Channel estimation and data detection algorithms for MIMO–OFDM systems, Proceedings of the 36th Asilomar Conference on Signals, Systems and Computers, Pacific Grove, CA, USA, November 2002.
[40] M.K. Varanasi and T. Guess, Optimum decision feedback multi-user equalization with successive decoding achieves the total capacity of the gaussian multiple-access channel, Proceedings of the Asilomar conference on Signals, Systems, and Computers, Monterey, CA, November 1997.
[41] S. Grant, J.-F. Cheng, L. Krasny, K. Molnar, Y.-P.E Wang, Per-antenna-rate-control (PARC) in frequency selective fading with SIC-GRAKE receiver, 60th IEEE Vehicular Technology Conference, Los Angeles, CA, USA 2, September 2004, 1458–1462.
[42] S.T. Chung, A.J. Goldsmith, Degrees of freedom in adaptive modulation: A unified view, IEEE T. Commun. 49 (9) (September 2001) 1561–1571.
[43] A.J. Goldsmith, P. Varaiya, Capacity of fading channels with channel side information, IEEE T. Inform. Theory 43 (November 1997) 1986–1992.
[44] R. Knopp, P.A. Humblet, Information capacity and power control in single-cell multi-user communications, Proceedings of the IEEE International Conference on Communications, Seattle, WA, USA, Vol. 1, 1995, 331–335.
[45] D. Tse, Optimal power allocation over parallel gaussian broadcast channels, Proceedings of the International Symposium on Information Theory, Ulm, Germany, June 1997, p. 7.
[46] M.L. Honig and U. Madhow, Hybrid intra-cell TDMA/inter-cell CDMA with inter-cell interference suppression for wireless networks, Proceedings of the IEEE Vehicular Technology Conference, Secaucus, NJ, USA, 1993, pp. 309–312.
[47] S. Ramakrishna, J.M. Holtzman, A scheme for throughput maximization in a dual-class CDMA system, IEEE J. Sel. Area Comm. 16 (6) (1998) 830–844.
[48] S.-J. Oh, K.M. Wasserman, Optimality of greedy power control and variable spreading gain in multi-class CDMA mobile networks, Proceedings of the AMC/IEEE MobiComp, Seattle, WA, USA, 1999, pp. 102–112.
[49] J.M. Holtzman, CDMA forward link waterfilling power control, Proceedings of the IEEE Vehicular Technology Conference, Tokyo, Japan, Vol. 3, May, 2000, 1663–1667.
[50] J.M. Holtzman, Asymptotic analysis of proportional fair algorithm, Proceedings of the IEEE Conference on Personal Indoor and Mobile Radio Communications, San Diego, CA, USA, Vol. 2, 2001, 33–37.
[51] P. Viswanath, D. Tse, R. Laroia, Opportunistic beamforming using dumb antennas, IEEE T. Inform. Theory 48 (6) (2002) 1277–1294.
[52] S. Lin and D. Costello, Error Control Coding, Prentice-Hall, Upper Saddle River, NJ, USA.
[53] C. Schlegel, Trellis and Turbo Coding, Wiley–IEEE Press, Chichester, UK, March 2004.
[54] J.M. Wozencraft, M. Horstein, Digitalised Communication Over Two-way Channels, Fourth London Symposium on Information Theory, London, UK, September 1960.
[55] D. Chase, Code combining – a maximum-likelihood decoding approach for combining and arbitrary number of noisy packets, IEEE T. Commun. 33 (May 1985) 385–393.
[56] M.B. Pursley, S.D. Sandberg, Incremental-redundancy transmission for meteor-burst communications, IEEE T. Commun. 39 (May 1991) 689–702.
[57] S.B. Wicker, M. Bartz, Type-I hybrid ARQ protocols using punctured MDS codes, IEEE T. Commun. 42 (April 1994) 1431–1440.

Petitioners' Exhibit 1003, p. 778
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

[58] J.-F. Cheng, Coding performance of hybrid ARQ schemes, IEEE T. Commun. 54 (June 2006) 1017–1029.
[59] P. Frenger, S. Parkvall, and E. Dahlman, Performance comparison of HARQ with chase combining and incremental redundancy for HSDPA, Proceedings of the IEEE Vehicular Technology Conference, Atlantic City, NJ, USA, October 2001, pp. 1829–1833.
[60] J. Hagenauer, Rate-compatible punctured convolutional codes (RCPC codes) and their applications, IEEE T. Commun. 36 (April 1988) 389–400.
[61] 3GPP, 3rd generation partnership project; Technical specification group radio access network; Physical Channels and Modulation (Release 8), 3GPP TS 36.211.
[62] 3GPP, 3rd generation partnership project; Technical specification group radio access network; Multiplexing and Channel Coding (Release 8), 3GPP TS 36.212.
[63] 3GPP, 3rd generation partnership project; Technical specification group radio access network; Physical Layer Procedures (Release 8), 3GPP TS 36.213.
[64] 3GPP, 3rd generation partnership project; Technical specification group radio access network; Physical Layer – Measurements (Release 8), 3GPP TS 36.214.
[65] ITU-R, Requirements related to technical performance for IMT-Advanced radio interface(s), Report ITU-R M.2134, 2008.
[66] 3GPP, 3rd generation partnership project; Technical specification group radio access network; Requirements for further advancements for Evolved Universal Terrestrial Radio Access (E-UTRA) (LTE-Advanced) (Release 9), 3GPP TR 36.913.
[67] 3GPP, 3rd generation partnership project; Technical specification group radio access network; Evolved universal terrestrial radio access (E-UTRA); User Equipment (UE) Radio Access Capabilities, 3GPP TS 36.306.
[68] IETF, Robust header compression (ROHC): Framework and four profiles: RTP, UDP, ESP, and Uncompressed, RFC 3095.
[69] J. Sun, O.Y. Takeshita, Interleavers for turbo codes using permutation polynomials over integer rings, IEEE T. Inform. Theory 51 (1) (January 2005) 101–119.
[70] O.Y. Takeshita, On maximum contention-free interleavers and permutation polynomials over integer rings, IEEE T. Inform. Theory 52 (3) (March 2006) 1249–1253.
[71] D.C. Chu, Polyphase codes with good periodic correlation properties, IEEE T. Inform. Theory 18 (4) (July 1972) 531–532.
[72] J. Padhye, V. Firoiu, D.F. Towsley, J.F. Kurose, Modelling TCP reno performance: A simple model and its empirical validation, ACM/IEEE T. Network. 8 (2) (2000) 133–145.
[73] CRAN International Workshop, CRAN – Road Towards Green Radio Access Network, China Mobile, 23 April 2010.
[74] 3GPP, 3rd generation partnership project; Technical specification group radio access network; Evolved universal terrestrial radio access (E-UTRA) and evolved universal terrestrial radio access network (E-UTRAN); User equipment (UE) conformance specification; Radio Transmission and Reception (Part 1, 2 and 3), 3GPP TS 36.521.
[75] 3GPP, Evolved universal terrestrial radio access (E-UTRA); Physical layer for relaying operation, 3GPP TS 36.216.
[76] 3GPP, 3rd generation partnership project; Technical specification group radio access network; Evolved universal terrestrial radio access (E-UTRA); User Equipment (UE) radio transmission and reception, 3GPP TS 36.101.

Petitioners' Exhibit 1003, p. 779
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

[77] APT Wireless Forum, APT Report on Harmonised Frequency Arrangements for The Band 698–806 MHz, APT/AWF/REP-14, September 2010 Edition.
[78] 3GPP, 3rd generation partnership project; Technical specification group radio access network; UMTS-LTE 3500 MHz Work Item Technical Report (Release 10), 3GPP TR 37.801.
[79] 3GPP, 3rd generation partnership project; Technical specification group radio access network; Feasibility Study for Evolved Universal Terrestrial Radio Access (UTRA) and Universal Terrestrial Radio Access Network (UTRAN) (Release 7), 3GPP TR 25.912.
[80] 3GPP, E-UTRA, UTRA and GSM/EDGE; Multi-Standard Radio (MSR) Base Station (BS) Radio Transmission and Reception, 3GPP TR 37.104.
[81] 3GPP, E-UTRA, UTRA and GSM/EDGE; Multi-Standard Radio (MSR) Base Station (BS) Conformance Testing, 3GPP TR 37.141.
[82] 3GPP, 3rd generation partnership project; Technical specification group radio access network; Evolved universal terrestrial radio access (E-UTRA); User Equipment (UE) Radio Transmission and Reception, 3GPP TR 36.803.
[83] 3GPP, 3rd generation partnership project; Technical specification group radio access network; Evolved universal terrestrial radio access (E-UTRA); Base Station (BS) Radio Transmission and Reception, 3GPP TR 36.804.
[84] 3GPP, Evolved universal terrestrial radio access (E-UTRA); User Equipment (UE) Radio transmission and reception, 3GPP TR 36.807.
[85] 3GPP, Evolved universal terrestrial radio access (E-UTRA); Carrier Aggregation Base Station (BS) Radio transmission and reception, 3GPP TR 36.808.
[86] 3GPP, 3rd generation partnership project; Technical specification group radio access network; Evolved universal terrestrial radio access (E-UTRA); Base Station (BS) Radio transmission and reception, 3GPP TS 36.104.
[87] 3GPP, 3rd generation partnership project; Technical specification group radio access network; Evolved universal terrestrial radio access (E-UTRA); Base Station (BS) conformance testing, 3GPP TS 36.141.
[88] FCC, Title 47 of the Code of Federal Regulations (CFR), Federal Communications Commission.
[89] 3GPP, 3rd generation partnership project; Technical specification group radio access network; Evolved universal terrestrial radio access (E-UTRA); Radio Frequency (RF) system scenarios, 3GPP TR 36.942.
[90] ITU-R, Unwanted Emissions in the Spurious Domain, Recommendation ITU-R SM.329-10, February 2003.
[91] 3GPP, 3rd generation partnership project; Technical specification group radio access network; Radio Frequency (RF) system scenarios, 3GPP TR 25.942.
[92] 3GPP, 3rd generation partnership project; Technical specification group radio access network; Feasibility study for further advancements for E-UTRA (LTE-Advanced) (Release 9), 3GPP TR 36.912.
[93] ITU-R, Guidelines for Evaluation of Radio Interface Technologies for IMT-Advanced, Report ITU-R M.2135-1, December 2009.
[94] A. Furuskär, Performance evaluations of LTE-advanced – the 3GPP ITU proposal, 12th International Symposium on Wireless Personal Multimedia Communications (WPMC 2009), Invited Paper.

Petitioners' Exhibit 1003, p. 780
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

[95] E. Dahlman, H. Ekström, A. Furuskär, Y. Jading, J. Karlsson, M. Lundevall, S. Parkvall, The 3G long-term evolution – radio interface concepts and performance evaluation, 63rd Vehicular Technology Conference, VTC 2006 – Spring, Vol. 1, pp. 137–141, IEEE, 2006.
[96] E. Dahlman, S. Parkvall, J. Sköld, P. Beming, 3G Evolution – HSPA and LTE for Mobile Broadband, second ed., Academic Press, 2008.
[97] WINNER, IST-WINNER II Deliverable 1.1.2 v. 1.2. WINNER II Channel Models, IST-WINNER2, Tech. Rep., 2007.
[98] 3GPP, 3rd generation partnership project; Technical specification group radio access network; Spatial Channel Model for Multiple Input Multiple Output (MIMO) Simulations (Release 9), 3GPP TR 25.996.
[99] Alcatel Shanghai Bell, CATT, CMCC, RITT, Spectrum Communications, TD-TECH, ZTE, Introduce TD-SCDMA Industry Standard in CCSA to 3GPP, Document R4-071394, 3GPP TSG-RAN WG4 meeting #44, Athens, Greece, August 2007.
[100] 3GPP, 3rd generation partnership project; Technical specification group GSM/EDGE radio access network; Feasibility Study for Evolved GSM/EDGE Radio Access Network (GERAN) (Release 7), 3GPP TR 45.912.
[101] H. Axelsson, P. Björkén, P. de Bruin, S. Eriksson, H. Persson, GSM/EDGE continued evolution, Ericsson Rev. (01) (2006) 20–29 Telefonaktiebolaget LM Ericsson, Stockholm, Sweden.
[102] 3GPP, Updated New WID on Higher Uplink Performance for GERAN Evolution (HUGE), Tdoc GP-061901, 3GPP TSG GERAN #31, Denver, USA, 4–8 September 2006.
[103] 3GPP, Circuit Switched Voice Capacity Evolution for GSM/EDGE Radio Access Network (GERAN), 3GPP TR 45.914.
[104] N. Bhushan, C. Lott, P. Black, R. Attar, Y.-C. Jou, M. Fan, et al., CDMA2000 1xEV-DO revision A: A physical layer and MAC layer overview, IEEE Commun. Mag. (February 2006) 75–87.
[105] M.W. Thelander, The 3G Evolution: Taking CDMA2000 into the Next Decade, Signal Research Group, LLC, White Paper developed for the CDMA Development Group, October 2005.
[106] R. Attar, Evolution of CDMA2000 cellular networks: Multicarrier EV-DO, IEEE Commun. Mag. (March 2006) 46–53.
[107] M. Alendal, Operators need an ecosystem to support 50 billion connections, Ericsson Bus. Rev. (3) (2010).
[108] M. Nekovee, A survey of cognitive radio access to TV white spaces, Int. J. Digi. Multimed. Broadcast. (2010) 1–11.
[109] J. Mitola, Cognitive Radio – An Integrated Agent Architecture for Software Defined Radio, Royal Institute of Technology (KTH), Sweden, May 2000.
[110] S. Haykin, Cognitive radio: Brain-empowered wireless communications, IEEE J. Sel. Area. Comm. 23 (2) (February 2005) 201–220.
[111] Wireless World Initiative New Radio, Eurescom, 2006, https://www.ist-winner.org.

Petitioners' Exhibit 1003, p. 781
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Index

1.28 Mcps TDD, 395
16QAM modulation, 19–21, 399–400
3G, 2–11
3GPP, 9–11
3GPP2, 9, 402–403
32QAM modulation, 399–400
64QAM modulation, 19–21
7.68 Mcps TDD, 395
8PSK modulation, 399–400

A

Absolute grant, 393
Access Stratum (AS), 110
ACIR, 370
Acknowledged mode (for RLC), 261
Acknowledged Resource Indicator (ARI), 184, 238
ACLR, 370–371
ACS, 370–371, 374
Adaptive Modulation and Coding (AMC), 81
Antenna port, 148
Automatic Repeat Request (ARQ), 90–93
  in LTE, 247–259
  for LTE relaying, 335–337

B

Bandwidth utilization, 16
Base-station classes, 365
BCCH *see* Broadcast Control Channel
BCH *see* Broadcast Channel
  transmission of, 305–307
Beam forming:
  classical, 68–70
  in LTE *see* Pre-coding, LTE
Blind decoding of PDCCH, 199–202
Blocking, receiver:
  general, 362, 374
  narrowband, 374
BM-SC *see* Broadcast Multicast Service Center
Broadcast, 43–44
  see also MBMS
Broadcast Control Channel (BCCH), 116
Broadcast Channel (BCH), 116
Broadcast Multicast Service Center (BM-SC), 325
Buffer status report, 277–280

C

Carrier aggregation:
  control signalling for, 193–199
  overview, 104
  physical resources, 132–134
  RF characteristics, 355–358
Carrier Indicator, 183, 190
Carrier raster, 136
CCCH *see* Common Control Channel
CCE *see* Control Channel Element
CDD *see* Cyclic Delay Diversity
CDMA2000, 10, 402–405
Cell identity, 301
Cell-identity group, 302
Cell search, 301–304
Centralized RAN (C-RAN), 292
Channel capacity, 15
Channel coding, LTE:
  downlink, 146–148
  uplink, 204
Channel rank, 166
Channel State Information (CSI), 152

Petitioners' Exhibit 1003, p. 782
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Channel-state report, 282–287
Channel-Quality Indicator (CQI), 242, 283
Charging, 109–110
Chase combining, 90–92
Closed Subscriber Group (CSG), 294
CN *see* Core Network
Code block, 146
Coexistence
  requirements, 352
  with TD-SCDMA, 140–141
Cognitive radio, 414
Co-location requirements, 352
Common Control Channel (CCCH), 116
Common Subframe Allocation (CSA), 328
CoMP *see* Coordinated Multipoint transmission
Component carrier, 104, 132
Contention resolution, 312, 319
Continuous Packet Connectivity (CPC), 390
Control-channel element, 195
Controlling RNC *see* RNC
Control region, 131, 173–174
Coordinated multipoint transmission, 412
Core Network (CN), 109–110
CQI *see* Channel-Quality Indicator
CRC *see* Cyclic Redundancy Check
C-RNTI, 125, 319
Cross-carrier scheduling, 193–194, 254
CSG *see* Closed Subscriber Group
CSI *see* Channel-State Information
Cubic metric, 54
Cyclic-Delay Diversity (CDD), 66
Cyclic prefix:
  extended, 127–128
  MBSFN, 131–132
  normal, 127–128
  OFDM, 32–34, 40
  Random-access preamble, 315–317
  single-carrier, 40
Cyclic Redundancy Check (CRC), 90
  for DL-SCH, 144–145
  for PDCCH, 195–196
  for UL-SCH, 203–204

D

Data region, 131, 173
DC-subcarrier, 130–131
DCCH *see* Dedicated Control Channel
DCI *see* Downlink Control Information
DCI format, 180–185
Dedicated Control Channel (DCCH), 116
Delay diversity, 65–66
Device-to-device communication, 414
DFT-spread OFDM (DFTS-OFDM), 52–57
  localized vs. distributed, 55–57
  receiver, 54–55
  user multiplexing, 55
  in LTE, 96–97, 205
Discontinuous Reception (DRX), 287–290
Discontinuous Transmission (DTX), 394
  DL-SCH *see* Downlink Shared Channel
Donor cell, 332
Downlink Control Information (DCI), 123, 179
Downlink Shared Channel (DL-SCH), 117
  processing, 143
Downlink Traffic Channel (DTCH), 116
DRX *see* Discontinuous Reception
DTCH *see* Downlink Traffic Channel
DTX *see* Discontinuous Transmission
DwPTS, 138–140

E

EDGE, 396–401
eNB *see* eNodeB
eNodeB, 111
EPC *see* Evolved Packet Core

Petitioners' Exhibit 1003, p. 783
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

EPS *see* Evolved Packet System
Equalization, 23, 45–49
  Decision-feedback, 49–50
  Frequency-domain, 47–49
  Time-domain, 45–47
EV-DO, 402–405
EV-DV, 402
EVM requirement, 367
Evolved Packet Core, 109–110
Evolved Packet System, 109

F

FDD *see* Frequency Division Duplex
Femto base station *see* Home-eNodeB
Frame, LTE, 127, 131
Frequency bands, 347–352
  numbering of, 349
Frequency Division Duplex, 3, 6, 101, 136–137, 281–282, 384
Frequency hopping, uplink, 207–209
Frequency-Switched Transmit Diversity, 164
FSTD *see* Frequency-Switched Transmit Diversity

G

GERAN, 10, 397–401
GGSN, 397
GMSK modulation, 399
GSM, 2–3, 7–8, 396–401
  migration from, 352–354
  multi-standard radio for, 359–361
Guard period, 139

H

Half-duplex FDD, 137–138
  in relation to scheduling, 281–282
HARQ *see* Hybrid ARQ
Heterogeneous network deployments, 293–299
Higher-order modulation, 19–21
High Interference Indicator (HII), 292
High Speed Packet Access (HSPA), 389–395
  in TDD, 395–396
HII *see* High Interference Indicator
Home-eNodeB, 293, 299
Home Subscriber Service (HSS), 110
HRPD, 402
HSPA *see* High Speed Packet Access
HSS *see* Home Subscriber Service
HS-SCCH-less operation, 394
Hybrid ARQ, 89–93
  adaptive, 250–251
  control signalling for, 177–179, 229–234
  in LTE, 99, 121–123, 247–259
  process, 248
  relaying, 335–337
  synchronous, 250–251
  with soft combining, 120–123

I

ICIC *see* Inter-cell interference coordination
ICS, 373–374
IEEE 802.16, 405–408
IMT-2000, 4–6
IMT-Advanced, 4–6, 11–13, 103, 408
Incremental redundancy (IR), 90–93, 249, 253
In-sequence delivery, 262
Inter-cell interference coordination (ICIC), 99, 290–299
  in heterogeneous deployments, 294–299
  in home-eNodeB, 299
Interference cancellation, 75

Petitioners' Exhibit 1003, p. 784
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Interference coordination *see Inter-cell Interference Coordination*
Interference Rejection Combining (IRC), 62
Intermodulation:
  receiver, 374–375
  transmitter, 372
Internet Protocol (IP), 7
IR *see* Incremental Redundancy
ITU, 3–6
  see also IMT, *IMT-Advanced*

L

Latency, 378–379
Layer mapping, LTE, 166, 222
Link adaptation, 79–81, 113, 389
  see also Rate adaptation
Logical channels, 113, 116
LTE-Advanced, 103
  see also Release 10, IMT-Advanced

M

MAC, 115
  control element, 118
Machine-type Communication, 413–414
Master Information Block (MIB), 305–307
MBMS, 323–330
MBMS Control Channel (MCCH), 116, 325–329
MBMS Traffic Channel (MTCH);, 116, 325, 329
MBSFN, 102, 128, 131–132, 324–328
MBSFN area, 324
MBSFN subframe, 131–132, 326–327, 335
MCCH *see* MBMS Control Channel
MCH *see* Multicast Channel
MCH Scheduling Information (MSI), 329
MCH Scheduling Period (MSP), 328
MCH subframe allocation (MSA), 329
MIB *see* Master Information Block
MIMO *see* spatial multiplexing
MME *see* Mobility Management Entity
Mobility Management Entity (MME), 110
MSR *see* Multi-Standard Radio
MTCH *see* MBMS Traffic Channel
Multi-carrier transmission, 21–25
  for CDMA2000, 405
  for EDGE, 398
  for HSPA, 395
  for LTE *see carrier aggregation*
  for TD-SCDMA, 396
Multicast, 43–44
  see also MBMS
Multicast/Broadcast over Single–Frequency Network *see* MBSFN
Multicast Channel (MCH), 117, 325–328
Multi-cell/multicast Coordination Entity (MCE), 324
Multi-Standard Radio (MSR) base stations, 359–361

N

NAS *see* Non-Access Stratum
New-data indicator, 184, 191, 249–253
NodeB, 391
Non-Access Stratum (NAS), 110

O

OCC *see* Orthogonal Cover Codes
OFDM *see* Orthogonal Frequency Division Multiplex
OFDMA, 41
OI *see* Overload Indicator
Operating bands, 348–352
Operating band unwanted emissions, 363, 368–369

Petitioners' Exhibit 1003, p. 785
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Orthogonal Cover Codes (OCC)
for downlink demodulation reference signals, 156
for CSI reference signals, 159
for uplink reference signals, 216
Orthogonal Frequency Division Multiplex (OFDM), 27–44
demodulation, 29
FFT/IFFT implementation, 30–32
in LTE, 127–131
Out-of-band
blocking, 374
emissions, 367–368
Overload Indicator (OI), 292

P

Packet Data Network Gateway (P-GW), 110
Packet Data Convergence Protocol (PDCP), 111
Paging, 319–321
Paging Channel (PCH), 116
Paging Control Channel (PCCH), 116
Partial path-loss compensation *see* path-loss compensation
Path-loss compensation, 270
PBCH *see* Physical Broadcast Channel
PCCH *see* Paging Control Channel
PCFICH *see* Physical Control Format Indicator Channel
PCH *see* Paging Channel
PCRF *see* Policy and Charging Rules Function
PDCCH *see* Physical Downlink Control Channel
PDCP *see* Packet Data Convergence Protocol
PDSCH *see* Physical Downlink Shared Channel
PDU *see* Protocol Data Unit
P-GW *see* Packet Data Network Gateway
PHICH *see* Physical Hybrid-ARQ Indicator Channel
Physical Broadcast Channel (PBCH), 123
Physical channel, 123
Physical Control Format Indicator Channel (PCFICH), 123, 174–177
Physical Downlink Control Channel (PDCCH), 123, 179–181, 195–202
Physical Downlink Shared Channel (PDSCH), 123, 143–152
Physical Hybrid-ARQ Indicator Channel, 123, 177–179
Physical-layer cell identity, 301
Physical Multicast Channel (PMCH), 123, 326–327
Physical Random Access Channel (PRACH), 124, 312
Physical Resource Block (PRB):
downlink, 129–130, 149–152
uplink, 129–130, 205–207
Physical Uplink Control Channel (PUCCH), 123, 227–242
transmit diversity for
Physical Uplink Shared Channel (PUSCH), 123, 203–210
PMCH *see* Physical Multicast Channel
PMI *see* Precoding-Matrix Indicator
Policy and Charging Rules Function (PCRF), 110
Positioning, 103
Power control, 79–81
for PRACH, 315
for PUCCH, 267–269
for PUSCH, 269–271
for SRS, 271–272
in LTE uplink, 265–272
Power Headroom, 271–272, 280
PRACH *see* Physical Random Access Channel

Petitioners' Exhibit 1003, p. 786
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

PRB *see* Physical Resource Block
Pre-coding, LTE, 161–173
  codebook-based, 165
  closed-loop, 167
  non-codebook-based, 169
  open-loop, 168
Precoding-Matrix Indicator (PMI), 167, 242, 283
Protocol Data Unit (PDU), 113
PUCCH *see* Physical Uplink Control Channel
PUSCH *see* Physical Uplink Shared Channel

Q

QoS, 110
QPP, 146
QPSK, 19–20

R

RACH *see* Random Access Channel
Radio access network, 95, 111
Radio bearer, 111
Radio frame *see* Frame
Radio Link Control (RLC), 113–115, 247, 257–264
Radio Network Controller (RNC), 391
Radio Resource Control (RRC), 124–125
Radio Resource Management (RRM), 111, 265
RAKE, 45
RAN *see* Radio access network
Random access, 310–319
  preamble, 312–317
Random Access Channel (RACH), 117
Rank indicator, 242, 283
Rate adaptation, 97–99, 115, 272
  see also link adaptation
Rate control, 106–7
  in LTE, 304
Rate matching, 147, 204
Receive diversity, 60, 100
Redundancy version, 92–93, 147, 184, 191, 204, 251, 253–254
Reference sensitivity:
  for LTE BS, 373
  for LTE terminal, 373
Reference signal:
  Cell-specific, 153–156
  CRS *see reference signal, cell specific*
  CSI *see reference signal, channel-state information*
  Demodulation (DM-RS, in downlink) *see reference signal, UE-specific*
  for channel-state information, 158–161
  for MBSFN, 153, 327–328
  for positioning, 153
  for sounding *see* sounding reference signal
  for uplink demodulation, 211–217
  power-boosted, 154UE-specific, 153
Reference-signal sequence:
  phase-rotated/“cyclically shifted”, 213–214
  frequency-domain, 210–211
Reference symbol, 35–36, 153
  frequency shifted, 154
Relay, 331–345
  access link, 332
  amplify-and-forward *see repeater*
  architecture, 333–334
  backhaul link, 332
  control signalling *see* Relay Physical Downlink Control Channel
  decode-and-forward, 331
  hybrid-ARQ operation, 336–337
  inband, 332
  outband, 332
Relay Physical Downlink Control Channel (R-PDCCH), 337–342

Petitioners' Exhibit 1003, p. 787
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Relative Narrowband Transmit Power (RNTP), 292
Release 8 (LTE), 95–102
Release 9 (LTE), 95, 102–103
Release 10 (LTE), 103–105
  see also LTE-Advanced
Reordering, 262
Repeater, 331
Resource-allocation type, 185–186, 192–193
Resource block:
  in downlink, 129–130, 149–153
  in uplink, 129–130, 205–210
  signaling of, 185–187
Resource-block pair, 130
Resource element, 129
Resource element group, 175
RI *see* Rank Indicator
RLC *see* Radio Link Control
Roaming, 2, 7, 11
RNC *see* Radio Network Controller
RNTP *see* Relative Narrowband Transmit Power
R-PDCCH *see* Relay Physical Downlink Control Channel
RRC *see* Radio Resource Control
RRC_IDLE, 125–126
RRC_CONNECTED, 125–126
RRM *see* Radio Resource Management

S

S1 interface, 111
SAE, 8, 95
Scheduling:
  assignment, 179, 181–189
  channel-dependent, 79, 81–89, 97–99
  downlink, 81–85, 273–275
  frequency-domain, 87, 97–98
  grant, 180, 189–93
  greedy filling, 85, 86
  half-duplex FDD, 281–82
  max-C/I, 82–85
  proportional fair, 83–84
  request, 229, 234, 238–239, 277–280
  round robin, 83–84
  semi-persistent, 119, 280–281
  uplink, 85–87, 275–280
SDU *see* Service Data Unit
Search space, 199
Selectivity:
  adjacent channel *see* ACS
  in-channel *see* ICS
Self-backhauling *see Relay*
Served traffic, 383
Service Data Unit (SDU), 113
Serving cell, 279
Serving Gateway (S-GW), 110
SFBC *see* Space-Frequency (Block) Coding
SFN *see* Single–frequency network
SFN *see* System Frame Number
S-GW *see* Serving Gateway
Shared-channel transmission, 97, 119
SI *see* System Information message
SIB *see* System Information Block
SIC *see* Successive Interference cancellation
Single-frequency network (SFN), 44
  see also MBSFN
SI-RNTI *see* System Information RNTI
Slot, 128–30
Soft handover, 391
Sounding reference signal, 217–221
Space-Frequency Block Coding (SFBC), 68, 163–165, 306
Space Time (Block) Coding (ST(B)C), 66–68

Spatial multiplexing, 71–79, 100, 105
multi-codeword based, 75–77
pre-coder based, 74–75
single-codeword based, 75–77
in LTE *see* Pre-coding (LTE)
Special subframe, 138–40
Spectral efficiency, 337
performance, 380–387
requirement, 380, 384
Spectrum flexibility, 100–102, 354
Spurious emissions, 363, 367–369, 372
Standardization, 8–13
Subcarrier spacing:
in general, 38
LTE, 127
reduced, 128
Subframe, 128
Successive Interference Cancellation (SIC) *see* Interference cancellation
Symbol quadruplet, 175
Synchronization signal, 302–304
System Frame Number (SFN), 128, 305
System Information, 305
System Information Block (SIB), 305, 308–310
System Information message (SI), 308–310
System Information RNTI (SI-RNTI), 308
System performance, 377–379
System throughput, 379, 383

T

TDD *see* Time Division Duplex
TD-SCDMA, 140, 395–396
Time Division Duplex, 3, 6, 101, 138–141, 385
Timing advance, 245–246
for relaying, 343–344
Transmission mode, 162
Transmission rank, 166
Transmission Time Interval (TTI), 116
Transmit Diversity, 67–69, 163–165
for PUCCH, 226
Transparent mode (for RLC), 261
Transport block, 116
signaling of size, 187–189
Transport channels, 116–118
Transport format, 116
Transport format selection, 116, 120, 273
TTI *see* Transmission Time Interval

U

UCI *see* Uplink Control Information
UE categories, 105–106
UL-SCH *see* Uplink Shared Channel
UMB, 403
Unacknowledged mode (for RLC), 261
Unwanted emissions, 362, 367–372
Uplink Control Information (UCI), 123
Uplink Shared Channel (UL-SCH), 117
UpPTS, 138–140
User Equipment (UE), 106
categories, 106–107
User throughput, 378
UTRA FDD *see* WCDMA
UTRA TDD, 11, 395–396

V

VAMOS, 401
Virtual Resource Block (VRB), 150
distributed vs. localized, 150–151
downlink, 150
uplink, 208
VRB *see* Virtual Resource Block

Petitioners' Exhibit 1003, p. 789
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

W
WCDMA, 3, 389–395
White space, 414
WiMAX, 405–408

X
X2 Interface, 111

Z
Zadoff-Chu sequences, 212

Petitioners' Exhibit 1003, p. 790
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

APPENDIX 3

3GPP TS 36.211 V10.7.0 (2013-02)

Technical Specification

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Evolved Universal Terrestrial Radio Access (E-UTRA);
Physical Channels and Modulation
(Release 10)





The present document has been developed within the 3rd Generation Partnership Project (3GPP ™) and may be further elaborated for the purposes of 3GPP.

The present document has not been subject to any approval process by the 3GPP Organizational Partners and shall not be implemented.
This Specification is provided for future development work within 3GPP only. The Organizational Partners accept no liability for any use of this Specification.
Specifications and reports for implementation of the 3GPP ™ system should be obtained via the 3GPP Organizational Partners' Publications Offices.

Keywords
UMTS, radio, layer 1

3GPP

Postal address

3GPP support office address
650 Route des Lucioles - Sophia Antipolis
Valbonne - FRANCE
Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Internet
http://www.3gpp.org

Copyright Notification

No part may be reproduced except as authorized by written permission.
The copyright and the foregoing restriction extend to reproduction in all media.

© 2013, 3GPP Organizational Partners (ARIB, ATIS, CCSA, ETSI, TTA, TTC).
All rights reserved.

UMTS™ is a Trade Mark of ETSI registered for the benefit of its members
3GPP™ is a Trade Mark of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners
LTE™ is a Trade Mark of ETSI currently being registered for the benefit of its Members and of the 3GPP Organizational Partners
GSM® and the GSM logo are registered and owned by the GSM Association

Petitioners' Exhibit 1003, p. 793
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Contents

Foreword....6
1 Scope....7
2 References....7
3 Definitions, symbols and abbreviations....7
3.1 Symbols....7
3.2 Abbreviations....9
4 Frame structure....9
4.1 Frame structure type 1....10
4.2 Frame structure type 2....10
5 Uplink....11
5.1 Overview....11
5.1.1 Physical channels....12
5.1.2 Physical signals....12
5.2 Slot structure and physical resources....12
5.2.1 Resource grid....12
5.2.2 Resource elements....14
5.2.3 Resource blocks....14
5.3 Physical uplink shared channel....14
5.3.1 Scrambling....15
5.3.2 Modulation....15
5.3.2A Layer mapping....16
5.3.2A.1 Layer mapping for transmission on a single antenna port....16
5.3.2A.2 Layer mapping for spatial multiplexing....16
5.3.3 Transform precoding....16
5.3.3A Precoding....17
5.3.3A.1 Precoding for transmission on a single antenna port....17
5.3.3A.2 Precoding for spatial multiplexing....17
5.3.4 Mapping to physical resources....20
5.4 Physical uplink control channel....21
5.4.1 PUCCH formats 1, 1a and 1b....22
5.4.2 PUCCH formats 2, 2a and 2b....24
5.4.2A PUCCH format 3....25
5.4.3 Mapping to physical resources....26
5.5 Reference signals....27
5.5.1 Generation of the reference signal sequence....27
5.5.1.1 Base sequences of length $3N_{sc}^{RB}$ or larger....28
5.5.1.2 Base sequences of length less than $3N_{sc}^{RB}$....28
5.5.1.3 Group hopping....30
5.5.1.4 Sequence hopping....31
5.5.2 Demodulation reference signal....31
5.5.2.1 Demodulation reference signal for PUSCH....31
5.5.2.1.1 Reference signal sequence....31
5.5.2.1.2 Mapping to physical resources....33
5.5.2.2 Demodulation reference signal for PUCCH....33
5.5.2.2.1 Reference signal sequence....33
5.5.2.2.2 Mapping to physical resources....35
5.5.3 Sounding reference signal....35
5.5.3.1 Sequence generation....35
5.5.3.2 Mapping to physical resources....35
5.5.3.3 Sounding reference signal subframe configuration....39
5.6 SC-FDMA baseband signal generation....39
5.7 Physical random access channel....40
5.7.1 Time and frequency structure....40

Petitioners' Exhibit 1003, p. 794
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.7.2 Preamble sequence generation 46
5.7.3 Baseband signal generation 49
5.8 Modulation and upconversion 49

6 Downlink 50
6.1 Overview 50
6.1.1 Physical channels 50
6.1.2 Physical signals 51
6.2 Slot structure and physical resource elements 51
6.2.1 Resource grid 51
6.2.2 Resource elements 51
6.2.3 Resource blocks 52
6.2.3.1 Virtual resource blocks of localized type 53
6.2.3.2 Virtual resource blocks of distributed type 53
6.2.4 Resource-element groups 54
6.2.5 Guard period for half-duplex FDD operation 55
6.2.6 Guard Period for TDD Operation 55
6.3 General structure for downlink physical channels 55
6.3.1 Scrambling 56
6.3.2 Modulation 56
6.3.3 Layer mapping 56
6.3.3.1 Layer mapping for transmission on a single antenna port 56
6.3.3.2 Layer mapping for spatial multiplexing 56
6.3.3.3 Layer mapping for transmit diversity 58
6.3.4 Precoding 58
6.3.4.1 Precoding for transmission on a single antenna port 58
6.3.4.2 Precoding for spatial multiplexing using antenna ports with cell-specific reference signals 58
6.3.4.2.1 Precoding without CDD 58
6.3.4.2.2 Precoding for large delay CDD 59
6.3.4.2.3 Codebook for precoding and CSI reporting 60
6.3.4.3 Precoding for transmit diversity 61
6.3.4.4 Precoding for spatial multiplexing using antenna ports with UE-specific reference signals 62
6.3.5 Mapping to resource elements 62
6.4 Physical downlink shared channel 63
6.5 Physical multicast channel 63
6.6 Physical broadcast channel 63
6.6.1 Scrambling 63
6.6.2 Modulation 64
6.6.3 Layer mapping and precoding 64
6.6.4 Mapping to resource elements 64
6.7 Physical control format indicator channel 64
6.7.1 Scrambling 65
6.7.2 Modulation 65
6.7.3 Layer mapping and precoding 65
6.7.4 Mapping to resource elements 65
6.8 Physical downlink control channel 66
6.8.1 PDCCH formats 66
6.8.2 PDCCH multiplexing and scrambling 66
6.8.3 Modulation 67
6.8.4 Layer mapping and precoding 67
6.8.5 Mapping to resource elements 67
6.9 Physical hybrid ARQ indicator channel 68
6.9.1 Modulation 68
6.9.2 Resource group alignment, layer mapping and precoding 69
6.9.3 Mapping to resource elements 71
6.10 Reference signals 73
6.10.1 Cell-specific reference signals 73
6.10.1.1 Sequence generation 73
6.10.1.2 Mapping to resource elements 73
6.10.2 MBSFN reference signals 76
6.10.2.1 Sequence generation 76
6.10.2.2 Mapping to resource elements 76

Petitioners' Exhibit 1003, p. 795
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.10.3 UE-specific reference signals 78
6.10.3.1 Sequence generation 78
6.10.3.2 Mapping to resource elements 79
6.10.4 Positioning reference signals 84
6.10.4.1 Sequence generation 84
6.10.4.2 Mapping to resource elements 84
6.10.4.3 Positioning reference signal subframe configuration 85
6.10.5 CSI reference signals 86
6.10.5.1 Sequence generation 86
6.10.5.2 Mapping to resource elements 86
6.10.5.3 CSI reference signal subframe configuration 90
6.11 Synchronization signals 90
6.11.1 Primary synchronization signal 90
6.11.1.1 Sequence generation 90
6.11.1.2 Mapping to resource elements 90
6.11.2 Secondary synchronization signal 91
6.11.2.1 Sequence generation 91
6.11.2.2 Mapping to resource elements 93
6.12 OFDM baseband signal generation 94
6.13 Modulation and upconversion 94

7 Generic functions 95
7.1 Modulation mapper 95
7.1.1 BPSK 95
7.1.2 QPSK 95
7.1.3 16QAM 96
7.1.4 64QAM 96
7.2 Pseudo-random sequence generation 97

8 Timing 98
8.1 Uplink-downlink frame timing 98

Annex A (informative): Change history 99

Petitioners' Exhibit 1003, p. 796
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

- x the first digit:
  - 1 presented to TSG for information;
  - 2 presented to TSG for approval;
  - 3 or greater indicates TSG approved document under change control.
- y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.
- z the third digit is incremented when editorial only changes have been incorporated in the document.

Petitioners' Exhibit 1003, p. 797
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

1 Scope

The present document describes the physical channels for evolved UTRA.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TS 36.201: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Layer – General Description".

[3] 3GPP TS 36.212: "Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding".

[4] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures".

[5] 3GPP TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer – Measurements".

[6] 3GPP TS 36.104: “Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception”.

[7] 3GPP TS 36.101: “Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception”.

[8] 3GPP TS36.321, “Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification”

3 Definitions, symbols and abbreviations

3.1 Symbols

For the purposes of the present document, the following symbols apply:

(k,l)	Resource element with frequency-domain index k and time-domain index l
$a_{k,l}^{(p)}$	Value of resource element (k,l) [for antenna port p]
D	Matrix for supporting cyclic delay diversity
D_{RA}	Density of random access opportunities per radio frame
f_0	Carrier frequency

Petitioners' Exhibit 1003, p. 798
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

f_{RA}	PRACH resource frequency index within the considered time-domain location
$M_{\text{sc}}^{\text{PUSCH}}$	Scheduled bandwidth for uplink transmission, expressed as a number of subcarriers
$M_{\text{RB}}^{\text{PUSCH}}$	Scheduled bandwidth for uplink transmission, expressed as a number of resource blocks
$M_{\text{bit}}^{(q)}$	Number of coded bits to transmit on a physical channel [for codeword q]
$M_{\text{symb}}^{(q)}$	Number of modulation symbols to transmit on a physical channel [for codeword q]
$M_{\text{symb}}^{\text{layer}}$	Number of modulation symbols to transmit per layer for a physical channel
$M_{\text{symb}}^{\text{ap}}$	Number of modulation symbols to transmit per antenna port for a physical channel
N	A constant equal to 2048 for $\Delta f = 15\,\text{kHz}$ and 4096 for $\Delta f = 7.5\,\text{kHz}$
$N_{\text{CP},l}$	Downlink cyclic prefix length for OFDM symbol l in a slot
N_{CS}	Cyclic shift value used for random access preamble generation
$N_{\text{cs}}^{(1)}$	Number of cyclic shifts used for PUCCH formats 1/1a/1b in a resource block with a mix of formats 1/1a/1b and 2/2a/2b
$N_{\text{RB}}^{(2)}$	Bandwidth available for use by PUCCH formats 2/2a/2b, expressed in multiples of $N_{\text{sc}}^{\text{RB}}$
$N_{\text{RB}}^{\text{HO}}$	The offset used for PUSCH frequency hopping, expressed in number of resource blocks (set by higher layers)
$N_{\text{ID}}^{\text{cell}}$	Physical layer cell identity
$N_{\text{ID}}^{\text{MBSFN}}$	MBSFN area identity
$N_{\text{RB}}^{\text{DL}}$	Downlink bandwidth configuration, expressed in multiples of $N_{\text{sc}}^{\text{RB}}$
$N_{\text{RB}}^{\text{min,DL}}$	Smallest downlink bandwidth configuration, expressed in multiples of $N_{\text{sc}}^{\text{RB}}$
$N_{\text{RB}}^{\text{max,DL}}$	Largest downlink bandwidth configuration, expressed in multiples of $N_{\text{sc}}^{\text{RB}}$
$N_{\text{RB}}^{\text{UL}}$	Uplink bandwidth configuration, expressed in multiples of $N_{\text{sc}}^{\text{RB}}$
$N_{\text{RB}}^{\text{min,UL}}$	Smallest uplink bandwidth configuration, expressed in multiples of $N_{\text{sc}}^{\text{RB}}$
$N_{\text{RB}}^{\text{max,UL}}$	Largest uplink bandwidth configuration, expressed in multiples of $N_{\text{sc}}^{\text{RB}}$
$N_{\text{symb}}^{\text{DL}}$	Number of OFDM symbols in a downlink slot
$N_{\text{symb}}^{\text{UL}}$	Number of SC-FDMA symbols in an uplink slot
$N_{\text{sc}}^{\text{RB}}$	Resource block size in the frequency domain, expressed as a number of subcarriers
N_{sb}	Number of sub-bands for PUSCH frequency-hopping with predefined hopping pattern
$N_{\text{RB}}^{\text{sb}}$	Size of each sub-band for PUSCH frequency-hopping with predefined hopping pattern, expressed as a number of resource blocks
N_{SP}	Number of downlink to uplink switch points within the radio frame
$N_{\text{RS}}^{\text{PUCCH}}$	Number of reference symbols per slot for PUCCH
N_{TA}	Timing offset between uplink and downlink radio frames at the UE, expressed in units of T_{s}
$N_{\text{TA offset}}$	Fixed timing advance offset, expressed in units of T_{s}
$n_{\text{PUCCH}}^{(1,\tilde{p})}$	Resource index for PUCCH formats 1/1a/1b
$n_{\text{PUCCH}}^{(2,\tilde{p})}$	Resource index for PUCCH formats 2/2a/2b
$n_{\text{PUCCH}}^{(3,\tilde{p})}$	Resource index for PUCCH formats 3
n_{PDCCH}	Number of PDCCHs present in a subframe
n_{PRB}	Physical resource block number
$n_{\text{PRB}}^{\text{RA}}$	First physical resource block occupied by PRACH resource considered
$n_{\text{PRB offset}}^{\text{RA}}$	First physical resource block available for PRACH
n_{VRB}	Virtual resource block number
n_{RNTI}	Radio network temporary identifier
n_{f}	System frame number

Petitioners' Exhibit 1003, p. 799
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

n_s	Slot number within a radio frame
P	Number of antenna ports used for transmission of a channel
p	Antenna port number
q	Codeword number
r_{RA}	Index for PRACH versions with same preamble format and PRACH density
Q_m	Modulation order: 2 for QPSK, 4 for 16QAM and 6 for 64QAM transmissions
$s_l^{(p)}(t)$	Time-continuous baseband signal for antenna port p and OFDM symbol l in a slot
$t_{RA}^{(0)}$	Radio frame indicator index of PRACH opportunity
$t_{RA}^{(1)}$	Half frame index of PRACH opportunity within the radio frame
$t_{RA}^{(2)}$	Uplink subframe number for start of PRACH opportunity within the half frame
T_f	Radio frame duration
T_s	Basic time unit
T_{slot}	Slot duration
W	Precoding matrix for downlink spatial multiplexing
β_{PRACH}	Amplitude scaling for PRACH
β_{PUCCH}	Amplitude scaling for PUCCH
β_{PUSCH}	Amplitude scaling for PUSCH
β_{SRS}	Amplitude scaling for sounding reference symbols
Δf	Subcarrier spacing
Δf_{RA}	Subcarrier spacing for the random access preamble
υ	Number of transmission layers

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

CCE	Control channel element
CDD	Cyclic delay diversity
CSI	Channel-State Information
PBCH	Physical broadcast channel
PCFICH	Physical control format indicator channel
PDCCH	Physical downlink control channel
PDSCH	Physical downlink shared channel
PHICH	Physical hybrid-ARQ indicator channel
PMCH	Physical multicast channel
PRACH	Physical random access channel
PUCCH	Physical uplink control channel
PUSCH	Physical uplink shared channel

4 Frame structure

Throughout this specification, unless otherwise noted, the size of various fields in the time domain is expressed as a number of time units $T_s = 1/(15000 \times 2048)$ seconds.

Downlink and uplink transmissions are organized into radio frames with $T_f = 307200 \times T_s = 10\,\text{ms}$ duration. Two radio frame structures are supported:

- Type 1, applicable to FDD,
- Type 2, applicable to TDD.

Petitioners' Exhibit 1003, p. 800
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Transmissions in multiple cells can be aggregated where up to four secondary cells can be used in addition to the primary cell. Unless otherwise noted, the description in this specification applies to each of the up to five serving cells. In case of multi-cell aggregation, the UE may assume the same frame structure is used in all the serving cells.

4.1 Frame structure type 1

Frame structure type 1 is applicable to both full duplex and half duplex FDD. Each radio frame is $T_f = 307200 \cdot T_s = 10\,\text{ms}$ long and consists of 20 slots of length $T_{slot} = 15360 \cdot T_s = 0.5\,\text{ms}$, numbered from 0 to 19. A subframe is defined as two consecutive slots where subframe i consists of slots $2i$ and $2i+1$.

For FDD, 10 subframes are available for downlink transmission and 10 subframes are available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain. In half-duplex FDD operation, the UE cannot transmit and receive at the same time while there are no such restrictions in full-duplex FDD.

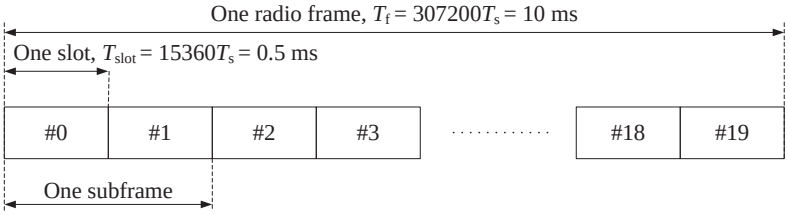


Figure 4.1-1: Frame structure type 1.

4.2 Frame structure type 2

Frame structure type 2 is applicable to TDD. Each radio frame of length $T_f = 307200 \cdot T_s = 10\,\text{ms}$ consists of two half-frames of length $153600 \cdot T_s = 5\,\text{ms}$ each. Each half-frame consists of five subframes of length $30720 \cdot T_s = 1\,\text{ms}$. The supported uplink-downlink configurations are listed in Table 4.2-2 where, for each subframe in a radio frame, “D” denotes the subframe is reserved for downlink transmissions, “U” denotes the subframe is reserved for uplink transmissions and “S” denotes a special subframe with the three fields DwPTS, GP and UpPTS. The length of DwPTS and UpPTS is given by Table 4.2-1 subject to the total length of DwPTS, GP and UpPTS being equal to $30720 \cdot T_s = 1\,\text{ms}$. Each subframe i is defined as two slots, $2i$ and $2i+1$ of length $T_{slot} = 15360 \cdot T_s = 0.5\,\text{ms}$ in each subframe.

Uplink-downlink configurations with both 5 ms and 10 ms downlink-to-uplink switch-point periodicity are supported.

In case of 5 ms downlink-to-uplink switch-point periodicity, the special subframe exists in both half-frames.

In case of 10 ms downlink-to-uplink switch-point periodicity, the special subframe exists in the first half-frame only.

Subframes 0 and 5 and DwPTS are always reserved for downlink transmission. UpPTS and the subframe immediately following the special subframe are always reserved for uplink transmission.

In case multiple cells are aggregated, the UE may assume the same uplink-downlink configuration across all the cells and that the guard period of the special subframe in the different cells have an overlap of at least $1456 \cdot T_s$.

Petitioners' Exhibit 1003, p. 801
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

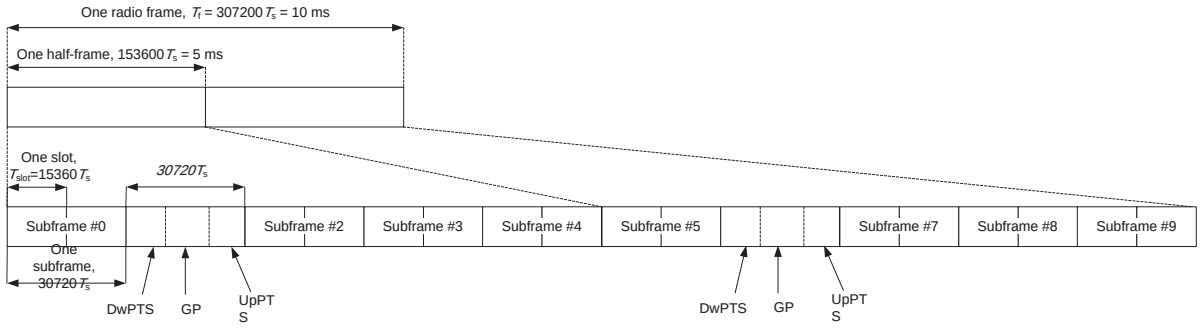


Figure 4.2-1: Frame structure type 2 (for 5 ms switch-point periodicity).

Table 4.2-1: Configuration of special subframe (lengths of DwPTS/GP/UpPTS).

Special subframe configuration	Normal cyclic prefix in downlink			Extended cyclic prefix in downlink		
	DwPTS	UpPTS		DwPTS	UpPTS	
		Normal cyclic prefix in uplink	Extended cyclic prefix in uplink		Normal cyclic prefix in uplink	Extended cyclic prefix in uplink
0	$6592 \cdot T_s$	$2192 \cdot T_s$	$2560 \cdot T_s$	$7680 \cdot T_s$	$2192 \cdot T_s$	$2560 \cdot T_s$
1	$19760 \cdot T_s$			$20480 \cdot T_s$		
2	$21952 \cdot T_s$			$23040 \cdot T_s$		
3	$24144 \cdot T_s$			$25600 \cdot T_s$		
4	$26336 \cdot T_s$			$7680 \cdot T_s$	$4384 \cdot T_s$	$5120 \cdot T_s$
5	$6592 \cdot T_s$	$4384 \cdot T_s$	$5120 \cdot T_s$	$20480 \cdot T_s$		
6	$19760 \cdot T_s$			$23040 \cdot T_s$		
7	$21952 \cdot T_s$			-	-	-
8	$24144 \cdot T_s$			-	-	-

Table 4.2-2: Uplink-downlink configurations.

Uplink-downlink configuration	Downlink-to-Uplink Switch-point periodicity	Subframe number									
		0	1	2	3	4	5	6	7	8	9
0	5 ms	D	S	U	U	U	D	S	U	U	U
1	5 ms	D	S	U	U	D	D	S	U	U	D
2	5 ms	D	S	U	D	D	D	S	U	D	D
3	10 ms	D	S	U	U	U	D	D	D	D	D
4	10 ms	D	S	U	U	D	D	D	D	D	D
5	10 ms	D	S	U	D	D	D	D	D	D	D
6	5 ms	D	S	U	U	U	D	S	U	U	D

5 Uplink

5.1 Overview

The smallest resource unit for uplink transmissions is denoted a resource element and is defined in section 5.2.2.

Petitioners' Exhibit 1003, p. 802
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.1.1 Physical channels

An uplink physical channel corresponds to a set of resource elements carrying information originating from higher layers and is the interface defined between 36.212 and 36.211. The following uplink physical channels are defined:

- Physical Uplink Shared Channel, PUSCH
- Physical Uplink Control Channel, PUCCH
- Physical Random Access Channel, PRACH

5.1.2 Physical signals

An uplink physical signal is used by the physical layer but does not carry information originating from higher layers. The following uplink physical signals are defined:

- Reference signal

5.2 Slot structure and physical resources

5.2.1 Resource grid

The transmitted signal in each slot is described by one or several resource grids of $N_{\mathrm{RB}}^{\mathrm{UL}} N_{\mathrm{sc}}^{\mathrm{RB}}$ subcarriers and $N_{\mathrm{symb}}^{\mathrm{UL}}$ SC-FDMA symbols. The resource grid is illustrated in Figure 5.2.1-1. The quantity $N_{\mathrm{RB}}^{\mathrm{UL}}$ depends on the uplink transmission bandwidth configured in the cell and shall fulfil

$$N_{\mathrm{RB}}^{\mathrm{min,UL}} \le N_{\mathrm{RB}}^{\mathrm{UL}} \le N_{\mathrm{RB}}^{\mathrm{max,UL}}$$

where $N_{\mathrm{RB}}^{\mathrm{min,UL}} = 6$ and $N_{\mathrm{RB}}^{\mathrm{max,UL}} = 110$ are the smallest and largest uplink bandwidths, respectively, supported by the current version of this specification. The set of allowed values for $N_{\mathrm{RB}}^{\mathrm{UL}}$ is given by [7].

The number of SC-FDMA symbols in a slot depends on the cyclic prefix length configured by the higher layer parameter *UL-CyclicPrefixLength* and is given in Table 5.2.3-1.

An antenna port is defined such that the channel over which a symbol on the antenna port is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed. There is one resource grid per antenna port. The antenna ports used for transmission of a physical channel or signal depends on the number of antenna ports configured for the physical channel or signal as shown in Table 5.2.1-1. The index $\tilde{p}$ is used throughout Section 5 when a sequential numbering of the antenna ports is necessary.

Petitioners' Exhibit 1003, p. 803
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

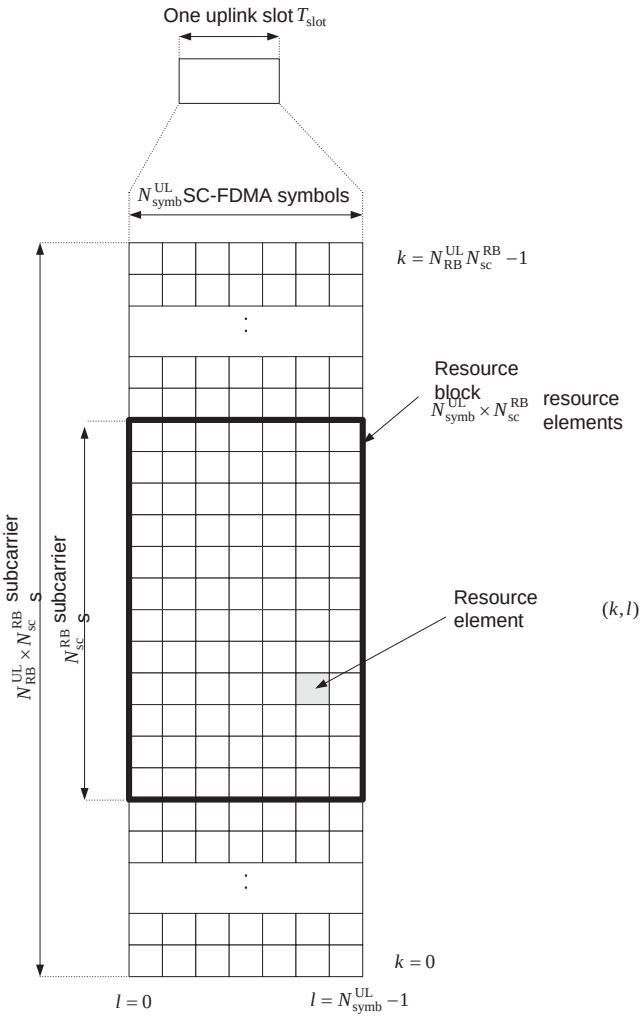


Figure 5.2.1-1: Uplink resource grid.

Table 5.2.1-1: The antenna ports used for different physical channels and signals.

Physical channel or signal	Index $\tilde{p}$	Antenna port number p as a function of the number of antenna ports configured for the respective physical channel/signal		
		1	2	4
PUSCH	0	10	20	40
	1	-	21	41
	2	-	-	42
	3	-	-	43
SRS	0	10	20	40
	1	-	21	41
	2	-	-	42
	3	-	-	43
PUCCH	0	100	200	-
	1	-	201	-

Petitioners' Exhibit 1003, p. 804
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.2.2 Resource elements

Each element in the resource grid is called a resource element and is uniquely defined by the index pair (k,l) in a slot where $k = 0,...,N_{\text{RB}}^{\text{UL}}N_{\text{sc}}^{\text{RB}} - 1$ and $l = 0,...,N_{\text{symb}}^{\text{UL}} - 1$ are the indices in the frequency and time domains, respectively. Resource element (k,l) on antenna port p corresponds to the complex value $a_{k,l}^{(p)}$. When there is no risk for confusion, or no particular antenna port is specified, the index p may be dropped. Quantities $a_{k,l}^{(p)}$ corresponding to resource elements not used for transmission of a physical channel or a physical signal in a slot shall be set to zero.

5.2.3 Resource blocks

A physical resource block is defined as $N_{\text{symb}}^{\text{UL}}$ consecutive SC-FDMA symbols in the time domain and $N_{\text{sc}}^{\text{RB}}$ consecutive subcarriers in the frequency domain, where $N_{\text{symb}}^{\text{UL}}$ and $N_{\text{sc}}^{\text{RB}}$ are given by Table 5.2.3-1. A physical resource block in the uplink thus consists of $N_{\text{symb}}^{\text{UL}} \times N_{\text{sc}}^{\text{RB}}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.

Table 5.2.3-1: Resource block parameters.

Configuration	$N_{\text{sc}}^{\text{RB}}$	$N_{\text{symb}}^{\text{UL}}$
Normal cyclic prefix	12	7
Extended cyclic prefix	12	6

The relation between the physical resource block number n_{PRB} in the frequency domain and resource elements (k,l) in a slot is given by

$$n_{\text{PRB}} = \left\lfloor \frac{k}{N_{\text{sc}}^{\text{RB}}} \right\rfloor$$

5.3 Physical uplink shared channel

The baseband signal representing the physical uplink shared channel is defined in terms of the following steps:

- scrambling
- modulation of scrambled bits to generate complex-valued symbols
- mapping of the complex-valued modulation symbols onto one or several transmission layers
- transform precoding to generate complex-valued symbols
- precoding of the complex-valued symbols
- mapping of precoded complex-valued symbols to resource elements
- generation of complex-valued time-domain SC-FDMA signal for each antenna port

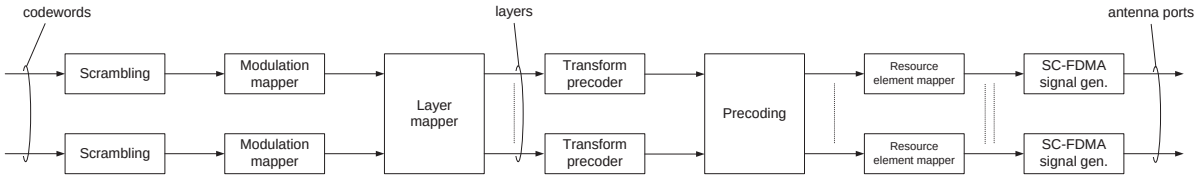


Figure 5.3-1: Overview of uplink physical channel processing.

Petitioners' Exhibit 1003, p. 805
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.3.1 Scrambling

For each codeword q, the block of bits $b^{(q)}(0),...,b^{(q)}(M_{\text{bit}}^{(q)}-1)$, where $M_{\text{bit}}^{(q)}$ is the number of bits transmitted in codeword q on the physical uplink shared channel in one subframe, shall be scrambled with a UE-specific scrambling sequence prior to modulation, resulting in a block of scrambled bits $\tilde{b}^{(q)}(0),...,\tilde{b}^{(q)}(M_{\text{bit}}^{(q)}-1)$ according to the following pseudo code

Set $i = 0$

while $i < M_{\text{bit}}^{(q)}$

if $b^{(q)}(i) = \text{x}$ // ACK/NACK or Rank Indication placeholder bits

$\tilde{b}^{(q)}(i) = 1$

else

if $b^{(q)}(i) = \text{y}$ // ACK/NACK or Rank Indication repetition placeholder bits

$\tilde{b}^{(q)}(i) = \tilde{b}^{(q)}(i-1)$

else // Data or channel quality coded bits, Rank Indication coded bits or ACK/NACK coded bits

$\tilde{b}^{(q)}(i) = \left(b^{(q)}(i) + c^{(q)}(i)\right) \bmod 2$

end if

end if

$i = i + 1$

end while

where x and y are tags defined in [3] section 5.2.2.6 and where the scrambling sequence $c^{(q)}(i)$ is given by Section 7.2. The scrambling sequence generator shall be initialised with $c_{\text{init}} = n_{\text{RNTI}} \cdot 2^{14} + q \cdot 2^{13} + \lfloor n_s/2 \rfloor \cdot 2^9 + N_{\text{ID}}^{\text{cell}}$ at the start of each subframe where n_{RNTI} corresponds to the RNTI associated with the PUSCH transmission as described in Section 8 in [4].

Up to two codewords can be transmitted in one subframe, i.e., $q \in \{0,1\}$. In the case of single-codeword transmission, $q = 0$.

5.3.2 Modulation

For each codeword q, the block of scrambled bits $\tilde{b}^{(q)}(0),...,\tilde{b}^{(q)}(M_{\text{bit}}^{(q)}-1)$ shall be modulated as described in Section 7.1, resulting in a block of complex-valued symbols $d^{(q)}(0),...,d^{(q)}(M_{\text{symb}}^{(q)}-1)$. Table 5.3.2-1 specifies the modulation mappings applicable for the physical uplink shared channel.

Table 5.3.2-1: Uplink modulation schemes.

Physical channel	Modulation schemes
PUSCH	QPSK, 16QAM, 64QAM

Petitioners' Exhibit 1003, p. 806
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.3.2A Layer mapping

The complex-valued modulation symbols for each of the codewords to be transmitted are mapped onto one or two layers. Complex-valued modulation symbols $d^{(q)}(0),...,d^{(q)}(M_{\text{symb}}^{(q)}-1)$ for codeword q shall be mapped onto the layers $x(i)=\left[x^{(0)}(i) \quad ... \quad x^{(\upsilon-1)}(i)\right]^T$, $i=0,1,...,M_{\text{symb}}^{\text{layer}}-1$ where υ is the number of layers and $M_{\text{symb}}^{\text{layer}}$ is the number of modulation symbols per layer.

5.3.2A.1 Layer mapping for transmission on a single antenna port

For transmission on a single antenna port, a single layer is used, $\upsilon=1$, and the mapping is defined by

$$x^{(0)}(i)=d^{(0)}(i)$$

with $M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}$.

5.3.2A.2 Layer mapping for spatial multiplexing

For spatial multiplexing, the layer mapping shall be done according to Table 5.3.2A.2-1. The number of layers υ is less than or equal to the number of antenna ports P used for transmission of the physical uplink shared channel. The case of a single codeword mapped to multiple layers is only applicable when the number of antenna ports used for PUSCH is four.

Table 5.3.2A.2-1: Codeword-to-layer mapping for spatial multiplexing.

Number of layers	Number of codewords	Codeword-to-layer mapping $i=0,1,...,M_{\text{symb}}^{\text{layer}}-1$
1	1	$x^{(0)}(i)=d^{(0)}(i)$ $\quad M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}$
2	1	$x^{(0)}(i)=d^{(0)}(2i)$ $x^{(1)}(i)=d^{(0)}(2i+1)$ $\quad M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}/2$
2	2	$x^{(0)}(i)=d^{(0)}(i)$ $x^{(1)}(i)=d^{(1)}(i)$ $\quad M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}=M_{\text{symb}}^{(1)}$
3	2	$x^{(0)}(i)=d^{(0)}(i)$ $x^{(1)}(i)=d^{(1)}(2i)$ $x^{(2)}(i)=d^{(1)}(2i+1)$ $\quad M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}=M_{\text{symb}}^{(1)}/2$
4	2	$x^{(0)}(i)=d^{(0)}(2i)$ $x^{(1)}(i)=d^{(0)}(2i+1)$ $x^{(2)}(i)=d^{(1)}(2i)$ $x^{(3)}(i)=d^{(1)}(2i+1)$ $\quad M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}/2=M_{\text{symb}}^{(1)}/2$

5.3.3 Transform precoding

For each layer $\lambda=0,1,...,\upsilon-1$ the block of complex-valued symbols $x^{(\lambda)}(0),...,x^{(\lambda)}(M_{\text{symb}}^{\text{layer}}-1)$ is divided into $M_{\text{symb}}^{\text{layer}}/M_{\text{sc}}^{\text{PUSCH}}$ sets, each corresponding to one SC-FDMA symbol. Transform precoding shall be applied according to

Petitioners' Exhibit 1003, p. 807
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$y^{(\lambda)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + k) = \frac{1}{\sqrt{M_{\text{sc}}^{\text{PUSCH}}}} \sum_{i=0}^{M_{\text{sc}}^{\text{PUSCH}}-1} x^{(\lambda)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + i) e^{-j\frac{2\pi ik}{M_{\text{sc}}^{\text{PUSCH}}}}$$
$$k = 0,...,M_{\text{sc}}^{\text{PUSCH}} - 1$$
$$l = 0,...,M_{\text{symb}}^{\text{layer}} / M_{\text{sc}}^{\text{PUSCH}} - 1$$

resulting in a block of complex-valued symbols $y^{(\lambda)}(0),...,y^{(\lambda)}(M_{\text{symb}}^{\text{layer}}-1)$. The variable $M_{\text{sc}}^{\text{PUSCH}} = M_{\text{RB}}^{\text{PUSCH}} \cdot N_{\text{sc}}^{\text{RB}}$, where $M_{\text{RB}}^{\text{PUSCH}}$ represents the bandwidth of the PUSCH in terms of resource blocks, and shall fulfil

$$M_{\text{RB}}^{\text{PUSCH}} = 2^{\alpha_2} \cdot 3^{\alpha_3} \cdot 5^{\alpha_5} \le N_{\text{RB}}^{\text{UL}}$$

where $\alpha_2, \alpha_3, \alpha_5$ is a set of non-negative integers.

5.3.3A Precoding

The precoder takes as input a block of vectors $\left[y^{(0)}(i) \quad ... \quad y^{(\upsilon-1)}(i)\right]^T$, $i = 0,1,...,M_{\text{symb}}^{\text{layer}}-1$ from the transform precoder and generates a block of vectors $\left[z^{(0)}(i) \quad \ldots \quad z^{(P-1)}(i)\right]^T$, $i = 0,1,...,M_{\text{symb}}^{\text{ap}}-1$ to be mapped onto resource elements.

5.3.3A.1 Precoding for transmission on a single antenna port

For transmission on a single antenna port, precoding is defined by

$$z^{(0)}(i) = y^{(0)}(i)$$

where $i = 0,1,...,M_{\text{symb}}^{\text{ap}}-1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

5.3.3A.2 Precoding for spatial multiplexing

Precoding for spatial multiplexing is only used in combination with layer mapping for spatial multiplexing as described in Section 5.3.2A.2. Spatial multiplexing supports $P = 2$ or $P = 4$ antenna ports where the set of antenna ports used for spatial multiplexing is $p \in \{20,21\}$ and $p \in \{40,41,42,43\}$, respectively.

Precoding for spatial multiplexing is defined by

$$\begin{bmatrix} z^{(0)}(i) \\ \vdots \\ z^{(P-1)}(i) \end{bmatrix} = W \begin{bmatrix} y^{(0)}(i) \\ \vdots \\ y^{(\upsilon-1)}(i) \end{bmatrix}$$

where $i = 0,1,...,M_{\text{symb}}^{\text{ap}}-1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

The precoding matrix W of size $P \times \upsilon$ is given by one of the entries in Table 5.3.3A.2-1 for $P = 2$ and by Tables 5.3.3A.2-2 through 5.3.3A.2-5 for $P = 4$ where the entries in each row are ordered from left to right in increasing order of codebook indices.

Table 5.3.3A.2-1: Codebook for transmission on antenna ports $\{20,21\}$.

Codebook index	Number of layers	
	$\upsilon = 1$	$\upsilon = 2$

Petitioners' Exhibit 1003, p. 808
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

0	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\1\end{bmatrix}$	$\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}$
1	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-1\end{bmatrix}$	-
2	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\j\end{bmatrix}$	-
3	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-j\end{bmatrix}$	-
4	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\0\end{bmatrix}$	-
5	$\frac{1}{\sqrt{2}}\begin{bmatrix}0\\1\end{bmatrix}$	-

Table 5.3.3A.2-2: Codebook for transmission on antenna ports $\{40,41,42,43\}$ with $\upsilon=1$.

Codebook index	Number of layers $\upsilon=1$							
0 – 7	$\frac{1}{2}\begin{bmatrix}1\\1\\1\\-1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\1\\j\\j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\1\\-1\\1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\1\\-j\\-j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\j\\1\\j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\j\\j\\1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\j\\-1\\-j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\j\\-j\\-1\end{bmatrix}$
8 – 15	$\frac{1}{2}\begin{bmatrix}1\\-1\\1\\1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\-1\\j\\-j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\-1\\-1\\-1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\-1\\-j\\j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\-j\\1\\-j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\-j\\j\\-1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\-j\\-1\\j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\-j\\-j\\1\end{bmatrix}$
16 – 23	$\frac{1}{2}\begin{bmatrix}1\\0\\1\\0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\0\\-1\\0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\0\\j\\0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\0\\-j\\0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}0\\1\\0\\1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}0\\1\\0\\-1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}0\\1\\0\\j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}0\\1\\0\\-j\end{bmatrix}$

Petitioners' Exhibit 1003, p. 809
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.3.3A.2-3: Codebook for transmission on antenna ports $\{40,41,42,43\}$ with $\upsilon=2$.

Codebook index	Number of layers $\upsilon=2$			
0 – 3	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 1 & 0\\ 0 & 1\\ 0 & -j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 1 & 0\\ 0 & 1\\ 0 & j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ -j & 0\\ 0 & 1\\ 0 & 1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ -j & 0\\ 0 & 1\\ 0 & -1\end{bmatrix}$
4 – 7	$\frac{1}{2}\begin{bmatrix}1 & 0\\ -1 & 0\\ 0 & 1\\ 0 & -j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ -1 & 0\\ 0 & 1\\ 0 & j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ j & 0\\ 0 & 1\\ 0 & 1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ j & 0\\ 0 & 1\\ 0 & -1\end{bmatrix}$
8 – 11	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ 1 & 0\\ 0 & 1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ 1 & 0\\ 0 & -1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ -1 & 0\\ 0 & 1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ -1 & 0\\ 0 & -1\end{bmatrix}$
12 – 15	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ 0 & 1\\ 1 & 0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ 0 & -1\\ 1 & 0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ 0 & 1\\ -1 & 0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ 0 & -1\\ -1 & 0\end{bmatrix}$

Table 5.3.3A.2-4: Codebook for transmission on antenna ports $\{40,41,42,43\}$ with $\upsilon=3$.

Codebook index	Number of layers $\upsilon=3$			
0 – 3	$\frac{1}{2}\begin{bmatrix}1 & 0 & 0\\ 1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0 & 0\\ -1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 1 & 0 & 0\\ 0 & 0 & 1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ -1 & 0 & 0\\ 0 & 0 & 1\end{bmatrix}$
4 – 7	$\frac{1}{2}\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\\ 1 & 0 & 0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\\ -1 & 0 & 0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}0 & 1 & 0\\ 1 & 0 & 0\\ 1 & 0 & 0\\ 0 & 0 & 1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}0 & 1 & 0\\ 1 & 0 & 0\\ -1 & 0 & 0\\ 0 & 0 & 1\end{bmatrix}$
8 – 11	$\frac{1}{2}\begin{bmatrix}0 & 1 & 0\\ 1 & 0 & 0\\ 0 & 0 & 1\\ 1 & 0 & 0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}0 & 1 & 0\\ 1 & 0 & 0\\ 0 & 0 & 1\\ -1 & 0 & 0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ 1 & 0 & 0\\ 1 & 0 & 0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ 1 & 0 & 0\\ -1 & 0 & 0\end{bmatrix}$

Table 5.3.3A.2-5: Codebook for transmission on antenna ports $\{40,41,42,43\}$ with $\upsilon=4$.

Codebook index	Number of layers $\upsilon=4$
0	$\frac{1}{2}\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}$

Petitioners' Exhibit 1003, p. 810
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.3.4 Mapping to physical resources

For each antenna port p used for transmission of the PUSCH in a subframe the block of complex-valued symbols $z^{(\tilde{p})}(0),\ldots,z^{(\tilde{p})}(M^{\text{ap}}_{\text{symb}}-1)$ shall be multiplied with the amplitude scaling factor β_{PUSCH} in order to conform to the transmit power P_{PUSCH} specified in Section 5.1.1.1 in [4], and mapped in sequence starting with $z^{(\tilde{p})}(0)$ to physical resource blocks on antenna port p and assigned for transmission of PUSCH. The relation between the index $\tilde{p}$ and the antenna port number p is given by Table 5.2.1-1. The mapping to resource elements (k,l) corresponding to the physical resource blocks assigned for transmission and

- not used for transmission of reference signals, and
- not part of the last SC-FDMA symbol in a subframe, if the UE transmits SRS in the same subframe, and
- not part of the last SC-FDMA symbol in a subframe configured with cell-specific SRS, if the PUSCH transmission partly or fully overlaps with the cell-specific SRS bandwidth, and
- not part of an SC-FDMA symbol reserved for possible SRS transmission in a UE-specific aperiodic SRS subframe

shall be in increasing order of first the index k, then the index l, starting with the first slot in the subframe.

If uplink frequency-hopping is disabled or the resource blocks allocated for PUSCH transmission are not contiguous in frequency, the set of physical resource blocks to be used for transmission is given by $n_{\text{PRB}} = n_{\text{VRB}}$ where n_{VRB} is obtained from the uplink scheduling grant as described in Section 8.1 in [4].

If uplink frequency-hopping with type 1 PUSCH hopping is enabled, the set of physical resource blocks to be used for transmission is given by Section 8.4.1 in [4].

If uplink frequency-hopping with predefined hopping pattern is enabled, the set of physical resource blocks to be used for transmission in slot n_s is given by the scheduling grant together with a predefined pattern according to

$$\tilde{n}_{\text{PRB}}(n_s) = \left(\tilde{n}_{\text{VRB}} + f_{\text{hop}}(i)\cdot N^{\text{sb}}_{\text{RB}} + \left(\left(N^{\text{sb}}_{\text{RB}}-1\right)-2\left(\tilde{n}_{\text{VRB}} \bmod N^{\text{sb}}_{\text{RB}}\right)\right)\cdot f_{\text{m}}(i)\right) \bmod (N^{\text{sb}}_{\text{RB}}\cdot N_{\text{sb}})$$

$$i = \begin{cases} \lfloor n_s/2 \rfloor & \text{inter-subframe hopping} \\ n_s & \text{intra and inter-subframe hopping} \end{cases}$$

$$n_{\text{PRB}}(n_s) = \begin{cases} \tilde{n}_{\text{PRB}}(n_s) & N_{sb}=1 \\ \tilde{n}_{\text{PRB}}(n_s)+\left\lceil N^{\text{HO}}_{\text{RB}}/2 \right\rceil & N_{sb}>1 \end{cases}$$

$$\tilde{n}_{\text{VRB}} = \begin{cases} n_{\text{VRB}} & N_{sb}=1 \\ n_{\text{VRB}}-\left\lceil N^{\text{HO}}_{\text{RB}}/2 \right\rceil & N_{sb}>1 \end{cases}$$

where n_{VRB} is obtained from the scheduling grant as described in Section 8.1 in [4]. The parameter *pusch-HoppingOffset*, $N^{\text{HO}}_{\text{RB}}$, is provided by higher layers. The size $N^{\text{sb}}_{\text{RB}}$ of each sub-band is given by,

$$N^{\text{sb}}_{\text{RB}} = \begin{cases} N^{\text{UL}}_{\text{RB}} & N_{\text{sb}}=1 \\ \left\lfloor \left(N^{\text{UL}}_{\text{RB}} - N^{\text{HO}}_{\text{RB}} - N^{\text{HO}}_{\text{RB}} \bmod 2\right)/N_{\text{sb}} \right\rfloor & N_{\text{sb}}>1 \end{cases}$$

where the number of sub-bands N_{sb} is given by higher layers. The function $f_{\text{m}}(i) \in \{0,1\}$ determines whether mirroring is used or not. The parameter *Hopping-mode* provided by higher layers determines if hopping is "inter-subframe" or "intra and inter-subframe".

The hopping function $f_{\text{hop}}(i)$ and the function $f_{\text{m}}(i)$ are given by

Petitioners' Exhibit 1003, p. 811
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$f_{\text{hop}}(i)=\begin{cases}0 & N_{\text{sb}}=1\\ (f_{\text{hop}}(i-1)+\sum_{k=i\cdot 10+1}^{i\cdot 10+9}c(k)\times 2^{k-(i\cdot 10+1)})\bmod N_{\text{sb}} & N_{\text{sb}}=2\\ (f_{\text{hop}}(i-1)+\left(\sum_{k=i\cdot 10+1}^{i\cdot 10+9}c(k)\times 2^{k-(i\cdot 10+1)}\right)\bmod(N_{\text{sb}}-1)+1)\bmod N_{\text{sb}} & N_{\text{sb}}>2\end{cases}$$

$$f_{\text{m}}(i)=\begin{cases}i \bmod 2 & N_{\text{sb}}=1 \text{ and intra and inter}-\text{subframe hopping}\\ \text{CURRENT\_TX\_NB} \bmod 2 & N_{\text{sb}}=1 \text{ and inter}-\text{subframe hopping}\\ c(i\cdot 10) & N_{\text{sb}}>1\end{cases}$$

where $f_{\text{hop}}(-1)=0$ and the pseudo-random sequence $c(i)$ is given by section 7.2 and CURRENT_TX_NB indicates the transmission number for the transport block transmitted in slot n_{s} as defined in [8]. The pseudo-random sequence generator shall be initialised with $c_{\text{init}}=N_{\text{ID}}^{\text{cell}}$ for frame structure type 1 and $c_{\text{init}}=2^9\cdot(n_{\text{f}} \bmod 4)+N_{\text{ID}}^{\text{cell}}$ for frame structure type 2 at the start of each frame.

5.4 Physical uplink control channel

The physical uplink control channel, PUCCH, carries uplink control information. Simultaneous transmission of PUCCH and PUSCH from the same UE is supported if enabled by higher layers. For frame structure type 2, the PUCCH is not transmitted in the UpPTS field.

The physical uplink control channel supports multiple formats as shown in Table 5.4-1. Formats 2a and 2b are supported for normal cyclic prefix only.

Table 5.4-1: Supported PUCCH formats.

PUCCH format	Modulation scheme	Number of bits per subframe, M_{bit}
1	N/A	N/A
1a	BPSK	1
1b	QPSK	2
2	QPSK	20
2a	QPSK+BPSK	21
2b	QPSK+QPSK	22
3	QPSK	48

All PUCCH formats use a cell-specific cyclic shift, $n_{\text{cs}}^{\text{cell}}(n_{\text{s}},l)$, which varies with the symbol number l and the slot number n_{s} according to

$$n_{\text{cs}}^{\text{cell}}(n_{\text{s}},l)=\sum_{i=0}^{7}c(8N_{\text{symb}}^{\text{UL}}\cdot n_{\text{s}}+8l+i)\cdot 2^i$$

where the pseudo-random sequence $c(i)$ is defined by section 7.2. The pseudo-random sequence generator shall be initialized with $c_{\text{init}}=N_{\text{ID}}^{\text{cell}}$ corresponding to the primary cell at the beginning of each radio frame.

The physical resources used for PUCCH depends on two parameters, $N_{\text{RB}}^{(2)}$ and $N_{\text{cs}}^{(1)}$, given by higher layers. The variable $N_{\text{RB}}^{(2)}\geq 0$ denotes the bandwidth in terms of resource blocks that are available for use by PUCCH formats 2/2a/2b transmission in each slot. The variable $N_{\text{cs}}^{(1)}$ denotes the number of cyclic shift used for PUCCH formats 1/1a/1b in a resource block used for a mix of formats 1/1a/1b and 2/2a/2b. The value of $N_{\text{cs}}^{(1)}$ is an integer multiple of $\Delta_{\text{shift}}^{\text{PUCCH}}$ within the range of {0, 1, …, 7}, where $\Delta_{\text{shift}}^{\text{PUCCH}}$ is provided by higher layers. No mixed resource block is present if $N_{\text{cs}}^{(1)}=0$. At most one resource block in each slot supports a mix of formats 1/1a/1b and 2/2a/2b. Resources

Petitioners' Exhibit 1003, p. 812
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

used for transmission of PUCCH formats 1/1a/1b, 2/2a/2b and 3 are represented by the non-negative indices $n_{\mathrm{PUCCH}}^{(1,\tilde{p})}$, $n_{\mathrm{PUCCH}}^{(2,\tilde{p})} < N_{\mathrm{RB}}^{(2)} N_{\mathrm{sc}}^{\mathrm{RB}} + \left\lceil \frac{N_{\mathrm{cs}}^{(1)}}{8} \right\rceil \cdot (N_{\mathrm{sc}}^{\mathrm{RB}} - N_{\mathrm{cs}}^{(1)} - 2)$, and $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$, respectively.

5.4.1 PUCCH formats 1, 1a and 1b

For PUCCH format 1, information is carried by the presence/absence of transmission of PUCCH from the UE. In the remainder of this section, $d(0) = 1$ shall be assumed for PUCCH format 1.

For PUCCH formats 1a and 1b, one or two explicit bits are transmitted, respectively. The block of bits $b(0),...,b(M_{\mathrm{bit}} - 1)$ shall be modulated as described in Table 5.4.1-1, resulting in a complex-valued symbol $d(0)$. The modulation schemes for the different PUCCH formats are given by Table 5.4-1.

The complex-valued symbol $d(0)$ shall be multiplied with a cyclically shifted length $N_{\mathrm{seq}}^{\mathrm{PUCCH}} = 12$ sequence $r_{u,v}^{(\alpha_{\tilde{p}})}(n)$ for each of the P antenna ports used for PUCCH transmission according to

$$y^{(\tilde{p})}(n) = \frac{1}{\sqrt{P}} d(0) \cdot r_{u,v}^{(\alpha_{\tilde{p}})}(n), \qquad n = 0,1,...,N_{\mathrm{seq}}^{\mathrm{PUCCH}} - 1$$

where $r_{u,v}^{(\alpha_{\tilde{p}})}(n)$ is defined by section 5.5.1 with $M_{\mathrm{sc}}^{\mathrm{RS}} = N_{\mathrm{seq}}^{\mathrm{PUCCH}}$. The antenna-port specific cyclic shift $\alpha_{\tilde{p}}$ varies between symbols and slots as defined below.

The block of complex-valued symbols $y^{(\tilde{p})}(0),...,y^{(\tilde{p})}(N_{\mathrm{seq}}^{\mathrm{PUCCH}} - 1)$ shall be scrambled by $S(n_s)$ and block-wise spread with the antenna-port specific orthogonal sequence $w_{n_{\mathrm{oc}}^{(\tilde{p})}}(i)$ according to

$$z^{(\tilde{p})}\left(m' \cdot N_{\mathrm{SF}}^{\mathrm{PUCCH}} \cdot N_{\mathrm{seq}}^{\mathrm{PUCCH}} + m \cdot N_{\mathrm{seq}}^{\mathrm{PUCCH}} + n\right) = S(n_{\mathrm{s}}) \cdot w_{n_{\mathrm{oc}}^{(\tilde{p})}}(m) \cdot y^{(\tilde{p})}(n)$$

where

$$m = 0,...,N_{\mathrm{SF}}^{\mathrm{PUCCH}} - 1$$
$$n = 0,...,N_{\mathrm{seq}}^{\mathrm{PUCCH}} - 1$$
$$m' = 0,1$$

and

$$S(n_{\mathrm{s}}) = \begin{cases} 1 & \text{if } n'_{\tilde{p}}(n_{\mathrm{s}}) \bmod 2 = 0 \\ e^{j\pi/2} & \text{otherwise} \end{cases}$$

with $N_{\mathrm{SF}}^{\mathrm{PUCCH}} = 4$ for both slots of normal PUCCH formats 1/1a/1b, and $N_{\mathrm{SF}}^{\mathrm{PUCCH}} = 4$ for the first slot and $N_{\mathrm{SF}}^{\mathrm{PUCCH}} = 3$ for the second slot of shortened PUCCH formats 1/1a/1b. The sequence $w_{n_{\mathrm{oc}}^{(\tilde{p})}}(i)$ is given by Table 5.4.1-2 and Table 5.4.1-3 and $n'_{\tilde{p}}(n_{\mathrm{s}})$ is defined below.

Resources used for transmission of PUCCH format 1, 1a and 1b are identified by a resource index $n_{\mathrm{PUCCH}}^{(1,\tilde{p})}$ from which the orthogonal sequence index $n_{\mathrm{oc}}^{(\tilde{p})}(n_{\mathrm{s}})$ and the cyclic shift $\alpha_{\tilde{p}}(n_{\mathrm{s}}, l)$ are determined according to

Petitioners' Exhibit 1003, p. 813
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$n_{\mathrm{oc}}^{(\tilde{p})}(n_{\mathrm{s}}) = \begin{cases} \left\lfloor n'_{\tilde{p}}(n_{\mathrm{s}}) \cdot \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} / N' \right\rfloor & \text{for normal cyclic prefix} \\ 2 \cdot \left\lfloor n'_{\tilde{p}}(n_{\mathrm{s}}) \cdot \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} / N' \right\rfloor & \text{for extended cyclic prefix} \end{cases}$$

$$\alpha_{\tilde{p}}(n_{\mathrm{s}}, l) = 2\pi \cdot n_{\mathrm{cs}}^{(\tilde{p})}(n_{\mathrm{s}}, l) / N_{\mathrm{sc}}^{\mathrm{RB}}$$

$$n_{\mathrm{cs}}^{(\tilde{p})}(n_{\mathrm{s}}, l) = \begin{cases} \left[n_{\mathrm{cs}}^{\mathrm{cell}}(n_{\mathrm{s}}, l) + \left(n'_{\tilde{p}}(n_{\mathrm{s}}) \cdot \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} + \left(n_{\mathrm{oc}}^{(\tilde{p})}(n_{\mathrm{s}}) \bmod \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} \right) \right) \bmod N' \right] \bmod N_{\mathrm{sc}}^{\mathrm{RB}} & \text{for normal cyclic prefix} \\ \left[n_{\mathrm{cs}}^{\mathrm{cell}}(n_{\mathrm{s}}, l) + \left(n'_{\tilde{p}}(n_{\mathrm{s}}) \cdot \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} + n_{\mathrm{oc}}^{(\tilde{p})}(n_{\mathrm{s}}) / 2 \right) \bmod N' \right] \bmod N_{\mathrm{sc}}^{\mathrm{RB}} & \text{for extended cyclic prefix} \end{cases}$$

where

$$N' = \begin{cases} N_{\mathrm{cs}}^{(1)} & \text{if } n_{\mathrm{PUCCH}}^{(1,\tilde{p})} < c \cdot N_{\mathrm{cs}}^{(1)} / \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} \\ N_{\mathrm{sc}}^{\mathrm{RB}} & \text{otherwise} \end{cases}$$

$$c = \begin{cases} 3 & \text{normal cyclic prefix} \\ 2 & \text{extended cyclic prefix} \end{cases}$$

The resource indices within the two resource blocks in the two slots of a subframe to which the PUCCH is mapped are given by

$$n'_{\tilde{p}}(n_{\mathrm{s}}) = \begin{cases} n_{\mathrm{PUCCH}}^{(1,\tilde{p})} & \text{if } n_{\mathrm{PUCCH}}^{(1,\tilde{p})} < c \cdot N_{\mathrm{cs}}^{(1)} / \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} \\ \left(n_{\mathrm{PUCCH}}^{(1,\tilde{p})} - c \cdot N_{\mathrm{cs}}^{(1)} / \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} \right) \bmod \left(c \cdot N_{\mathrm{sc}}^{\mathrm{RB}} / \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} \right) & \text{otherwise} \end{cases}$$

for $n_{\mathrm{s}} \bmod 2 = 0$ and by

$$n'_{\tilde{p}}(n_{\mathrm{s}}) = \begin{cases} \left[c\left(n'_{\tilde{p}}(n_{\mathrm{s}} - 1) + 1 \right) \right] \bmod \left(c N_{\mathrm{sc}}^{\mathrm{RB}} / \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} + 1 \right) - 1 & n_{\mathrm{PUCCH}}^{(1,\tilde{p})} \geq c \cdot N_{\mathrm{cs}}^{(1)} / \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} \\ \left\lfloor h_{\tilde{p}} / c \right\rfloor + \left(h_{\tilde{p}} \bmod c \right) N' / \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} & \text{otherwise} \end{cases}$$

for $n_{\mathrm{s}} \bmod 2 = 1$, where $h_{\tilde{p}} = \left(n'_{\tilde{p}}(n_{\mathrm{s}} - 1) + d \right) \bmod \left(c N' / \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} \right)$, with $d = 2$ for normal CP and $d = 0$ for extended CP.

The parameter *deltaPUCCH-Shift* $\Delta_{\mathrm{shift}}^{\mathrm{PUCCH}}$ is provided by higher layers.

Table 5.4.1-1: Modulation symbol $d(0)$ for PUCCH formats 1a and 1b.

PUCCH format	$b(0),\ldots,b(M_{\mathrm{bit}}-1)$	$d(0)$
1a	0	1
	1	-1
1b	00	1
	01	$-j$
	10	j
	11	-1

Table 5.4.1-2: Orthogonal sequences $\left[w(0) \quad \cdots \quad w(N_{\mathrm{SF}}^{\mathrm{PUCCH}} - 1) \right]$ for $N_{\mathrm{SF}}^{\mathrm{PUCCH}} = 4$.

Sequence index $n_{\mathrm{oc}}^{(\tilde{p})}(n_{\mathrm{s}})$	Orthogonal sequences $\left[w(0) \quad \cdots \quad w(N_{\mathrm{SF}}^{\mathrm{PUCCH}} - 1) \right]$
0	$[+1 \quad +1 \quad +1 \quad +1]$
1	$[+1 \quad -1 \quad +1 \quad -1]$
2	$[+1 \quad -1 \quad -1 \quad +1]$

Petitioners' Exhibit 1003, p. 814
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.4.1-3: Orthogonal sequences $\left[w(0) \quad \cdots \quad w(N_{\mathrm{SF}}^{\mathrm{PUCCH}}-1)\right]$ for $N_{\mathrm{SF}}^{\mathrm{PUCCH}}=3$.

Sequence index $n_{\mathrm{oc}}^{(\tilde{p})}(n_s)$	Orthogonal sequences $\left[w(0) \quad \cdots \quad w(N_{\mathrm{SF}}^{\mathrm{PUCCH}}-1)\right]$
0	$\left[1 \quad 1 \quad 1\right]$
1	$\left[1 \quad e^{j2\pi/3} \quad e^{j4\pi/3}\right]$
2	$\left[1 \quad e^{j4\pi/3} \quad e^{j2\pi/3}\right]$

5.4.2 PUCCH formats 2, 2a and 2b

The block of bits $b(0),\ldots,b(19)$ shall be scrambled with a UE-specific scrambling sequence, resulting in a block of scrambled bits $\tilde{b}(0),\ldots,\tilde{b}(19)$ according to

$$\tilde{b}(i)=\left(b(i)+c(i)\right)\bmod 2$$

where the scrambling sequence $c(i)$ is given by Section 7.2. The scrambling sequence generator shall be initialised with $c_{\mathrm{init}}=\left(\lfloor n_s/2\rfloor+1\right)\cdot\left(2N_{\mathrm{ID}}^{\mathrm{cell}}+1\right)\cdot 2^{16}+n_{\mathrm{RNTI}}$ at the start of each subframe where n_{RNTI} is C-RNTI.

The block of scrambled bits $\tilde{b}(0),\ldots,\tilde{b}(19)$ shall be QPSK modulated as described in Section 7.1, resulting in a block of complex-valued modulation symbols $d(0),\ldots,d(9)$.

Each complex-valued symbol $d(0),\ldots,d(9)$ shall be multiplied with a cyclically shifted length $N_{\mathrm{seq}}^{\mathrm{PUCCH}}=12$ sequence $r_{u,v}^{(\alpha_{\tilde{p}})}(n)$ for each of the P antenna ports used for PUCCH transmission according to

$$z^{(\tilde{p})}(N_{\mathrm{seq}}^{\mathrm{PUCCH}}\cdot n+i)=\frac{1}{\sqrt{P}}d(n)\cdot r_{u,v}^{(\alpha_{\tilde{p}})}(i)$$
$$n=0,1,\ldots,9$$
$$i=0,1,\ldots,N_{\mathrm{sc}}^{\mathrm{RB}}-1$$

where $r_{u,v}^{(\alpha_{\tilde{p}})}(i)$ is defined by section 5.5.1 with $M_{\mathrm{sc}}^{\mathrm{RS}}=N_{\mathrm{seq}}^{\mathrm{PUCCH}}$.

Resources used for transmission of PUCCH formats 2/2a/2b are identified by a resource index $n_{\mathrm{PUCCH}}^{(2,\tilde{p})}$ from which the cyclic shift $\alpha_{\tilde{p}}(n_s,l)$ is determined according to

$$\alpha_{\tilde{p}}(n_s,l)=2\pi\cdot n_{\mathrm{cs}}^{(\tilde{p})}(n_s,l)/N_{\mathrm{sc}}^{\mathrm{RB}}$$

where

$$n_{\mathrm{cs}}^{(\tilde{p})}(n_s,l)=\left(n_{\mathrm{cs}}^{\mathrm{cell}}(n_s,l)+n'_{\tilde{p}}(n_s)\right)\bmod N_{\mathrm{sc}}^{\mathrm{RB}}$$

and

$$n'_{\tilde{p}}(n_s)=\begin{cases}n_{\mathrm{PUCCH}}^{(2,\tilde{p})}\bmod N_{\mathrm{sc}}^{\mathrm{RB}} & \text{if } n_{\mathrm{PUCCH}}^{(2,\tilde{p})}<N_{\mathrm{sc}}^{\mathrm{RB}}N_{\mathrm{RB}}^{(2)}\\ \left(n_{\mathrm{PUCCH}}^{(2,\tilde{p})}+N_{\mathrm{cs}}^{(1)}+1\right)\bmod N_{\mathrm{sc}}^{\mathrm{RB}} & \text{otherwise}\end{cases}$$

for $n_s \bmod 2=0$ and by

Petitioners' Exhibit 1003, p. 815
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$n'_{\tilde{p}}(n_s)=\begin{cases}\left[N_{sc}^{RB}\left(n'_{\tilde{p}}(n_s-1)+1\right)\right]\bmod\left(N_{sc}^{RB}+1\right)-1 & \text{if } n_{PUCCH}^{(2,\tilde{p})}<N_{sc}^{RB}N_{RB}^{(2)}\\ \left(N_{sc}^{RB}-2-n_{PUCCH}^{(2,\tilde{p})}\right)\bmod N_{sc}^{RB} & \text{otherwise}\end{cases}$$

for $n_s \bmod 2 = 1$.

For PUCCH formats 2a and 2b, supported for normal cyclic prefix only, the bit(s) $b(20),...,b(M_{bit}-1)$ shall be modulated as described in Table 5.4.2-1 resulting in a single modulation symbol $d(10)$ used in the generation of the reference-signal for PUCCH format 2a and 2b as described in Section 5.5.2.2.1.

Table 5.4.2-1: Modulation symbol $d(10)$ for PUCCH formats 2a and 2b.

PUCCH format	$b(20),...,b(M_{bit}-1)$	$d(10)$
2a	0	1
	1	−1
2b	00	1
	01	$-j$
	10	j
	11	−1

5.4.2A PUCCH format 3

The block of bits $b(0),...,b(M_{bit}-1)$ shall be scrambled with a UE-specific scrambling sequence, resulting in a block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{bit}-1)$ according to

$$\tilde{b}(i)=\left(b(i)+c(i)\right)\bmod 2$$

where the scrambling sequence $c(i)$ is given by Section 7.2. The scrambling sequence generator shall be initialised with $c_{init}=\left(\lfloor n_s/2\rfloor+1\right)\cdot\left(2N_{ID}^{cell}+1\right)\cdot 2^{16}+n_{RNTI}$ at the start of each subframe where n_{RNTI} is the C-RNTI.

The block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{bit}-1)$ shall be QPSK modulated as described in Section 7.1, resulting in a block of complex-valued modulation symbols $d(0),...,d(M_{symb}-1)$ where $M_{symb}=M_{bit}/2=2N_{sc}^{RB}$.

The complex-valued symbols $d(0),...,d(M_{symb}-1)$ shall be block-wise spread with the orthogonal sequences $w_{n_{oc,0}^{(\tilde{p})}}(i)$ and $w_{n_{oc,1}^{(\tilde{p})}}(i)$ resulting in $N_{SF,0}^{PUCCH}+N_{SF,1}^{PUCCH}$ sets of N_{sc}^{RB} values each according to

$$y_n^{(\tilde{p})}(i)=\begin{cases}w_{n_{oc,0}^{(\tilde{p})}}(\bar{n})\cdot e^{j\pi\left\lfloor n_{cs}^{cell}(n_s,l)/64\right\rfloor/2}\cdot d(i) & n<N_{SF,0}^{PUCCH}\\ w_{n_{oc,1}^{(\tilde{p})}}(\bar{n})\cdot e^{j\pi\left\lfloor n_{cs}^{cell}(n_s,l)/64\right\rfloor/2}\cdot d(N_{sc}^{RB}+i) & \text{otherwise}\end{cases}$$

$$\bar{n}=n \bmod N_{SF,0}^{PUCCH}$$

$$n=0,...,N_{SF,0}^{PUCCH}+N_{SF,1}^{PUCCH}-1$$

$$i=0,1,...,N_{sc}^{RB}-1$$

where $N_{SF,0}^{PUCCH}=N_{SF,1}^{PUCCH}=5$ for both slots in a subframe using normal PUCCH format 3 and $N_{SF,0}^{PUCCH}=5$, $N_{SF,1}^{PUCCH}=4$ holds for the first and second slot, respectively, in a subframe using shortened PUCCH format 3. The orthogonal sequences $w_{n_{oc,0}^{(\tilde{p})}}(i)$ and $w_{n_{oc,1}^{(\tilde{p})}}(i)$ are given by Table 5.4.2A-1. Resources used for transmission of PUCCH formats 3 are identified by a resource index $n_{PUCCH}^{(3,\tilde{p})}$ from which the quantities $n_{oc,0}^{(\tilde{p})}$ and $n_{oc,1}^{(\tilde{p})}$ are derived according to

Petitioners' Exhibit 1003, p. 816
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$n_{\text{oc},0}^{(\tilde{p})} = n_{\text{PUCCH}}^{(3,\tilde{p})} \bmod N_{\text{SF},1}^{\text{PUCCH}}$$
$$n_{\text{oc},1}^{(\tilde{p})} = \begin{cases} \left(3n_{\text{oc},0}^{(\tilde{p})}\right) \bmod N_{\text{SF},1}^{\text{PUCCH}} & \text{if } N_{\text{SF},1}^{\text{PUCCH}} = 5 \\ n_{\text{oc},0}^{(\tilde{p})} \bmod N_{\text{SF},1}^{\text{PUCCH}} & \text{otherwise} \end{cases}$$

Each set of complex-valued symbols shall be cyclically shifted according to

$$\tilde{y}_n^{(\tilde{p})}(i) = y_n^{(\tilde{p})}\left(\left(i + n_{\text{cs}}^{\text{cell}}(n_{\text{s}}, l)\right) \bmod N_{\text{sc}}^{\text{RB}}\right)$$

where $n_{\text{cs}}^{\text{cell}}(n_{\text{s}}, l)$ is given by Section 5.4, n_{s} is the slot number within a radio frame and l is the SC-FDMA symbol number within a slot.

The shifted sets of complex-valued symbols shall be transform precoded according to

$$z^{(\tilde{p})}(n \cdot N_{\text{sc}}^{\text{RB}} + k) = \frac{1}{\sqrt{P}} \frac{1}{\sqrt{N_{\text{sc}}^{\text{RB}}}} \sum_{i=0}^{N_{\text{sc}}^{\text{RB}}-1} \tilde{y}_n^{(\tilde{p})}(i) e^{-j\frac{2\pi ik}{N_{\text{sc}}^{\text{RB}}}}$$
$$k = 0, \ldots, N_{\text{sc}}^{\text{RB}} - 1$$
$$n = 0, \ldots, N_{\text{SF},0}^{\text{PUCCH}} + N_{\text{SF},1}^{\text{PUCCH}} - 1$$

where P is the number of antenna ports used for PUCCH transmission, resulting in a block of complex-valued symbols $z^{(\tilde{p})}(0), \ldots, z^{(\tilde{p})}\left(\left(N_{\text{SF},0}^{\text{PUCCH}} + N_{\text{SF},1}^{\text{PUCCH}}\right) N_{\text{sc}}^{\text{RB}} - 1\right)$.

Table 5.4.2A-1: The orthogonal sequence $w_{n_{\text{oc}}}(i)$.

Sequence index n_{oc}	Orthogonal sequence $\left[w_{n_{\text{oc}}}(0) \quad \cdots \quad w_{n_{\text{oc}}}(N_{\text{SF}}^{\text{PUCCH}} - 1)\right]$	
	$N_{\text{SF}}^{\text{PUCCH}} = 5$	$N_{\text{SF}}^{\text{PUCCH}} = 4$
0	$\left[1 \quad 1 \quad 1 \quad 1 \quad 1\right]$	$\left[+1 \quad +1 \quad +1 \quad +1\right]$
1	$\left[1 \quad e^{j2\pi/5} \quad e^{j4\pi/5} \quad e^{j6\pi/5} \quad e^{j8\pi/5}\right]$	$\left[+1 \quad -1 \quad +1 \quad -1\right]$
2	$\left[1 \quad e^{j4\pi/5} \quad e^{j8\pi/5} \quad e^{j2\pi/5} \quad e^{j6\pi/5}\right]$	$\left[+1 \quad +1 \quad -1 \quad -1\right]$
3	$\left[1 \quad e^{j6\pi/5} \quad e^{j2\pi/5} \quad e^{j8\pi/5} \quad e^{j4\pi/5}\right]$	$\left[+1 \quad -1 \quad -1 \quad +1\right]$
4	$\left[1 \quad e^{j8\pi/5} \quad e^{j6\pi/5} \quad e^{j4\pi/5} \quad e^{j2\pi/5}\right]$	-

5.4.3 Mapping to physical resources

The block of complex-valued symbols $z^{(\tilde{p})}(i)$ shall be multiplied with the amplitude scaling factor β_{PUCCH} in order to conform to the transmit power P_{PUCCH} specified in Section 5.1.2.1 in [4], and mapped in sequence starting with $z^{(\tilde{p})}(0)$ to resource elements. PUCCH uses one resource block in each of the two slots in a subframe. Within the physical resource block used for transmission, the mapping of $z^{(\tilde{p})}(i)$ to resource elements (k,l) on antenna port p and not used for transmission of reference signals shall be in increasing order of first k, then l and finally the slot number, starting with the first slot in the subframe. The relation between the index $\tilde{p}$ and the antenna port number p is given by Table 5.2.1-1.

The physical resource blocks to be used for transmission of PUCCH in slot n_{s} are given by

Petitioners' Exhibit 1003, p. 817
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$n_{\mathrm{PRB}} = \begin{cases} \left\lfloor \frac{m}{2} \right\rfloor & \text{if } (m + n_{\mathrm{s}} \bmod 2) \bmod 2 = 0 \\ N_{\mathrm{RB}}^{\mathrm{UL}} - 1 - \left\lfloor \frac{m}{2} \right\rfloor & \text{if } (m + n_{\mathrm{s}} \bmod 2) \bmod 2 = 1 \end{cases}$$

where the variable m depends on the PUCCH format. For formats 1, 1a and 1b

$$m = \begin{cases} N_{\mathrm{RB}}^{(2)} & \text{if } n_{\mathrm{PUCCH}}^{(1,\tilde{p})} < c \cdot N_{\mathrm{cs}}^{(1)} / \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} \\ \left\lfloor \frac{n_{\mathrm{PUCCH}}^{(1,\tilde{p})} - c \cdot N_{\mathrm{cs}}^{(1)} / \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}}}{c \cdot N_{\mathrm{sc}}^{\mathrm{RB}} / \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}}} \right\rfloor + N_{\mathrm{RB}}^{(2)} + \left\lceil \frac{N_{\mathrm{cs}}^{(1)}}{8} \right\rceil & \text{otherwise} \end{cases}$$

$$c = \begin{cases} 3 & \text{normal cyclic prefix} \\ 2 & \text{extended cyclic prefix} \end{cases}$$

and for formats 2, 2a and 2b

$$m = \left\lfloor n_{\mathrm{PUCCH}}^{(2,\tilde{p})} / N_{\mathrm{sc}}^{\mathrm{RB}} \right\rfloor$$

and for format 3

$$m = \left\lfloor n_{\mathrm{PUCCH}}^{(3,\tilde{p})} / N_{\mathrm{SF},0}^{\mathrm{PUCCH}} \right\rfloor$$

Mapping of modulation symbols for the physical uplink control channel is illustrated in Figure 5.4.3-1.

In case of simultaneous transmission of sounding reference signal and PUCCH format 1, 1a, 1b or 3 when there is one serving cell configured, a shortened PUCCH format shall be used where the last SC-FDMA symbol in the second slot of a subframe shall be left empty.

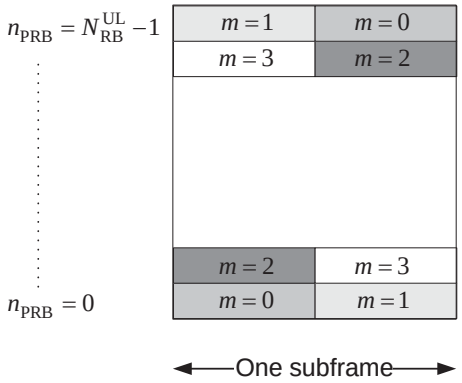


Figure 5.4.3-1: Mapping to physical resource blocks for PUCCH.

5.5 Reference signals

Two types of uplink reference signals are supported:

- Demodulation reference signal, associated with transmission of PUSCH or PUCCH
- Sounding reference signal, not associated with transmission of PUSCH or PUCCH

The same set of base sequences is used for demodulation and sounding reference signals.

5.5.1 Generation of the reference signal sequence

Reference signal sequence $r_{u,v}^{(\alpha)}(n)$ is defined by a cyclic shift α of a base sequence $\bar{r}_{u,v}(n)$ according to

Petitioners' Exhibit 1003, p. 818
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$r_{u,v}^{(\alpha)}(n) = e^{j\alpha n}\bar{r}_{u,v}(n), \quad 0 \le n < M_{\text{sc}}^{\text{RS}}$$

where $M_{\text{sc}}^{\text{RS}} = mN_{\text{sc}}^{\text{RB}}$ is the length of the reference signal sequence and $1 \le m \le N_{\text{RB}}^{\max,\text{UL}}$. Multiple reference signal sequences are defined from a single base sequence through different values of α.

Base sequences $\bar{r}_{u,v}(n)$ are divided into groups, where $u \in \{0,1,...,29\}$ is the group number and v is the base sequence number within the group, such that each group contains one base sequence ($v=0$) of each length $M_{\text{sc}}^{\text{RS}} = mN_{\text{sc}}^{\text{RB}}$, $1 \le m \le 5$ and two base sequences ($v=0,1$) of each length $M_{\text{sc}}^{\text{RS}} = mN_{\text{sc}}^{\text{RB}}$, $6 \le m \le N_{\text{RB}}^{\max,\text{UL}}$. The sequence group number u and the number v within the group may vary in time as described in Sections 5.5.1.3 and 5.5.1.4, respectively. The definition of the base sequence $\bar{r}_{u,v}(0),...,\bar{r}_{u,v}(M_{\text{sc}}^{\text{RS}}-1)$ depends on the sequence length $M_{\text{sc}}^{\text{RS}}$.

5.5.1.1 Base sequences of length $3N_{\text{sc}}^{\text{RB}}$ or larger

For $M_{\text{sc}}^{\text{RS}} \ge 3N_{\text{sc}}^{\text{RB}}$, the base sequence $\bar{r}_{u,v}(0),...,\bar{r}_{u,v}(M_{\text{sc}}^{\text{RS}}-1)$ is given by

$$\bar{r}_{u,v}(n) = x_q(n \bmod N_{\text{ZC}}^{\text{RS}}), \quad 0 \le n < M_{\text{sc}}^{\text{RS}}$$

where the qth root Zadoff-Chu sequence is defined by

$$x_q(m) = e^{-j\frac{\pi q m(m+1)}{N_{\text{ZC}}^{\text{RS}}}}, \quad 0 \le m \le N_{\text{ZC}}^{\text{RS}}-1$$

with q given by

$$q = \lfloor \bar{q} + 1/2 \rfloor + v \cdot (-1)^{\lfloor 2\bar{q} \rfloor}$$
$$\bar{q} = N_{\text{ZC}}^{\text{RS}} \cdot (u+1)/31$$

The length $N_{\text{ZC}}^{\text{RS}}$ of the Zadoff-Chu sequence is given by the largest prime number such that $N_{\text{ZC}}^{\text{RS}} < M_{\text{sc}}^{\text{RS}}$.

5.5.1.2 Base sequences of length less than $3N_{\text{sc}}^{\text{RB}}$

For $M_{\text{sc}}^{\text{RS}} = N_{\text{sc}}^{\text{RB}}$ and $M_{\text{sc}}^{\text{RS}} = 2N_{\text{sc}}^{\text{RB}}$, base sequence is given by

$$\bar{r}_{u,v}(n) = e^{j\varphi(n)\pi/4}, \quad 0 \le n \le M_{\text{sc}}^{\text{RS}}-1$$

where the value of $\varphi(n)$ is given by Table 5.5.1.2-1 and Table 5.5.1.2-2 for $M_{\text{sc}}^{\text{RS}} = N_{\text{sc}}^{\text{RB}}$ and $M_{\text{sc}}^{\text{RS}} = 2N_{\text{sc}}^{\text{RB}}$, respectively.

Petitioners' Exhibit 1003, p. 819
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.5.1.2-1: Definition of $\varphi(n)$ for $M_{sc}^{RS} = N_{sc}^{RB}$.

u	$\varphi(0),...,\varphi(11)$											
0	-1	1	3	-3	3	3	1	1	3	1	-3	3
1	1	1	3	3	3	-1	1	-3	-3	1	-3	3
2	1	1	-3	-3	-3	-1	-3	-3	1	-3	1	-1
3	-1	1	1	1	1	-1	-3	-3	1	-3	3	-1
4	-1	3	1	-1	1	-1	-3	-1	1	-1	1	3
5	1	-3	3	-1	-1	1	1	-1	-1	3	-3	1
6	-1	3	-3	-3	-3	3	1	-1	3	3	-3	1
7	-3	-1	-1	-1	1	-3	3	-1	1	-3	3	1
8	1	-3	3	1	-1	-1	-1	1	1	3	-1	1
9	1	-3	-1	3	3	-1	-3	1	1	1	1	1
10	-1	3	-1	1	1	-3	-3	-1	-3	-3	3	-1
11	3	1	-1	-1	3	3	-3	1	3	1	3	3
12	1	-3	1	1	-3	1	1	1	-3	-3	-3	1
13	3	3	-3	3	-3	1	1	3	-1	-3	3	3
14	-3	1	-1	-3	-1	3	1	3	3	3	-1	1
15	3	-1	1	-3	-1	-1	1	1	3	1	-1	-3
16	1	3	1	-1	1	3	3	3	-1	-1	3	-1
17	-3	1	1	3	-3	3	-3	-3	3	1	3	-1
18	-3	3	1	1	-3	1	-3	-3	-1	-1	1	-3
19	-1	3	1	3	1	-1	-1	3	-3	-1	-3	-1
20	-1	-3	1	1	1	1	3	1	-1	1	-3	-1
21	-1	3	-1	1	-3	-3	-3	-3	-3	1	-1	-3
22	1	1	-3	-3	-3	-3	-1	3	-3	1	-3	3
23	1	1	-1	-3	-1	-3	1	-1	1	3	-1	1
24	1	1	3	1	3	3	-1	1	-1	-3	-3	1
25	1	-3	3	3	1	3	3	1	-3	-1	-1	3
26	1	3	-3	-3	3	-3	1	-1	-1	3	-1	-3
27	-3	-1	-3	-1	-3	3	1	-1	1	3	-3	-3
28	-1	3	-3	3	-1	3	3	-3	3	3	-1	-1
29	3	-3	-3	-1	-1	-3	-1	3	-3	3	1	-1

Petitioners' Exhibit 1003, p. 820
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.5.1.2-2: Definition of $\varphi(n)$ for $M_{sc}^{RS} = 2N_{sc}^{RB}$.

u	$\varphi(0),...,\varphi(23)$																							
0	-1	3	1	-3	3	-1	1	3	-3	3	1	3	-3	3	1	1	-1	1	3	-3	3	-3	-1	-3
1	-3	3	-3	-3	-3	1	-3	-3	3	-1	1	1	1	3	1	-1	3	-3	-3	1	3	1	1	-3
2	3	-1	3	3	1	1	-3	3	3	3	3	1	-1	3	-1	1	1	-1	-3	-1	-1	1	3	3
3	-1	-3	1	1	3	-3	1	1	-3	-1	-1	1	3	1	3	1	-1	3	1	1	-3	-1	-3	-1
4	-1	-1	-1	-3	-3	-1	1	1	3	3	-1	3	-1	1	-1	-3	1	-1	-3	-3	1	-3	-1	-1
5	-3	1	1	3	-1	1	3	1	-3	1	-3	1	1	-1	-1	3	-1	-3	3	-3	-3	-3	1	1
6	1	1	-1	-1	3	-3	-3	3	-3	1	-1	-1	1	-1	1	1	-1	-3	-1	1	-1	3	-1	-3
7	-3	3	3	-1	-1	-3	-1	3	1	3	1	3	1	1	-1	3	1	-1	1	3	-3	-1	-1	1
8	-3	1	3	-3	1	-1	-3	3	-3	3	-1	-1	-1	-1	1	-3	-3	-3	1	-3	-3	-3	1	-3
9	1	1	-3	3	3	-1	-3	-1	3	-3	3	3	3	-1	1	1	-3	1	-1	1	1	-3	1	1
10	-1	1	-3	-3	3	-1	3	-1	-1	-3	-3	-3	-1	-3	-3	1	-1	1	3	3	-1	1	-1	3
11	1	3	3	-3	-3	1	3	1	-1	-3	-3	-3	3	3	-3	3	3	-1	-3	3	-1	1	-3	1
12	1	3	3	1	1	1	-1	-1	1	-3	3	-1	1	1	-3	3	3	-1	-3	3	-3	-1	-3	-1
13	3	-1	-1	-1	-1	-3	-1	3	3	1	-1	1	3	3	3	-1	1	1	-3	1	3	-1	-3	3
14	-3	-3	3	1	3	1	-3	3	1	3	1	1	3	3	-1	-1	-3	1	-3	-1	3	1	1	3
15	-1	-1	1	-3	1	3	-3	1	-1	-3	-1	3	1	3	1	-1	-3	-3	-1	-1	-3	-3	-3	-1
16	-1	-3	3	-1	-1	-1	-1	1	1	-3	3	1	3	3	1	-1	1	-3	1	-3	1	1	-3	-1
17	1	3	-1	3	3	-1	-3	1	-1	-3	3	3	3	-1	1	1	3	-1	-3	-1	3	-1	-1	-1
18	1	1	1	1	1	-1	3	-1	-3	1	1	3	-3	1	-3	-1	1	1	-3	-3	3	1	1	-3
19	1	3	3	1	-1	-3	3	-1	3	3	3	-3	1	-1	1	-1	-3	-1	1	3	-1	3	-3	-3
20	-1	-3	3	-3	-3	-3	-1	-1	-3	-1	-3	3	1	3	-3	-1	3	-1	1	-1	3	-3	1	-1
21	-3	-3	1	1	-1	1	-1	1	-1	3	1	-3	-1	1	-1	1	-1	-1	3	3	-3	-1	1	-3
22	-3	-1	-3	3	1	-1	-3	-1	-3	-3	3	-3	3	-3	-1	1	3	1	-3	1	3	3	-1	-3
23	-1	-1	-1	-1	3	3	3	1	3	3	-3	1	3	-1	3	-1	3	3	-3	3	1	-1	3	3
24	1	-1	3	3	-1	-3	3	-3	-1	-1	3	-1	3	-1	-1	1	1	1	1	-1	-1	-3	-1	3
25	1	-1	1	-1	3	-1	3	1	1	-1	-1	-3	1	1	-3	1	3	-3	1	1	-3	-3	-1	-1
26	-3	-1	1	3	1	1	-3	-1	-1	-3	3	-3	3	1	-3	3	-3	1	-1	1	-3	1	1	1
27	-1	-3	3	3	1	1	3	-1	-3	-1	-1	-1	3	1	-3	-3	-1	3	-3	-1	-3	-1	-3	-1
28	-1	-3	-1	-1	1	-3	-1	-1	1	-1	-3	1	1	-3	1	-3	-3	3	1	1	-1	3	-1	-1
29	1	1	-1	-1	-3	-1	3	-1	3	-1	1	3	1	-1	3	1	3	-3	-3	1	-1	-1	1	3

5.5.1.3 Group hopping

The sequence-group number u in slot n_s is defined by a group hopping pattern $f_{gh}(n_s)$ and a sequence-shift pattern f_{ss} according to

$$u = \left(f_{gh}(n_s) + f_{ss}\right) \bmod 30$$

There are 17 different hopping patterns and 30 different sequence-shift patterns. Sequence-group hopping can be enabled or disabled by means of the cell-specific parameter *Group-hopping-enabled* provided by higher layers. Sequence-group hopping for PUSCH can be disabled for a certain UE through the higher-layer parameter *Disable-sequence-group-hopping* despite being enabled on a cell basis unless the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure. PUCCH and PUSCH have the same hopping pattern but may have different sequence-shift patterns.

The group-hopping pattern $f_{gh}(n_s)$ is the same for PUSCH and PUCCH and given by

$$f_{gh}(n_s) = \begin{cases} 0 & \text{if group hopping is disabled} \\ \left(\sum_{i=0}^{7} c(8n_s + i) \cdot 2^i\right) \bmod 30 & \text{if group hopping is enabled} \end{cases}$$

where the pseudo-random sequence $c(i)$ is defined by section 7.2. The pseudo-random sequence generator shall be initialized with $c_{init} = \left\lfloor \frac{N_{ID}^{cell}}{30} \right\rfloor$ at the beginning of each radio frame.

The sequence-shift pattern f_{ss} definition differs between PUCCH and PUSCH.

Petitioners' Exhibit 1003, p. 821
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

For PUCCH, the sequence-shift pattern f_{ss}^{PUCCH} is given by $f_{ss}^{PUCCH} = N_{ID}^{cell} \bmod 30$.

For PUSCH, the sequence-shift pattern f_{ss}^{PUSCH} is given by $f_{ss}^{PUSCH} = \left(f_{ss}^{PUCCH} + \Delta_{ss}\right) \bmod 30$, where $\Delta_{ss} \in \{0,1,...,29\}$ is configured by higher layers.

5.5.1.4 Sequence hopping

Sequence hopping only applies for reference-signals of length $M_{sc}^{RS} \geq 6N_{sc}^{RB}$.

For reference-signals of length $M_{sc}^{RS} < 6N_{sc}^{RB}$, the base sequence number v within the base sequence group is given by $v = 0$.

For reference-signals of length $M_{sc}^{RS} \geq 6N_{sc}^{RB}$, the base sequence number v within the base sequence group in slot n_s is defined by

$$v = \begin{cases} c(n_s) & \text{if group hopping is disabled and sequence hopping is enabled} \\ 0 & \text{otherwise} \end{cases}$$

where the pseudo-random sequence $c(i)$ is given by section 7.2. The parameter *Sequence-hopping-enabled* provided by higher layers determines if sequence hopping is enabled or not. Sequence hopping for PUSCH can be disabled for a certain UE through the higher-layer parameter *Disable-sequence-group-hopping* despite being enabled on a cell basis unless the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure.

The pseudo-random sequence generator shall be initialized with $c_{init} = \left\lfloor \frac{N_{ID}^{cell}}{30} \right\rfloor \cdot 2^5 + f_{ss}^{PUSCH}$ at the beginning of each radio frame.

5.5.2 Demodulation reference signal

5.5.2.1 Demodulation reference signal for PUSCH

5.5.2.1.1 Reference signal sequence

The PUSCH demodulation reference signal sequence $r_{PUSCH}^{(\lambda)}(\cdot)$ associated with layer $\lambda \in \{0,1,...,\upsilon-1\}$ is defined by

$$r_{PUSCH}^{(\lambda)}\left(m \cdot M_{sc}^{RS} + n\right) = w^{(\lambda)}(m) r_{u,v}^{(\alpha_\lambda)}(n)$$

where

$$m = 0,1$$
$$n = 0,...,M_{sc}^{RS} - 1$$

and

$$M_{sc}^{RS} = M_{sc}^{PUSCH}$$

Section 5.5.1 defines the sequence $r_{u,v}^{(\alpha_\lambda)}(0),...,r_{u,v}^{(\alpha_\lambda)}(M_{sc}^{RS}-1)$. The orthogonal sequence $w^{(\lambda)}(m)$ is given by $\left[w^{\lambda}(0) \quad w^{\lambda}(1)\right] = \left[1 \quad 1\right]$ for DCI format 0 if the higher-layer parameter *Activate-DMRS-with OCC* is not set or if the temporary C-RNTI was used to transmit the most recent uplink-related DCI for the transport block associated with the corresponding PUSCH transmission, otherwise it is given by Table 5.5.2.1.1-1 using the cyclic shift field in most recent uplink-related DCI [3] for the transport block associated with the corresponding PUSCH transmission.

The cyclic shift α_λ in a slot n_s is given as $\alpha_\lambda = 2\pi n_{cs,\lambda}/12$ with

Petitioners' Exhibit 1003, p. 822
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$n_{\mathrm{cs},\lambda} = \left(n_{\mathrm{DMRS}}^{(1)} + n_{\mathrm{DMRS},\lambda}^{(2)} + n_{\mathrm{PN}}(n_{\mathrm{s}})\right) \bmod 12$$

where the values of $n_{\mathrm{DMRS}}^{(1)}$ is given by Table 5.5.2.1.1-2 according to the parameter *cyclicShift* provided by higher layers, $n_{\mathrm{DMRS},\lambda}^{(2)}$ is given by the cyclic shift for DMRS field in most recent uplink-related DCI [3] for the transport block associated with the corresponding PUSCH transmission where the value of $n_{\mathrm{DMRS},\lambda}^{(2)}$ is given in Table 5.5.2.1.1-1.

The first row of Table 5.5.2.1.1-1 shall be used to obtain $n_{\mathrm{DMRS},0}^{(2)}$ and $w^{(\lambda)}(m)$ if there is no uplink-related DCI for the same transport block associated with the corresponding PUSCH transmission, and

- if the initial PUSCH for the same transport block is semi-persistently scheduled, or
- if the initial PUSCH for the same transport block is scheduled by the random access response grant.

The quantity $n_{\mathrm{PN}}(n_{\mathrm{s}})$ is given by

$$n_{\mathrm{PN}}(n_{\mathrm{s}}) = \sum_{i=0}^{7} c(8N_{\mathrm{symb}}^{\mathrm{UL}} \cdot n_{\mathrm{s}} + i) \cdot 2^{i}$$

where the pseudo-random sequence $c(i)$ is defined by section 7.2. The application of $c(i)$ is cell-specific. The pseudo-random sequence generator shall be initialized with $c_{\mathrm{init}} = \left\lfloor \frac{N_{\mathrm{ID}}^{\mathrm{cell}}}{30} \right\rfloor \cdot 2^5 + f_{\mathrm{ss}}^{\mathrm{PUSCH}}$ at the beginning of each radio frame.

The vector of reference signals shall be precoded according to

$$\begin{bmatrix} \tilde{r}_{\mathrm{PUSCH}}^{(0)} \\ \vdots \\ \tilde{r}_{\mathrm{PUSCH}}^{(P-1)} \end{bmatrix} = W \begin{bmatrix} r_{\mathrm{PUSCH}}^{(0)} \\ \vdots \\ r_{\mathrm{PUSCH}}^{(\upsilon-1)} \end{bmatrix}$$

where P is the number of antenna ports used for PUSCH transmission.

For PUSCH transmission using a single antenna port, $P = 1$, $W = 1$ and $\upsilon = 1$.

For spatial multiplexing, $P = 2$ or $P = 4$ and the precoding matrix W shall be identical to the precoding matrix used in Section 5.3.3A.2 for precoding of the PUSCH in the same subframe.

Table 5.5.2.1.1-1: Mapping of Cyclic Shift Field in uplink-related DCI format to $n_{\mathrm{DMRS},\lambda}^{(2)}$ and $\left[w^{(\lambda)}(0) \quad w^{(\lambda)}(1)\right]$.

Cyclic Shift Field in uplink-related DCI format [3]	$n_{\mathrm{DMRS},\lambda}^{(2)}$				$\left[w^{(\lambda)}(0) \quad w^{(\lambda)}(1)\right]$			
	$\lambda=0$	$\lambda=1$	$\lambda=2$	$\lambda=3$	$\lambda=0$	$\lambda=1$	$\lambda=2$	$\lambda=3$
000	0	6	3	9	[1 1]	[1 1]	[1 −1]	[1 −1]
001	6	0	9	3	[1 −1]	[1 −1]	[1 1]	[1 1]
010	3	9	6	0	[1 −1]	[1 −1]	[1 1]	[1 1]
011	4	10	7	1	[1 1]	[1 1]	[1 1]	[1 1]
100	2	8	5	11	[1 1]	[1 1]	[1 1]	[1 1]
101	8	2	11	5	[1 −1]	[1 −1]	[1 −1]	[1 −1]
110	10	4	1	7	[1 −1]	[1 −1]	[1 −1]	[1 −1]
111	9	3	0	6	[1 1]	[1 1]	[1 −1]	[1 −1]

Petitioners' Exhibit 1003, p. 823
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.5.2.1.1-2: Mapping of *cyclicShift* to $n_{\mathrm{DMRS}}^{(1)}$ values.

cyclicShift	$n_{\mathrm{DMRS}}^{(1)}$
0	0
1	2
2	3
3	4
4	6
5	8
6	9
7	10

5.5.2.1.2 Mapping to physical resources

For each antenna port used for transmission of the PUSCH, the sequence $\tilde{r}_{\mathrm{PUSCH}}^{(\tilde{p})}(\cdot)$ shall be multiplied with the amplitude scaling factor β_{PUSCH} and mapped in sequence starting with $\tilde{r}_{\mathrm{PUSCH}}^{(\tilde{p})}(0)$ to the resource blocks. The set of physical resource blocks used in the mapping process and the relation between the index $\tilde{p}$ and the antenna port number p shall be identical to the corresponding PUSCH transmission as defined in Section 5.3.4. The mapping to resource elements (k,l), with $l=3$ for normal cyclic prefix and $l=2$ for extended cyclic prefix, in the subframe shall be in increasing order of first k, then the slot number.

5.5.2.2 Demodulation reference signal for PUCCH

5.5.2.2.1 Reference signal sequence

The PUCCH demodulation reference signal sequence $r_{\mathrm{PUCCH}}^{(\tilde{p})}(\cdot)$ is defined by

$$r_{\mathrm{PUCCH}}^{(\tilde{p})}\left(m' N_{\mathrm{RS}}^{\mathrm{PUCCH}} M_{\mathrm{sc}}^{\mathrm{RS}} + m M_{\mathrm{sc}}^{\mathrm{RS}} + n\right) = \frac{1}{\sqrt{P}} \overline{w}^{(\tilde{p})}(m) z(m) r_{u,v}^{(\alpha_{\tilde{p}})}(n)$$

where

$$\begin{aligned} m &= 0,\ldots,N_{\mathrm{RS}}^{\mathrm{PUCCH}} - 1 \\ n &= 0,\ldots,M_{\mathrm{sc}}^{\mathrm{RS}} - 1 \\ m' &= 0,1 \end{aligned}$$

and P is the number of antenna ports used for PUCCH transmission. For PUCCH formats 2a and 2b, $z(m)$ equals $d(10)$ for $m=1$, where $d(10)$ is defined in Section 5.4.2. For all other cases, $z(m)=1$.

The sequence $r_{u,v}^{(\alpha_{\tilde{p}})}(n)$ is given by Section 5.5.1 with $M_{\mathrm{sc}}^{\mathrm{RS}}=12$ where the expression for the cyclic shift $\alpha_{\tilde{p}}$ is determined by the PUCCH format.

For PUCCH formats 1, 1a and 1b, $\alpha_{\tilde{p}}(n_s,l)$ is given by

$$\bar{n}_{\mathrm{oc}}^{(\tilde{p})}(n_s) = \left\lfloor n'_{\tilde{p}}(n_s) \cdot \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} / N' \right\rfloor$$

$$\alpha_{\tilde{p}}(n_s,l) = 2\pi \cdot \bar{n}_{\mathrm{cs}}^{(\tilde{p})}(n_s,l) / N_{\mathrm{sc}}^{\mathrm{RB}}$$

$$\bar{n}_{\mathrm{cs}}^{(\tilde{p})}(n_s,l) = \begin{cases} \left[n_{\mathrm{cs}}^{\mathrm{cell}}(n_s,l) + \left(n'_{\tilde{p}}(n_s) \cdot \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} + \left(\bar{n}_{\mathrm{oc}}^{(\tilde{p})}(n_s) \bmod \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}}\right)\right) \bmod N'\right] \bmod N_{\mathrm{sc}}^{\mathrm{RB}} & \text{for normal cyclic prefix} \\ \left[n_{\mathrm{cs}}^{\mathrm{cell}}(n_s,l) + \left(n'_{\tilde{p}}(n_s) \cdot \Delta_{\mathrm{shift}}^{\mathrm{PUCCH}} + \bar{n}_{\mathrm{oc}}^{(\tilde{p})}(n_s)\right) \bmod N'\right] \bmod N_{\mathrm{sc}}^{\mathrm{RB}} & \text{for extended cyclic prefix} \end{cases}$$

Petitioners' Exhibit 1003, p. 824
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

where $n'_{\tilde{p}}(n_s)$, N', $\Delta_{\text{shift}}^{\text{PUCCH}}$ and $n_{\text{cs}}^{\text{cell}}(n_s,l)$ are defined by Section 5.4.1. The number of reference symbols per slot $N_{\text{RS}}^{\text{PUCCH}}$ and the sequence $\overline{w}(n)$ are given by Table 5.5.2.2.1-1 and 5.5.2.2.1-2, respectively.

For PUCCH formats 2, 2a and 2b, $\alpha_{\tilde{p}}(n_s,l)$ is defined by Section 5.4.2. The number of reference symbols per slot $N_{\text{RS}}^{\text{PUCCH}}$ and the sequence $\overline{w}^{(\tilde{p})}(n)$ are given by Table 5.5.2.2.1-1 and 5.5.2.2.1-3, respectively.

For PUCCH format 3, $\alpha_{\tilde{p}}(n_s,l)$ is given by

$$\alpha_{\tilde{p}}(n_s,l) = 2\pi \cdot n_{\text{cs}}^{(\tilde{p})}(n_s,l) \big/ N_{\text{sc}}^{\text{RB}}$$
$$n_{\text{cs}}^{(\tilde{p})}(n_s,l) = \left(n_{\text{cs}}^{\text{cell}}(n_s,l) + n'_{\tilde{p}}(n_s)\right) \bmod N_{\text{sc}}^{\text{RB}}$$

where $n'_{\tilde{p}}(n_s)$ is given by Table 5.5.2.2.1-4 and $n_{\text{oc},0}^{(\tilde{p})}$ and $n_{\text{oc},1}^{(\tilde{p})}$ for the first and second slot in a subframe, respectively, are obtained from Section 5.4.2A. The number of reference symbols per slot $N_{\text{RS}}^{\text{PUCCH}}$ and the sequence $\overline{w}(n)$ are given by Table 5.5.2.2.1-1 and 5.5.2.2.1-3, respectively.

Table 5.5.2.2.1-1: Number of PUCCH demodulation reference symbols per slot $N_{\text{RS}}^{\text{PUCCH}}$.

PUCCH format	Normal cyclic prefix	Extended cyclic prefix
1, 1a, 1b	3	2
2, 3	2	1
2a, 2b	2	N/A

Table 5.5.2.2.1-2: Orthogonal sequences $\left[\overline{w}^{(\tilde{p})}(0) \quad \cdots \quad \overline{w}^{(\tilde{p})}(N_{\text{RS}}^{\text{PUCCH}}-1)\right]$ for PUCCH formats 1, 1a and 1b.

Sequence index $\overline{n}_{\text{oc}}^{(\tilde{p})}(n_s)$	Normal cyclic prefix	Extended cyclic prefix
0	$\begin{bmatrix}1 & 1 & 1\end{bmatrix}$	$\begin{bmatrix}1 & 1\end{bmatrix}$
1	$\begin{bmatrix}1 & e^{j2\pi/3} & e^{j4\pi/3}\end{bmatrix}$	$\begin{bmatrix}1 & -1\end{bmatrix}$
2	$\begin{bmatrix}1 & e^{j4\pi/3} & e^{j2\pi/3}\end{bmatrix}$	N/A

Table 5.5.2.2.1-3: Orthogonal sequences $\left[\overline{w}^{(\tilde{p})}(0) \quad \cdots \quad \overline{w}^{(\tilde{p})}(N_{\text{RS}}^{\text{PUCCH}}-1)\right]$ for PUCCH formats 2, 2a, 2b and 3.

Normal cyclic prefix	Extended cyclic prefix
$\begin{bmatrix}1 & 1\end{bmatrix}$	$\begin{bmatrix}1\end{bmatrix}$

Table 5.5.2.2.1-4: Relation between $n_{\text{oc}}^{(\tilde{p})}$ and $n'_{\tilde{p}}(n_s)$ for PUCCH format 3.

$n_{\text{oc}}^{(\tilde{p})}$	$n'_{\tilde{p}}(n_s)$	
	$N_{\text{SF},1}=5$	$N_{\text{SF},1}=4$
0	0	0
1	3	3
2	6	6
3	8	9
4	10	N/A

Petitioners' Exhibit 1003, p. 825
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.5.2.2.2 Mapping to physical resources

The sequence $r_{\text{PUCCH}}^{(\tilde{p})}(\cdot)$ shall be multiplied with the amplitude scaling factor β_{PUCCH} and mapped in sequence starting with $r_{\text{PUCCH}}^{(\tilde{p})}(0)$ to resource elements (k,l) on antenna port p. The mapping shall be in increasing order of first k, then l and finally the slot number. The set of values for k and the relation between the index $\tilde{p}$ and the antenna port number p shall be identical to the values used for the corresponding PUCCH transmission. The values of the symbol index l in a slot are given by Table 5.5.2.2.2-1.

Table 5.5.2.2.2-1: Demodulation reference signal location for different PUCCH formats.

PUCCH format	Set of values for l	
	Normal cyclic prefix	Extended cyclic prefix
1, 1a, 1b	2, 3, 4	2, 3
2, 3	1, 5	3
2a, 2b	1, 5	N/A

5.5.3 Sounding reference signal

5.5.3.1 Sequence generation

The sounding reference signal sequence $r_{\text{SRS}}^{(\tilde{p})}(n) = r_{u,v}^{(\alpha_{\tilde{p}})}(n)$ is defined by Section 5.5.1, where u is the PUCCH sequence-group number defined in Section 5.5.1.3 and v is the base sequence number defined in Section 5.5.1.4. The cyclic shift $\alpha_{\tilde{p}}$ of the sounding reference signal is given as

$$\alpha_{\tilde{p}} = 2\pi \frac{n_{\text{SRS}}^{\text{cs},\tilde{p}}}{8}$$

$$n_{\text{SRS}}^{\text{cs},\tilde{p}} = \left(n_{\text{SRS}}^{\text{cs}} + \frac{8\tilde{p}}{N_{\text{ap}}} \right) \bmod 8,$$

$$\tilde{p} \in \{0,1,\ldots,N_{\text{ap}}-1\}$$

where $n_{\text{SRS}}^{\text{cs}} = \{0,1,2,3,4,5,6,7\}$ is configured separately for periodic and each configuration of aperiodic sounding by the higher-layer parameters *cyclicShift* and *cyclicShift-ap*, respectively, for each UE and N_{ap} is the number of antenna ports used for sounding reference signal transmission.

5.5.3.2 Mapping to physical resources

The sequence shall be multiplied with the amplitude scaling factor β_{SRS} in order to conform to the transmit power P_{SRS} specified in Section 5.1.3.1 in [4], and mapped in sequence starting with $r_{\text{SRS}}^{(\tilde{p})}(0)$ to resource elements (k,l) on antenna port p according to

$$a_{2k'+k_0^{(p)},l}^{(p)} = \begin{cases} \frac{1}{\sqrt{N_{\text{ap}}}} \beta_{\text{SRS}} r_{SRS}^{(\tilde{p})}(k') & k' = 0,1,\ldots,M_{\text{sc},b}^{\text{RS}}-1 \\ 0 & \text{otherwise} \end{cases}$$

where N_{ap} is the number of antenna ports used for sounding reference signal transmission and the relation between the index $\tilde{p}$ and the antenna port p is given by Table 5.2.1-1. The set of antenna ports used for sounding reference signal transmission is configured independently for periodic and each configuration of aperiodic sounding. The quantity $k_0^{(p)}$ is the frequency-domain starting position of the sounding reference signal and for $b = B_{\text{SRS}}$ and $M_{\text{sc},b}^{\text{RS}}$ is the length of the sounding reference signal sequence defined as

Petitioners' Exhibit 1003, p. 826
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$M_{sc,b}^{RS} = m_{SRS,b} N_{sc}^{RB} / 2$$

where $m_{SRS,b}$ is given by Table 5.5.3.2-1 through Table 5.5.3.2-4 for each uplink bandwidth N_{RB}^{UL}. The cell-specific parameter *srs-BandwidthConfig*, $C_{SRS} \in \{0,1,2,3,4,5,6,7\}$ and the UE-specific parameter *srs-Bandwidth*, $B_{SRS} \in \{0,1,2,3\}$ are given by higher layers. For UpPTS, $m_{SRS,0}$ shall be reconfigured to $m_{SRS,0}^{max} = \max_{c \in C}\left\{m_{SRS,0}^{c}\right\} \le \left(N_{RB}^{UL} - 6N_{RA}\right)$ if this reconfiguration is enabled by the cell-specific parameter *srsMaxUpPts* given by higher layers, otherwise if the reconfiguration is disabled $m_{SRS,0}^{max} = m_{SRS,0}$,where c is a SRS BW configuration and C_{SRS} is the set of SRS BW configurations from the Tables 5.5.3.2-1 to 5.5.3.2-4 for each uplink bandwidth N_{RB}^{UL}, N_{RA} is the number of format 4 PRACH in the addressed UpPTS and derived from Table 5.7.1-4.

The frequency-domain starting position $k_0^{(p)}$ is defined by

$$k_0^{(p)} = \bar{k}_0^{(p)} + \sum_{b=0}^{B_{SRS}} 2M_{sc,b}^{RS} n_b$$

where for normal uplink subframes $\bar{k}_0^{(p)}$ is defined by

$$\bar{k}_0^{(p)} = \left(\left\lfloor N_{RB}^{UL}/2 \right\rfloor - m_{SRS,0}/2\right) N_{SC}^{RB} + k_{TC}^{(p)}$$

and for UpPTS by

$$\bar{k}_0^{(p)} = \begin{cases} (N_{RB}^{UL} - m_{SRS,0}^{max}) N_{sc}^{RB} + k_{TC}^{(p)} & \text{if } ((n_f \bmod 2)\cdot(2 - N_{SP}) + n_{hf}) \bmod 2 = 0 \\ k_{TC}^{(p)} & \text{otherwise} \end{cases}$$

The quantity $k_{TC}^{(p)} \in \{0,1\}$ is given by

$$k_{TC}^{(p)} = \begin{cases} 1 - \bar{k}_{TC} & \text{if } n_{SRS}^{cs} \in \{4,5,6,7\} \text{ and } \tilde{p} \in \{1,3\} \text{ and } N_{ap} = 4 \\ \bar{k}_{TC} & \text{otherwise} \end{cases}$$

where the relation between the index $\tilde{p}$ and the antenna port p is given by Table 5.2.1-1, $\bar{k}_{TC} \in \{0,1\}$ is given by the UE-specific parameter *transmissionComb* or *transmissionComb-ap* for periodic and each configuration of aperiodic transmission, respectively, provided by higher layers for the UE, and n_b is frequency position index. The variable n_{hf} is equal to 0 for UpPTS in the first half frame and equal to 1 for UpPTS in the second half frame of a radio frame.

The frequency hopping of the sounding reference signal is configured by the parameter $b_{hop} \in \{0,1,2,3\}$, provided by higher-layer parameter *srs-HoppingBandwidth*. Frequency hopping is not supported for aperiodic transmission.. If frequency hopping of the sounding reference signal is not enabled (i.e., $b_{hop} \ge B_{SRS}$), the frequency position index n_b remains constant (unless re-configured) and is defined by $n_b = \lfloor 4n_{RRC}/m_{SRS,b} \rfloor \bmod N_b$ where the parameter n_{RRC} is given by higher-layer parameters *freqDomainPosition* and *freqDomainPosition-ap* for periodic and each configuration of aperiodic transmission, respectively. If frequency hopping of the sounding reference signal is enabled (i.e., $b_{hop} < B_{SRS}$), the frequency position indexes n_b are defined by

$$n_b = \begin{cases} \lfloor 4n_{RRC}/m_{SRS,b} \rfloor \bmod N_b & b \le b_{hop} \\ \left\{F_b(n_{SRS}) + \lfloor 4n_{RRC}/m_{SRS,b} \rfloor\right\} \bmod N_b & \text{otherwise} \end{cases}$$

where N_b is given by Table 5.5.3.2-1 through Table 5.5.3.2-4 for each uplink bandwidth N_{RB}^{UL},

Petitioners' Exhibit 1003, p. 827
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$F_b(n_{\mathrm{SRS}}) = \begin{cases} (N_b/2)\left\lfloor \dfrac{n_{\mathrm{SRS}} \bmod \Pi_{b'=b_{\mathrm{hop}}}^{b} N_{b'}}{\Pi_{b'=b_{\mathrm{hop}}}^{b-1} N_{b'}} \right\rfloor + \left\lfloor \dfrac{n_{\mathrm{SRS}} \bmod \Pi_{b'=b_{\mathrm{hop}}}^{b} N_{b'}}{2\Pi_{b'=b_{\mathrm{hop}}}^{b-1} N_{b'}} \right\rfloor & \text{if } N_b \text{ even} \\ \lfloor N_b/2 \rfloor \left\lfloor n_{\mathrm{SRS}} / \Pi_{b'=b_{\mathrm{hop}}}^{b-1} N_{b'} \right\rfloor & \text{if } N_b \text{ odd} \end{cases}$$

where $N_{b_{\mathrm{hop}}} = 1$ regardless of the N_b value on Table 5.5.3.2-1 through Table 5.5.3.2-4, and

$$n_{\mathrm{SRS}} = \begin{cases} 2N_{\mathrm{SP}} n_{\mathrm{f}} + 2(N_{\mathrm{SP}} - 1)\left\lfloor \dfrac{n_{\mathrm{s}}}{10} \right\rfloor + \left\lfloor \dfrac{T_{\mathrm{offset}}}{T_{\mathrm{offset\_max}}} \right\rfloor, & \text{for 2 ms SRS periodicity of frame structure type 2} \\ \left\lfloor (n_{\mathrm{f}} \times 10 + \lfloor n_{\mathrm{s}}/2 \rfloor)/T_{\mathrm{SRS}} \right\rfloor, & \text{otherwise} \end{cases}$$

counts the number of UE-specific SRS transmissions, where T_{SRS} is UE-specific periodicity of SRS transmission defined in section 8.2 of [4], T_{offset} is SRS subframe offset defined in Table 8.2-2 of [4] and $T_{\mathrm{offset\_max}}$ is the maximum value of T_{offset} for a certain configuration of SRS subframe offset.

For all subframes other than special subframes, the sounding reference signal shall be transmitted in the last symbol of the subframe.

Petitioners' Exhibit 1003, p. 828
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.5.3.2-1: $m_{\mathrm{SRS},b}$ and N_b, $b=0,1,2,3$, values for the uplink bandwidth of $6 \le N_{\mathrm{RB}}^{\mathrm{UL}} \le 40$.

SRS bandwidth configuration	SRS-Bandwidth $B_{\mathrm{SRS}}=0$		SRS-Bandwidth $B_{\mathrm{SRS}}=1$		SRS-Bandwidth $B_{\mathrm{SRS}}=2$		SRS-Bandwidth $B_{\mathrm{SRS}}=3$	
C_{SRS}	$m_{\mathrm{SRS},0}$	N_0	$m_{\mathrm{SRS},1}$	N_1	$m_{\mathrm{SRS},2}$	N_2	$m_{\mathrm{SRS},3}$	N_3
0	36	1	12	3	4	3	4	1
1	32	1	16	2	8	2	4	2
2	24	1	4	6	4	1	4	1
3	20	1	4	5	4	1	4	1
4	16	1	4	4	4	1	4	1
5	12	1	4	3	4	1	4	1
6	8	1	4	2	4	1	4	1
7	4	1	4	1	4	1	4	1

Table 5.5.3.2-2: $m_{\mathrm{SRS},b}$ and N_b, $b=0,1,2,3$, values for the uplink bandwidth of $40 < N_{\mathrm{RB}}^{\mathrm{UL}} \le 60$.

SRS bandwidth configuration	SRS-Bandwidth $B_{\mathrm{SRS}}=0$		SRS-Bandwidth $B_{\mathrm{SRS}}=1$		SRS-Bandwidth $B_{\mathrm{SRS}}=2$		SRS-Bandwidth $B_{\mathrm{SRS}}=3$	
C_{SRS}	$m_{\mathrm{SRS},0}$	N_0	$m_{\mathrm{SRS},1}$	N_1	$m_{\mathrm{SRS},2}$	N_2	$m_{\mathrm{SRS},3}$	N_3
0	48	1	24	2	12	2	4	3
1	48	1	16	3	8	2	4	2
2	40	1	20	2	4	5	4	1
3	36	1	12	3	4	3	4	1
4	32	1	16	2	8	2	4	2
5	24	1	4	6	4	1	4	1
6	20	1	4	5	4	1	4	1
7	16	1	4	4	4	1	4	1

Table 5.5.3.2-3: $m_{\mathrm{SRS},b}$ and N_b, $b=0,1,2,3$, values for the uplink bandwidth of $60 < N_{\mathrm{RB}}^{\mathrm{UL}} \le 80$.

SRS bandwidth configuration	SRS-Bandwidth $B_{\mathrm{SRS}}=0$		SRS-Bandwidth $B_{\mathrm{SRS}}=1$		SRS-Bandwidth $B_{\mathrm{SRS}}=2$		SRS-Bandwidth $B_{\mathrm{SRS}}=3$	
C_{SRS}	$m_{\mathrm{SRS},0}$	N_0	$m_{\mathrm{SRS},1}$	N_1	$m_{\mathrm{SRS},2}$	N_2	$m_{\mathrm{SRS},3}$	N_3
0	72	1	24	3	12	2	4	3
1	64	1	32	2	16	2	4	4
2	60	1	20	3	4	5	4	1
3	48	1	24	2	12	2	4	3
4	48	1	16	3	8	2	4	2
5	40	1	20	2	4	5	4	1
6	36	1	12	3	4	3	4	1
7	32	1	16	2	8	2	4	2

Table 5.5.3.2-4: $m_{\mathrm{SRS},b}$ and N_b, $b=0,1,2,3$, values for the uplink bandwidth of $80 < N_{\mathrm{RB}}^{\mathrm{UL}} \le 110$.

SRS bandwidth configuration	SRS-Bandwidth $B_{\mathrm{SRS}}=0$		SRS-Bandwidth $B_{\mathrm{SRS}}=1$		SRS-Bandwidth $B_{\mathrm{SRS}}=2$		SRS-Bandwidth $B_{\mathrm{SRS}}=3$	
C_{SRS}	$m_{\mathrm{SRS},0}$	N_0	$m_{\mathrm{SRS},1}$	N_1	$m_{\mathrm{SRS},2}$	N_2	$m_{\mathrm{SRS},3}$	N_3
0	96	1	48	2	24	2	4	6
1	96	1	32	3	16	2	4	4
2	80	1	40	2	20	2	4	5
3	72	1	24	3	12	2	4	3
4	64	1	32	2	16	2	4	4
5	60	1	20	3	4	5	4	1
6	48	1	24	2	12	2	4	3
7	48	1	16	3	8	2	4	2

Petitioners' Exhibit 1003, p. 829
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.5.3.3 Sounding reference signal subframe configuration

The cell-specific subframe configuration period T_{SFC} and the cell-specific subframe offset Δ_{SFC} for the transmission of sounding reference signals are listed in Tables 5.5.3.3-1 and 5.5.3.3-2, for frame structures type 1 and 2 respectively, where the parameter *srs-SubframeConfig* is provided by higher layers. Sounding reference signal subframes are the subframes satisfying $\lfloor n_s / 2 \rfloor \bmod T_{\text{SFC}} \in \Delta_{\text{SFC}}$. For frame structure type 2, sounding reference signal is transmitted only in configured UL subframes or UpPTS.

Table 5.5.3.3-1: Frame structure type 1 sounding reference signal subframe configuration.

srs-SubframeConfig	Binary	Configuration Period T_{SFC} (subframes)	Transmission offset Δ_{SFC} (subframes)
0	0000	1	{0}
1	0001	2	{0}
2	0010	2	{1}
3	0011	5	{0}
4	0100	5	{1}
5	0101	5	{2}
6	0110	5	{3}
7	0111	5	{0,1}
8	1000	5	{2,3}
9	1001	10	{0}
10	1010	10	{1}
11	1011	10	{2}
12	1100	10	{3}
13	1101	10	{0,1,2,3,4,6,8}
14	1110	10	{0,1,2,3,4,5,6,8}
15	1111	reserved	reserved

Table 5.5.3.3-2: Frame structure type 2 sounding reference signal subframe configuration.

srs-SubframeConfig	Binary	Configuration Period T_{SFC} (subframes)	Transmission offset Δ_{SFC} (subframes)
0	0000	5	{1}
1	0001	5	{1, 2}
2	0010	5	{1, 3}
3	0011	5	{1, 4}
4	0100	5	{1, 2, 3}
5	0101	5	{1, 2, 4}
6	0110	5	{1, 3, 4}
7	0111	5	{1, 2, 3, 4}
8	1000	10	{1, 2, 6}
9	1001	10	{1, 3, 6}
10	1010	10	{1, 6, 7}
11	1011	10	{1, 2, 6, 8}
12	1100	10	{1, 3, 6, 9}
13	1101	10	{1, 4, 6, 7}
14	1110	reserved	reserved
15	1111	reserved	reserved

5.6 SC-FDMA baseband signal generation

This section applies to all uplink physical signals and physical channels except the physical random access channel.

The time-continuous signal $s_l^{(p)}(t)$ for antenna port p in SC-FDMA symbol l in an uplink slot is defined by

Petitioners' Exhibit 1003, p. 830
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$s_l^{(p)}(t) = \sum_{k=-\lfloor N_{\mathrm{RB}}^{\mathrm{UL}} N_{\mathrm{sc}}^{\mathrm{RB}}/2 \rfloor}^{\lceil N_{\mathrm{RB}}^{\mathrm{UL}} N_{\mathrm{sc}}^{\mathrm{RB}}/2 \rceil - 1} a_{k^{(-)},l}^{(p)} \cdot e^{j2\pi(k+1/2)\Delta f\left(t - N_{\mathrm{CP},l} T_{\mathrm{s}}\right)}$$

for $0 \le t < (N_{\mathrm{CP},l} + N) \times T_{\mathrm{s}}$ where $k^{(-)} = k + \lfloor N_{RB}^{UL} N_{sc}^{RB}/2 \rfloor$, $N = 2048$, $\Delta f = 15\,\mathrm{kHz}$ and $a_{k,l}^{(p)}$ is the content of resource element (k,l) on antenna port p.

The SC-FDMA symbols in a slot shall be transmitted in increasing order of l, starting with $l = 0$, where SC-FDMA symbol $l > 0$ starts at time $\sum_{l'=0}^{l-1} (N_{\mathrm{CP},l'} + N) T_{\mathrm{s}}$ within the slot.

Table 5.6-1 lists the values of $N_{\mathrm{CP},l}$ that shall be used.

Table 5.6-1: SC-FDMA parameters.

Configuration	Cyclic prefix length $N_{\mathrm{CP},l}$
Normal cyclic prefix	160 for $l = 0$ 144 for $l = 1,2,...,6$
Extended cyclic prefix	512 for $l = 0,1,...,5$

5.7 Physical random access channel

5.7.1 Time and frequency structure

The physical layer random access preamble, illustrated in Figure 5.7.1-1, consists of a cyclic prefix of length T_{CP} and a sequence part of length T_{SEQ}. The parameter values are listed in Table 5.7.1-1 and depend on the frame structure and the random access configuration. Higher layers control the preamble format.

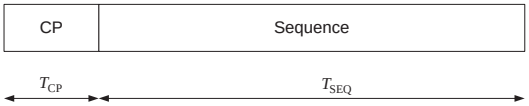


Figure 5.7.1-1: Random access preamble format.

Table 5.7.1-1: Random access preamble parameters.

Preamble format	T_{CP}	T_{SEQ}
0	$3168 \cdot T_{\mathrm{s}}$	$24576 \cdot T_{\mathrm{s}}$
1	$21024 \cdot T_{\mathrm{s}}$	$24576 \cdot T_{\mathrm{s}}$
2	$6240 \cdot T_{\mathrm{s}}$	$2 \cdot 24576 \cdot T_{\mathrm{s}}$
3	$21024 \cdot T_{\mathrm{s}}$	$2 \cdot 24576 \cdot T_{\mathrm{s}}$
4*	$448 \cdot T_{\mathrm{s}}$	$4096 \cdot T_{\mathrm{s}}$

* Frame structure type 2 and special subframe configurations with UpPTS lengths $4384 \cdot T_{\mathrm{s}}$ and $5120 \cdot T_{\mathrm{s}}$ only.

The transmission of a random access preamble, if triggered by the MAC layer, is restricted to certain time and frequency resources. These resources are enumerated in increasing order of the subframe number within the radio frame and the physical resource blocks in the frequency domain such that index 0 correspond to the lowest numbered physical resource block and subframe within the radio frame. PRACH resources within the radio frame are indicated by a PRACH Resource Index, where the indexing is in the order of appearance in Table 5.7.1-2 and Table 5.7.1-4.

Petitioners' Exhibit 1003, p. 831
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

For frame structure type 1 with preamble format 0-3, there is at most one random access resource per subframe. Table 5.7.1-2 lists the preamble formats according to Table 5.7.1-1 and the subframes in which random access preamble transmission is allowed for a given configuration in frame structure type 1. The parameter *prach-ConfigurationIndex* is given by higher layers. The start of the random access preamble shall be aligned with the start of the corresponding uplink subframe at the UE assuming $N_{\mathrm{TA}} = 0$, where N_{TA} is defined in section 8.1. For PRACH configurations 0, 1, 2, 15, 16, 17, 18, 31, 32, 33, 34, 47, 48, 49, 50 and 63 the UE may for handover purposes assume an absolute value of the relative time difference between radio frame i in the current cell and the target cell of less than $153600 \cdot T_{\mathrm{s}}$. The first physical resource block $n_{\mathrm{PRB}}^{\mathrm{RA}}$ allocated to the PRACH opportunity considered for preamble formats 0, 1, 2 and 3 is defined as $n_{\mathrm{PRB}}^{\mathrm{RA}} = n_{\mathrm{PRB\,offset}}^{\mathrm{RA}}$, where the parameter *prach-FrequencyOffset*, $n_{\mathrm{PRBoffset}}^{\mathrm{RA}}$ is expressed as a physical resource block number configured by higher layers and fulfilling $0 \le n_{\mathrm{PRBoffset}}^{\mathrm{RA}} \le N_{\mathrm{RB}}^{\mathrm{UL}} - 6$.

Table 5.7.1-2: Frame structure type 1 random access configuration for preamble formats 0-3.

PRACH Configuration Index	Preamble Format	System frame number	Subframe number	PRACH Configuration Index	Preamble Format	System frame number	Subframe number
0	0	Even	1	32	2	Even	1
1	0	Even	4	33	2	Even	4
2	0	Even	7	34	2	Even	7
3	0	Any	1	35	2	Any	1
4	0	Any	4	36	2	Any	4
5	0	Any	7	37	2	Any	7
6	0	Any	1, 6	38	2	Any	1, 6
7	0	Any	2 ,7	39	2	Any	2 ,7
8	0	Any	3, 8	40	2	Any	3, 8
9	0	Any	1, 4, 7	41	2	Any	1, 4, 7
10	0	Any	2, 5, 8	42	2	Any	2, 5, 8
11	0	Any	3, 6, 9	43	2	Any	3, 6, 9
12	0	Any	0, 2, 4, 6, 8	44	2	Any	0, 2, 4, 6, 8
13	0	Any	1, 3, 5, 7, 9	45	2	Any	1, 3, 5, 7, 9
14	0	Any	0, 1, 2, 3, 4, 5, 6, 7, 8, 9	46	N/A	N/A	N/A
15	0	Even	9	47	2	Even	9
16	1	Even	1	48	3	Even	1
17	1	Even	4	49	3	Even	4
18	1	Even	7	50	3	Even	7
19	1	Any	1	51	3	Any	1
20	1	Any	4	52	3	Any	4
21	1	Any	7	53	3	Any	7
22	1	Any	1, 6	54	3	Any	1, 6
23	1	Any	2 ,7	55	3	Any	2 ,7
24	1	Any	3, 8	56	3	Any	3, 8
25	1	Any	1, 4, 7	57	3	Any	1, 4, 7
26	1	Any	2, 5, 8	58	3	Any	2, 5, 8
27	1	Any	3, 6, 9	59	3	Any	3, 6, 9
28	1	Any	0, 2, 4, 6, 8	60	N/A	N/A	N/A
29	1	Any	1, 3, 5, 7, 9	61	N/A	N/A	N/A
30	N/A	N/A	N/A	62	N/A	N/A	N/A
31	1	Even	9	63	3	Even	9

For frame structure type 2 with preamble formats 0-4, there might be multiple random access resources in an UL subframe (or UpPTS for preamble format 4) depending on the UL/DL configuration [see table 4.2-2]. Table 5.7.1-3 lists PRACH configurations allowed for frame structure type 2 where the configuration index corresponds to a certain combination of preamble format, PRACH density value, D_{RA} and version index, r_{RA}. The parameter *prach-ConfigurationIndex* is given by higher layers. For frame structure type 2 with PRACH configuration 0, 1, 2, 20, 21, 22, 30, 31, 32, 40, 41, 42, 48, 49, 50, or with PRACH configuration 51, 53, 54, 55, 56, 57 in UL/DL configuration 3, 4, 5, the UE may for handover purposes assume an absolute value of the relative time difference between radio frame i in the current cell and the target cell is less than $153600 \cdot T_{\mathrm{s}}$.

Petitioners' Exhibit 1003, p. 832
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.7.1-3: Frame structure type 2 random access configurations for preamble formats 0-4.

PRACH configuration Index	Preamble Format	Density Per 10 ms D_{RA}	Version r_{RA}	PRACH configuration Index	Preamble Format	Density Per 10 ms D_{RA}	Version r_{RA}
0	0	0.5	0	32	2	0.5	2
1	0	0.5	1	33	2	1	0
2	0	0.5	2	34	2	1	1
3	0	1	0	35	2	2	0
4	0	1	1	36	2	3	0
5	0	1	2	37	2	4	0
6	0	2	0	38	2	5	0
7	0	2	1	39	2	6	0
8	0	2	2	40	3	0.5	0
9	0	3	0	41	3	0.5	1
10	0	3	1	42	3	0.5	2
11	0	3	2	43	3	1	0
12	0	4	0	44	3	1	1
13	0	4	1	45	3	2	0
14	0	4	2	46	3	3	0
15	0	5	0	47	3	4	0
16	0	5	1	48	4	0.5	0
17	0	5	2	49	4	0.5	1
18	0	6	0	50	4	0.5	2
19	0	6	1	51	4	1	0
20	1	0.5	0	52	4	1	1
21	1	0.5	1	53	4	2	0
22	1	0.5	2	54	4	3	0
23	1	1	0	55	4	4	0
24	1	1	1	56	4	5	0
25	1	2	0	57	4	6	0
26	1	3	0	58	N/A	N/A	N/A
27	1	4	0	59	N/A	N/A	N/A
28	1	5	0	60	N/A	N/A	N/A
29	1	6	0	61	N/A	N/A	N/A
30	2	0.5	0	62	N/A	N/A	N/A
31	2	0.5	1	63	N/A	N/A	N/A

Table 5.7.1-4 lists the mapping to physical resources for the different random access opportunities needed for a certain PRACH density value, D_{RA}. Each quadruple of the format $(f_{RA}, t_{RA}^{(0)}, t_{RA}^{(1)}, t_{RA}^{(2)})$ indicates the location of a specific random access resource, where f_{RA} is a frequency resource index within the considered time instance, $t_{RA}^{(0)} = 0,1,2$ indicates whether the resource is reoccurring in all radio frames, in even radio frames, or in odd radio frames, respectively, $t_{RA}^{(1)} = 0,1$ indicates whether the random access resource is located in first half frame or in second half frame, respectively, and where $t_{RA}^{(2)}$ is the uplink subframe number where the preamble starts, counting from 0 at the first uplink subframe between 2 consecutive downlink-to-uplink switch points, with the exception of preamble format 4 where $t_{RA}^{(2)}$ is denoted as (*). The start of the random access preamble formats 0-3 shall be aligned with the start of the corresponding uplink subframe at the UE assuming $N_{TA} = 0$ and the random access preamble format 4 shall start $4832 \cdot T_s$ before the end of the UpPTS at the UE, where the UpPTS is referenced to the UE's uplink frame timing assuming $N_{TA} = 0$.

The random access opportunities for each PRACH configuration shall be allocated in time first and then in frequency if and only if time multiplexing is not sufficient to hold all opportunities of a PRACH configuration needed for a certain density value D_{RA} without overlap in time. For preamble format 0-3, the frequency multiplexing shall be done according to

Petitioners' Exhibit 1003, p. 833
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$n_{\mathrm{PRB}}^{\mathrm{RA}} = \begin{cases} n_{\mathrm{PRB\,offset}}^{\mathrm{RA}} + 6\left\lfloor \frac{f_{\mathrm{RA}}}{2} \right\rfloor, & \text{if } f_{\mathrm{RA}} \bmod 2 = 0 \\ N_{\mathrm{RB}}^{\mathrm{UL}} - 6 - n_{\mathrm{PRB\,offset}}^{\mathrm{RA}} - 6\left\lfloor \frac{f_{\mathrm{RA}}}{2} \right\rfloor, & \text{otherwise} \end{cases}$$

where $N_{\mathrm{RB}}^{\mathrm{UL}}$ is the number of uplink resource blocks, $n_{\mathrm{PRB}}^{\mathrm{RA}}$ is the first physical resource block allocated to the PRACH opportunity considered and where the parameter *prach-FrequencyOffset*, $n_{\mathrm{PRB\,offset}}^{\mathrm{RA}}$ is the first physical resource block available for PRACH expressed as a physical resource block number configured by higher layers and fulfilling $0 \le n_{\mathrm{PRBoffset}}^{\mathrm{RA}} \le N_{\mathrm{RB}}^{\mathrm{UL}} - 6$.

For preamble format 4, the frequency multiplexing shall be done according to

$$n_{\mathrm{PRB}}^{\mathrm{RA}} = \begin{cases} 6 f_{\mathrm{RA}}, & \text{if } \left((n_{\mathrm{f}} \bmod 2) \times (2 - N_{\mathrm{SP}}) + t_{\mathrm{RA}}^{(1)}\right) \bmod 2 = 0 \\ N_{\mathrm{RB}}^{\mathrm{UL}} - 6(f_{\mathrm{RA}} + 1), & \text{otherwise} \end{cases}$$

where n_{f} is the system frame number and where N_{SP} is the number of DL to UL switch points within the radio frame.

Each random access preamble occupies a bandwidth corresponding to 6 consecutive resource blocks for both frame structures.

Petitioners' Exhibit 1003, p. 834
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.7.1-4: Frame structure type 2 random access preamble mapping in time and frequency.

PRACH configuration Index (See Table 5.7.1-3)	UL/DL configuration (See Table 4.2-2)						
	0	1	2	3	4	5	6
0	(0,1,0,2)	(0,1,0,1)	(0,1,0,0)	(0,1,0,2)	(0,1,0,1)	(0,1,0,0)	(0,1,0,2)
1	(0,2,0,2)	(0,2,0,1)	(0,2,0,0)	(0,2,0,2)	(0,2,0,1)	(0,2,0,0)	(0,2,0,2)
2	(0,1,1,2)	(0,1,1,1)	(0,1,1,0)	(0,1,0,1)	(0,1,0,0)	N/A	(0,1,1,1)
3	(0,0,0,2)	(0,0,0,1)	(0,0,0,0)	(0,0,0,2)	(0,0,0,1)	(0,0,0,0)	(0,0,0,2)
4	(0,0,1,2)	(0,0,1,1)	(0,0,1,0)	(0,0,0,1)	(0,0,0,0)	N/A	(0,0,1,1)
5	(0,0,0,1)	(0,0,0,0)	N/A	(0,0,0,0)	N/A	N/A	(0,0,0,1)
6	(0,0,0,2) (0,0,1,2)	(0,0,0,1) (0,0,1,1)	(0,0,0,0) (0,0,1,0)	(0,0,0,1) (0,0,0,2)	(0,0,0,0) (0,0,0,1)	(0,0,0,0) (1,0,0,0)	(0,0,0,2) (0,0,1,1)
7	(0,0,0,1) (0,0,1,1)	(0,0,0,0) (0,0,1,0)	N/A	(0,0,0,0) (0,0,0,2)	N/A	N/A	(0,0,0,1) (0,0,1,0)
8	(0,0,0,0) (0,0,1,0)	N/A	N/A	(0,0,0,0) (0,0,0,1)	N/A	N/A	(0,0,0,0) (0,0,1,1)
9	(0,0,0,1) (0,0,0,2) (0,0,1,2)	(0,0,0,0) (0,0,0,1) (0,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2)	(0,0,0,0) (0,0,0,1) (1,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0)	(0,0,0,1) (0,0,0,2) (0,0,1,1)
10	(0,0,0,0) (0,0,1,0) (0,0,1,1)	(0,0,0,1) (0,0,1,0) (0,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,1,0)	N/A	(0,0,0,0) (0,0,0,1) (1,0,0,0)	N/A	(0,0,0,0) (0,0,0,2) (0,0,1,0)
11	N/A	(0,0,0,0) (0,0,0,1) (0,0,1,0)	N/A	N/A	N/A	N/A	(0,0,0,1) (0,0,1,0) (0,0,1,1)
12	(0,0,0,1) (0,0,0,2) (0,0,1,1) (0,0,1,2)	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,2)	(0,0,0,0) (0,0,0,1) (1,0,0,0) (1,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0)	(0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,1)
13	(0,0,0,0) (0,0,0,2) (0,0,1,0) (0,0,1,2)	N/A	N/A	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,1)	N/A	N/A	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,1)
14	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1)	N/A	N/A	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,0)	N/A	N/A	(0,0,0,0) (0,0,0,2) (0,0,1,0) (0,0,1,1)
15	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,1) (0,0,1,2)	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1) (1,0,0,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0) (2,0,0,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,1) (1,0,0,2)	(0,0,0,0) (0,0,0,1) (1,0,0,0) (1,0,0,1) (2,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0) (4,0,0,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,1)
16	(0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,1) (0,0,1,2)	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1) (1,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0) (2,0,1,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,0) (1,0,0,2)	(0,0,0,0) (0,0,0,1) (1,0,0,0) (1,0,0,1) (2,0,0,0)	N/A	N/A
17	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,2)	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1) (1,0,0,0)	N/A	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,0) (1,0,0,1)	N/A	N/A	N/A
18	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,1) (0,0,1,2)	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1) (1,0,0,1) (1,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0) (2,0,0,0) (2,0,1,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,0) (1,0,0,1) (1,0,0,2)	(0,0,0,0) (0,0,0,1) (1,0,0,0) (1,0,0,1) (2,0,0,0) (2,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0) (4,0,0,0) (5,0,0,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,1) (1,0,0,2)
19	N/A	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1) (1,0,0,0) (1,0,1,0)	N/A	N/A	N/A	N/A	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,1) (1,0,1,1)
20 / 30	(0,1,0,1)	(0,1,0,0)	N/A	(0,1,0,1)	(0,1,0,0)	N/A	(0,1,0,1)
21 / 31	(0,2,0,1)	(0,2,0,0)	N/A	(0,2,0,1)	(0,2,0,0)	N/A	(0,2,0,1)

Petitioners' Exhibit 1003, p. 835
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

22 / 32	(0,1,1,1)	(0,1,1,0)	N/A	N/A	N/A	N/A	(0,1,1,0)
23 / 33	(0,0,0,1)	(0,0,0,0)	N/A	(0,0,0,1)	(0,0,0,0)	N/A	(0,0,0,1)
24 / 34	(0,0,1,1)	(0,0,1,0)	N/A	N/A	N/A	N/A	(0,0,1,0)
25 / 35	(0,0,0,1) (0,0,1,1)	(0,0,0,0) (0,0,1,0)	N/A	(0,0,0,1) (1,0,0,1)	(0,0,0,0) (1,0,0,0)	N/A	(0,0,0,1) (0,0,1,0)
26 / 36	(0,0,0,1) (0,0,1,1) (1,0,0,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0)	N/A	(0,0,0,1) (1,0,0,1) (2,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0)	N/A	(0,0,0,1) (0,0,1,0) (1,0,0,1)
27 / 37	(0,0,0,1) (0,0,1,1) (1,0,0,1) (1,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0)	N/A	(0,0,0,1) (1,0,0,1) (2,0,0,1) (3,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0)	N/A	(0,0,0,1) (0,0,1,0) (1,0,0,1) (1,0,1,0)
28 / 38	(0,0,0,1) (0,0,1,1) (1,0,0,1) (1,0,1,1) (2,0,0,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0) (2,0,0,0)	N/A	(0,0,0,1) (1,0,0,1) (2,0,0,1) (3,0,0,1) (4,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0) (4,0,0,0)	N/A	(0,0,0,1) (0,0,1,0) (1,0,0,1) (1,0,1,0) (2,0,0,1)
29 /39	(0,0,0,1) (0,0,1,1) (1,0,0,1) (1,0,1,1) (2,0,0,1) (2,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0) (2,0,0,0) (2,0,1,0)	N/A	(0,0,0,1) (1,0,0,1) (2,0,0,1) (3,0,0,1) (4,0,0,1) (5,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0) (4,0,0,0) (5,0,0,0)	N/A	(0,0,0,1) (0,0,1,0) (1,0,0,1) (1,0,1,0) (2,0,0,1) (2,0,1,0)
40	(0,1,0,0)	N/A	N/A	(0,1,0,0)	N/A	N/A	(0,1,0,0)
41	(0,2,0,0)	N/A	N/A	(0,2,0,0)	N/A	N/A	(0,2,0,0)
42	(0,1,1,0)	N/A	N/A	N/A	N/A	N/A	N/A
43	(0,0,0,0)	N/A	N/A	(0,0,0,0)	N/A	N/A	(0,0,0,0)
44	(0,0,1,0)	N/A	N/A	N/A	N/A	N/A	N/A
45	(0,0,0,0) (0,0,1,0)	N/A	N/A	(0,0,0,0) (1,0,0,0)	N/A	N/A	(0,0,0,0) (1,0,0,0)
46	(0,0,0,0) (0,0,1,0) (1,0,0,0)	N/A	N/A	(0,0,0,0) (1,0,0,0) (2,0,0,0)	N/A	N/A	(0,0,0,0) (1,0,0,0) (2,0,0,0)
47	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0)	N/A	N/A	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0)	N/A	N/A	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0)
48	(0,1,0,*)	(0,1,0,*)	(0,1,0,*)	(0,1,0,*)	(0,1,0,*)	(0,1,0,*)	(0,1,0,*)
49	(0,2,0,*)	(0,2,0,*)	(0,2,0,*)	(0,2,0,*)	(0,2,0,*)	(0,2,0,*)	(0,2,0,*)
50	(0,1,1,*)	(0,1,1,*)	(0,1,1,*)	N/A	N/A	N/A	(0,1,1,*)
51	(0,0,0,*)	(0,0,0,*)	(0,0,0,*)	(0,0,0,*)	(0,0,0,*)	(0,0,0,*)	(0,0,0,*)
52	(0,0,1,*)	(0,0,1,*)	(0,0,1,*)	N/A	N/A	N/A	(0,0,1,*)
53	(0,0,0,*) (0,0,1,*)	(0,0,0,*) (0,0,1,*)	(0,0,0,*) (0,0,1,*)	(0,0,0,*) (1,0,0,*)	(0,0,0,*) (1,0,0,*)	(0,0,0,*) (1,0,0,*)	(0,0,0,*) (0,0,1,*)
54	(0,0,0,*) (0,0,1,*) (1,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*)
55	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*)
56	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*) (4,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*) (4,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*) (4,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*)
57	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*) (2,0,1,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*) (2,0,1,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*) (2,0,1,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*) (4,0,0,*) (5,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*) (4,0,0,*) (5,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*) (4,0,0,*) (5,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*) (2,0,1,*)
58	N/A	N/A	N/A	N/A	N/A	N/A	N/A
59	N/A	N/A	N/A	N/A	N/A	N/A	N/A
60	N/A	N/A	N/A	N/A	N/A	N/A	N/A
61	N/A	N/A	N/A	N/A	N/A	N/A	N/A
62	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Petitioners' Exhibit 1003, p. 836
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

63	N/A	N/A	N/A	N/A	N/A	N/A	N/A

* UpPTS

5.7.2 Preamble sequence generation

The random access preambles are generated from Zadoff-Chu sequences with zero correlation zone, generated from one or several root Zadoff-Chu sequences. The network configures the set of preamble sequences the UE is allowed to use.

There are 64 preambles available in each cell. The set of 64 preamble sequences in a cell is found by including first, in the order of increasing cyclic shift, all the available cyclic shifts of a root Zadoff-Chu sequence with the logical index RACH_ROOT_SEQUENCE, where RACH_ROOT_SEQUENCE is broadcasted as part of the System Information. Additional preamble sequences, in case 64 preambles cannot be generated from a single root Zadoff-Chu sequence, are obtained from the root sequences with the consecutive logical indexes until all the 64 sequences are found. The logical root sequence order is cyclic: the logical index 0 is consecutive to 837. The relation between a logical root sequence index and physical root sequence index u is given by Tables 5.7.2-4 and 5.7.2-5 for preamble formats 0 – 3 and 4, respectively.

The uth root Zadoff-Chu sequence is defined by

$$x_u(n) = e^{-j\frac{\pi un(n+1)}{N_{\text{ZC}}}}, \quad 0 \le n \le N_{\text{ZC}} - 1$$

where the length N_{ZC} of the Zadoff-Chu sequence is given by Table 5.7.2-1. From the uth root Zadoff-Chu sequence, random access preambles with zero correlation zones of length $N_{\text{CS}} - 1$ are defined by cyclic shifts according to

$$x_{u,v}(n) = x_u((n + C_v) \bmod N_{\text{ZC}})$$

where the cyclic shift is given by

$$C_v = \begin{cases} vN_{\text{CS}} & v = 0,1,...,\lfloor N_{\text{ZC}}/N_{\text{CS}} \rfloor - 1, N_{\text{CS}} \neq 0 \quad \text{for unrestricted sets} \\ 0 & N_{\text{CS}} = 0 \quad \text{for unrestricted sets} \\ d_{\text{start}} \lfloor v/n_{\text{shift}}^{\text{RA}} \rfloor + (v \bmod n_{\text{shift}}^{\text{RA}}) N_{\text{CS}} & v = 0,1,..., n_{\text{shift}}^{\text{RA}} n_{\text{group}}^{\text{RA}} + \bar{n}_{\text{shift}}^{\text{RA}} - 1 \quad \text{for restricted sets} \end{cases}$$

and N_{CS} is given by Tables 5.7.2-2 and 5.7.2-3 for preamble formats 0-3 and 4, respectively, where the parameter *zeroCorrelationZoneConfig* is provided by higher layers. The parameter *High-speed-flag* provided by higher layers determines if unrestricted set or restricted set shall be used.

The variable d_u is the cyclic shift corresponding to a Doppler shift of magnitude $1/T_{\text{SEQ}}$ and is given by

$$d_u = \begin{cases} p & 0 \le p < N_{\text{ZC}}/2 \\ N_{\text{ZC}} - p & \text{otherwise} \end{cases}$$

where p is the smallest non-negative integer that fulfils $(pu) \bmod N_{\text{ZC}} = 1$. The parameters for restricted sets of cyclic shifts depend on d_u. For $N_{\text{CS}} \le d_u < N_{\text{ZC}}/3$, the parameters are given by

$$\begin{aligned} n_{\text{shift}}^{\text{RA}} &= \lfloor d_u / N_{\text{CS}} \rfloor \\ d_{\text{start}} &= 2d_u + n_{\text{shift}}^{\text{RA}} N_{\text{CS}} \\ n_{\text{group}}^{\text{RA}} &= \lfloor N_{\text{ZC}} / d_{\text{start}} \rfloor \\ \bar{n}_{\text{shift}}^{\text{RA}} &= \max\left(\left\lfloor (N_{\text{ZC}} - 2d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{\text{CS}} \right\rfloor, 0\right) \end{aligned}$$

For $N_{\text{ZC}}/3 \le d_u \le (N_{\text{ZC}} - N_{\text{CS}})/2$, the parameters are given by

Petitioners' Exhibit 1003, p. 837
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$n_{\text{shift}}^{\text{RA}} = \lfloor (N_{\text{ZC}} - 2d_u)/N_{\text{CS}} \rfloor$$
$$d_{\text{start}} = N_{\text{ZC}} - 2d_u + n_{\text{shift}}^{\text{RA}} N_{\text{CS}}$$
$$n_{\text{group}}^{\text{RA}} = \lfloor d_u / d_{\text{start}} \rfloor$$
$$\bar{n}_{\text{shift}}^{\text{RA}} = \min\left(\max\left(\left\lfloor (d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}})/N_{\text{CS}} \right\rfloor, 0\right), n_{\text{shift}}^{\text{RA}}\right)$$

For all other values of d_u, there are no cyclic shifts in the restricted set.

Table 5.7.2-1: Random access preamble sequence length.

Preamble format	N_{ZC}
0 – 3	839
4	139

Table 5.7.2-2: N_{CS} for preamble generation (preamble formats 0-3).

zeroCorrelationZoneConfig	N_{CS} value	
	Unrestricted set	Restricted set
0	0	15
1	13	18
2	15	22
3	18	26
4	22	32
5	26	38
6	32	46
7	38	55
8	46	68
9	59	82
10	76	100
11	93	128
12	119	158
13	167	202
14	279	237
15	419	-

Table 5.7.2-3: N_{CS} for preamble generation (preamble format 4).

zeroCorrelationZoneConfig	N_{CS} value
0	2
1	4
2	6
3	8
4	10
5	12
6	15
7	N/A
8	N/A
9	N/A
10	N/A
11	N/A
12	N/A
13	N/A
14	N/A
15	N/A

Petitioners' Exhibit 1003, p. 838
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.7.2-4: Root Zadoff-Chu sequence order for preamble formats 0 – 3.

Logical root sequence number	Physical root sequence number u (in increasing order of the corresponding logical sequence number)
0–23	129, 710, 140, 699, 120, 719, 210, 629, 168, 671, 84, 755, 105, 734, 93, 746, 70, 769, 60, 779 2, 837, 1, 838
24–29	56, 783, 112, 727, 148, 691
30–35	80, 759, 42, 797, 40, 799
36–41	35, 804, 73, 766, 146, 693
42–51	31, 808, 28, 811, 30, 809, 27, 812, 29, 810
52–63	24, 815, 48, 791, 68, 771, 74, 765, 178, 661, 136, 703
64–75	86, 753, 78, 761, 43, 796, 39, 800, 20, 819, 21, 818
76–89	95, 744, 202, 637, 190, 649, 181, 658, 137, 702, 125, 714, 151, 688
90–115	217, 622, 128, 711, 142, 697, 122, 717, 203, 636, 118, 721, 110, 729, 89, 750, 103, 736, 61, 778, 55, 784, 15, 824, 14, 825
116–135	12, 827, 23, 816, 34, 805, 37, 802, 46, 793, 207, 632, 179, 660, 145, 694, 130, 709, 223, 616
136–167	228, 611, 227, 612, 132, 707, 133, 706, 143, 696, 135, 704, 161, 678, 201, 638, 173, 666, 106, 733, 83, 756, 91, 748, 66, 773, 53, 786, 10, 829, 9, 830
168–203	7, 832, 8, 831, 16, 823, 47, 792, 64, 775, 57, 782, 104, 735, 101, 738, 108, 731, 208, 631, 184, 655, 197, 642, 191, 648, 121, 718, 141, 698, 149, 690, 216, 623, 218, 621
204–263	152, 687, 144, 695, 134, 705, 138, 701, 199, 640, 162, 677, 176, 663, 119, 720, 158, 681, 164, 675, 174, 665, 171, 668, 170, 669, 87, 752, 169, 670, 88, 751, 107, 732, 81, 758, 82, 757, 100, 739, 98, 741, 71, 768, 59, 780, 65, 774, 50, 789, 49, 790, 26, 813, 17, 822, 13, 826, 6, 833
264–327	5, 834, 33, 806, 51, 788, 75, 764, 99, 740, 96, 743, 97, 742, 166, 673, 172, 667, 175, 664, 187, 652, 163, 676, 185, 654, 200, 639, 114, 725, 189, 650, 115, 724, 194, 645, 195, 644, 192, 647, 182, 657, 157, 682, 156, 683, 211, 628, 154, 685, 123, 716, 139, 700, 212, 627, 153, 686, 213, 626, 215, 624, 150, 689
328–383	225, 614, 224, 615, 221, 618, 220, 619, 127, 712, 147, 692, 124, 715, 193, 646, 205, 634, 206, 633, 116, 723, 160, 679, 186, 653, 167, 672, 79, 760, 85, 754, 77, 762, 92, 747, 58, 781, 62, 777, 69, 770, 54, 785, 36, 803, 32, 807, 25, 814, 18, 821, 11, 828, 4, 835
384–455	3, 836, 19, 820, 22, 817, 41, 798, 38, 801, 44, 795, 52, 787, 45, 794, 63, 776, 67, 772, 72 767, 76, 763, 94, 745, 102, 737, 90, 749, 109, 730, 165, 674, 111, 728, 209, 630, 204, 635, 117, 722, 188, 651, 159, 680, 198, 641, 113, 726, 183, 656, 180, 659, 177, 662, 196, 643, 155, 684, 214, 625, 126, 713, 131, 708, 219, 620, 222, 617, 226, 613
456–513	230, 609, 232, 607, 262, 577, 252, 587, 418, 421, 416, 423, 413, 426, 411, 428, 376, 463, 395, 444, 283, 556, 285, 554, 379, 460, 390, 449, 363, 476, 384, 455, 388, 451, 386, 453, 361, 478, 387, 452, 360, 479, 310, 529, 354, 485, 328, 511, 315, 524, 337, 502, 349, 490, 335, 504, 324, 515
514–561	323, 516, 320, 519, 334, 505, 359, 480, 295, 544, 385, 454, 292, 547, 291, 548, 381, 458, 399, 440, 380, 459, 397, 442, 369, 470, 377, 462, 410, 429, 407, 432, 281, 558, 414, 425, 247, 592, 277, 562, 271, 568, 272, 567, 264, 575, 259, 580
562–629	237, 602, 239, 600, 244, 595, 243, 596, 275, 564, 278, 561, 250, 589, 246, 593, 417, 422, 248, 591, 394, 445, 393, 446, 370, 469, 365, 474, 300, 539, 299, 540, 364, 475, 362, 477, 298, 541, 312, 527, 313, 526, 314, 525, 353, 486, 352, 487, 343, 496, 327, 512, 350, 489, 326, 513, 319, 520, 332, 507, 333, 506, 348, 491, 347, 492, 322, 517
630–659	330, 509, 338, 501, 341, 498, 340, 499, 342, 497, 301, 538, 366, 473, 401, 438, 371, 468, 408, 431, 375, 464, 249, 590, 269, 570, 238, 601, 234, 605
660–707	257, 582, 273, 566, 255, 584, 254, 585, 245, 594, 251, 588, 412, 427, 372, 467, 282, 557, 403, 436, 396, 443, 392, 447, 391, 448, 382, 457, 389, 450, 294, 545, 297, 542, 311, 528, 344, 495, 345, 494, 318, 521, 331, 508, 325, 514, 321, 518
708–729	346, 493, 339, 500, 351, 488, 306, 533, 289, 550, 400, 439, 378, 461, 374, 465, 415, 424, 270, 569, 241, 598
730–751	231, 608, 260, 579, 268, 571, 276, 563, 409, 430, 398, 441, 290, 549, 304, 535, 308, 531, 358, 481, 316, 523
752–765	293, 546, 288, 551, 284, 555, 368, 471, 253, 586, 256, 583, 263, 576
766–777	242, 597, 274, 565, 402, 437, 383, 456, 357, 482, 329, 510
778–789	317, 522, 307, 532, 286, 553, 287, 552, 266, 573, 261, 578
790–795	236, 603, 303, 536, 356, 483
796–803	355, 484, 405, 434, 404, 435, 406, 433
804–809	235, 604, 267, 572, 302, 537
810–815	309, 530, 265, 574, 233, 606
816–819	367, 472, 296, 543
820–837	336, 503, 305, 534, 373, 466, 280, 559, 279, 560, 419, 420, 240, 599, 258, 581, 229, 610

Petitioners' Exhibit 1003, p. 839
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.7.2-5: Root Zadoff-Chu sequence order for preamble format 4.

Logical root sequence number	Physical root sequence number u (in increasing order of the corresponding logical sequence number)																			
0 – 19	1	138	2	137	3	136	4	135	5	134	6	133	7	132	8	131	9	130	10	129
20 – 39	11	128	12	127	13	126	14	125	15	124	16	123	17	122	18	121	19	120	20	119
40 – 59	21	118	22	117	23	116	24	115	25	114	26	113	27	112	28	111	29	110	30	109
60 – 79	31	108	32	107	33	106	34	105	35	104	36	103	37	102	38	101	39	100	40	99
80 – 99	41	98	42	97	43	96	44	95	45	94	46	93	47	92	48	91	49	90	50	89
100 – 119	51	88	52	87	53	86	54	85	55	84	56	83	57	82	58	81	59	80	60	79
120 – 137	61	78	62	77	63	76	64	75	65	74	66	73	67	72	68	71	69	70	-	-
138 – 837	N/A																			

5.7.3 Baseband signal generation

The time-continuous random access signal $s(t)$ is defined by

$$s(t) = \beta_{\text{PRACH}} \sum_{k=0}^{N_{ZC}-1} \sum_{n=0}^{N_{ZC}-1} x_{u,v}(n) \cdot e^{-j\frac{2\pi nk}{N_{ZC}}} \cdot e^{j2\pi\left(k+\varphi+K\left(k_0+\frac{1}{2}\right)\right)\Delta f_{\text{RA}}\left(t-T_{\text{CP}}\right)}$$

where $0 \le t < T_{\text{SEQ}} + T_{\text{CP}}$, β_{PRACH} is an amplitude scaling factor in order to conform to the transmit power P_{PRACH} specified in Section 6.1 in [4], and $k_0 = n_{\text{PRB}}^{\text{RA}} N_{\text{sc}}^{\text{RB}} - N_{\text{RB}}^{\text{UL}} N_{\text{sc}}^{\text{RB}} / 2$. The location in the frequency domain is controlled by the parameter $n_{\text{PRB}}^{\text{RA}}$ is derived from section 5.7.1. The factor $K = \Delta f / \Delta f_{\text{RA}}$ accounts for the difference in subcarrier spacing between the random access preamble and uplink data transmission. The variable Δf_{RA}, the subcarrier spacing for the random access preamble, and the variable φ, a fixed offset determining the frequency-domain location of the random access preamble within the physical resource blocks, are both given by Table 5.7.3-1.

Table 5.7.3-1: Random access baseband parameters.

Preamble format	Δf_{RA}	φ
0 – 3	1250 Hz	7
4	7500 Hz	2

5.8 Modulation and upconversion

Modulation and upconversion to the carrier frequency of the complex-valued SC-FDMA baseband signal for each antenna port or the complex-valued PRACH baseband signal is shown in Figure 5.8-1. The filtering required prior to transmission is defined by the requirements in [7].

Petitioners' Exhibit 1003, p. 840
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

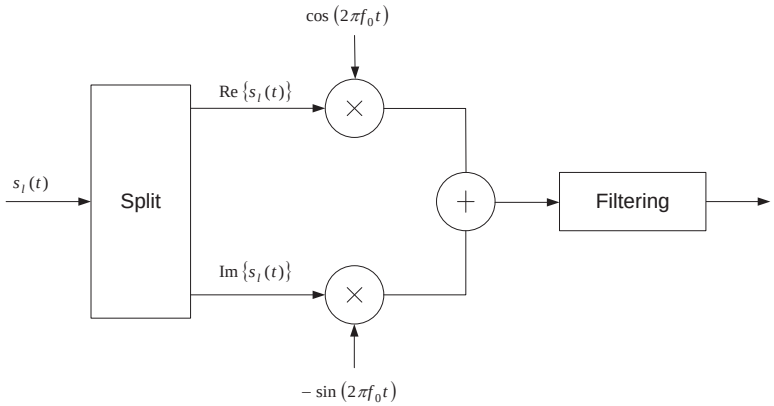


Figure 5.8-1: Uplink modulation.

6 Downlink

6.1 Overview

The smallest time-frequency unit for downlink transmission is denoted a resource element and is defined in Section 6.2.2.

A subset of the downlink subframes in a radio frame on a carrier supporting PDSCH transmission can be configured as MBSFN subframes by higher layers. Each MBSFN subframe is divided into a non-MBSFN region and an MBSFN region.

- The non-MBSFN region spans the first one or two OFDM symbols in an MBSFN subframe where the length of the non-MBSFN region is given by Table 6.7-1.
- The MBSFN region in an MBSFN subframe is defined as the OFDM symbols not used for the non-MBSFN region.

Unless otherwise specified, transmission in each downlink subframe shall use the same cyclic prefix length as used for downlink subframe #0.

6.1.1 Physical channels

A downlink physical channel corresponds to a set of resource elements carrying information originating from higher layers and is the interface defined between 36.212 and 36.211. The following downlink physical channels are defined:

- Physical Downlink Shared Channel, PDSCH
- Physical Broadcast Channel, PBCH
- Physical Multicast Channel, PMCH
- Physical Control Format Indicator Channel, PCFICH
- Physical Downlink Control Channel, PDCCH
- Physical Hybrid ARQ Indicator Channel, PHICH

Petitioners' Exhibit 1003, p. 841
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.1.2 Physical signals

A downlink physical signal corresponds to a set of resource elements used by the physical layer but does not carry information originating from higher layers. The following downlink physical signals are defined:

- Reference signal
- Synchronization signal

6.2 Slot structure and physical resource elements

6.2.1 Resource grid

The transmitted signal in each slot is described by one or several resource grids of $N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}$ subcarriers and $N_{\mathrm{symb}}^{\mathrm{DL}}$ OFDM symbols. The resource grid structure is illustrated in Figure 6.2.2-1. The quantity $N_{\mathrm{RB}}^{\mathrm{DL}}$ depends on the downlink transmission bandwidth configured in the cell and shall fulfil

$$N_{\mathrm{RB}}^{\mathrm{min,DL}} \le N_{\mathrm{RB}}^{\mathrm{DL}} \le N_{\mathrm{RB}}^{\mathrm{max,DL}}$$

where $N_{\mathrm{RB}}^{\mathrm{min,DL}} = 6$ and $N_{\mathrm{RB}}^{\mathrm{max,DL}} = 110$ are the smallest and largest downlink bandwidths, respectively, supported by the current version of this specification.

The set of allowed values for $N_{\mathrm{RB}}^{\mathrm{DL}}$ is given by [6]. The number of OFDM symbols in a slot depends on the cyclic prefix length and subcarrier spacing configured and is given in Table 6.2.3-1.

An antenna port is defined such that the channel over which a symbol on the antenna port is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed. There is one resource grid per antenna port. The set of antenna ports supported depends on the reference signal configuration in the cell:

- Cell-specific reference signals support a configuration of one, two, or four antenna ports and are transmitted on antenna ports $p = 0$, $p \in \{0,1\}$, and $p \in \{0,1,2,3\}$, respectively.
- MBSFN reference signals are transmitted on antenna port $p = 4$.
- UE-specific reference signals are transmitted on antenna port(s) $p = 5$, $p = 7$, $p = 8$, or one or several of $p \in \{7,8,9,10,11,12,13,14\}$..
- Positioning reference signals are transmitted on antenna port $p = 6$.
- CSI reference signals support a configuration of one, two, four or eight antenna ports and are transmitted on antenna ports $p = 15$, $p = 15,16$, $p = 15,...,18$ and $p = 15,...,22$, respectively..

6.2.2 Resource elements

Each element in the resource grid for antenna port p is called a resource element and is uniquely identified by the index pair (k,l) in a slot where $k = 0,...,N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}} - 1$ and $l = 0,...,N_{\mathrm{symb}}^{\mathrm{DL}} - 1$ are the indices in the frequency and time domains, respectively. Resource element (k,l) on antenna port p corresponds to the complex value $a_{k,l}^{(p)}$. When there is no risk for confusion, or no particular antenna port is specified, the index p may be dropped.

Petitioners' Exhibit 1003, p. 842
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

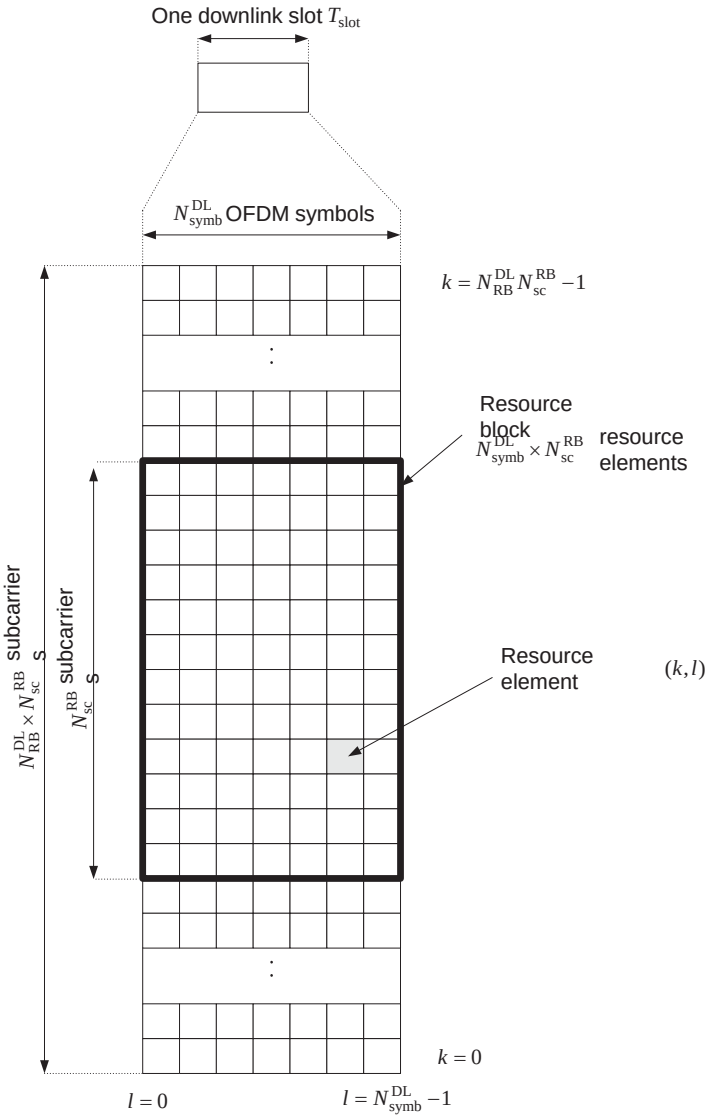


Figure 6.2.2-1: Downlink resource grid.

6.2.3 Resource blocks

Resource blocks are used to describe the mapping of certain physical channels to resource elements. Physical and virtual resource blocks are defined.

A physical resource block is defined as N_{symb}^{DL} consecutive OFDM symbols in the time domain and N_{sc}^{RB} consecutive subcarriers in the frequency domain, where N_{symb}^{DL} and N_{sc}^{RB} are given by Table 6.2.3-1. A physical resource block thus consists of $N_{symb}^{DL} \times N_{sc}^{RB}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.

Physical resource blocks are numbered from 0 to $N_{RB}^{DL} - 1$ in the frequency domain. The relation between the physical resource block number n_{PRB} in the frequency domain and resource elements (k,l) in a slot is given by

$$n_{PRB} = \left\lfloor \frac{k}{N_{sc}^{RB}} \right\rfloor$$

Petitioners' Exhibit 1003, p. 843
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.2.3-1: Physical resource blocks parameters.

Configuration		N_{sc}^{RB}	N_{symb}^{DL}
Normal cyclic prefix	$\Delta f = 15\,\text{kHz}$	12	7
Extended cyclic prefix	$\Delta f = 15\,\text{kHz}$		6
	$\Delta f = 7.5\,\text{kHz}$	24	3

A virtual resource block is of the same size as a physical resource block. Two types of virtual resource blocks are defined:

- Virtual resource blocks of localized type
- Virtual resource blocks of distributed type

For each type of virtual resource blocks, a pair of virtual resource blocks over two slots in a subframe is assigned together by a single virtual resource block number, n_{VRB}.

6.2.3.1 Virtual resource blocks of localized type

Virtual resource blocks of localized type are mapped directly to physical resource blocks such that virtual resource block n_{VRB} corresponds to physical resource block $n_{PRB} = n_{VRB}$. Virtual resource blocks are numbered from 0 to $N_{VRB}^{DL} - 1$, where $N_{VRB}^{DL} = N_{RB}^{DL}$.

6.2.3.2 Virtual resource blocks of distributed type

Virtual resource blocks of distributed type are mapped to physical resource blocks as described below.

Table 6.2.3.2-1: RB gap values.

System BW (N_{RB}^{DL})	Gap (N_{gap})	
	1st Gap ($N_{gap,1}$)	2nd Gap ($N_{gap,2}$)
6-10	$\lceil N_{RB}^{DL}/2 \rceil$	N/A
11	4	N/A
12-19	8	N/A
20-26	12	N/A
27-44	18	N/A
45-49	27	N/A
50-63	27	9
64-79	32	16
80-110	48	16

The parameter N_{gap} is given by Table 6.2.3.2-1. For $6 \le N_{RB}^{DL} \le 49$, only one gap value $N_{gap,1}$ is defined and $N_{gap} = N_{gap,1}$. For $50 \le N_{RB}^{DL} \le 110$, two gap values $N_{gap,1}$ and $N_{gap,2}$ are defined. Whether $N_{gap} = N_{gap,1}$ or $N_{gap} = N_{gap,2}$ is signaled as part of the downlink scheduling assignment as described in [3].

Virtual resource blocks of distributed type are numbered from 0 to $N_{VRB}^{DL} - 1$, where $N_{VRB}^{DL} = N_{VRB,gap1}^{DL} = 2 \cdot \min(N_{gap}, N_{RB}^{DL} - N_{gap})$ for $N_{gap} = N_{gap,1}$ and $N_{VRB}^{DL} = N_{VRB,gap2}^{DL} = \lfloor N_{RB}^{DL}/2N_{gap} \rfloor \cdot 2N_{gap}$ for $N_{gap} = N_{gap,2}$.

Consecutive $\tilde{N}_{VRB}^{DL}$ VRB numbers compose a unit of VRB number interleaving, where $\tilde{N}_{VRB}^{DL} = N_{VRB}^{DL}$ for $N_{gap} = N_{gap,1}$ and $\tilde{N}_{VRB}^{DL} = 2N_{gap}$ for $N_{gap} = N_{gap,2}$. Interleaving of VRB numbers of each interleaving unit is performed with 4

Petitioners' Exhibit 1003, p. 844
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

columns and N_{row} rows, where $N_{\text{row}} = \left\lceil \tilde{N}_{\text{VRB}}^{\text{DL}} / (4P) \right\rceil \cdot P$, and P is RBG size as described in [4]. VRB numbers are written row by row in the rectangular matrix, and read out column by column. N_{null} nulls are inserted in the last $N_{\text{null}} / 2$ rows of the 2nd and 4th column, where $N_{\text{null}} = 4N_{\text{row}} - \tilde{N}_{\text{VRB}}^{\text{DL}}$. Nulls are ignored when reading out. The VRB numbers mapping to PRB numbers including interleaving is derived as follows:

For even slot number n_s;

$$\tilde{n}_{\text{PRB}}(n_s) = \begin{cases} \tilde{n}'_{\text{PRB}} - N_{\text{row}} & , N_{\text{null}} \neq 0 \quad \text{and} \quad \tilde{n}_{\text{VRB}} \geq \tilde{N}_{\text{VRB}}^{\text{DL}} - N_{\text{null}} \quad \text{and} \quad \tilde{n}_{\text{VRB}} \bmod 2 = 1 \\ \tilde{n}'_{\text{PRB}} - N_{\text{row}} + N_{\text{null}} / 2 & , N_{\text{null}} \neq 0 \quad \text{and} \quad \tilde{n}_{\text{VRB}} \geq \tilde{N}_{\text{VRB}}^{\text{DL}} - N_{\text{null}} \quad \text{and} \quad \tilde{n}_{\text{VRB}} \bmod 2 = 0 \\ \tilde{n}''_{\text{PRB}} - N_{\text{null}} / 2 & , N_{\text{null}} \neq 0 \quad \text{and} \quad \tilde{n}_{\text{VRB}} < \tilde{N}_{\text{VRB}}^{\text{DL}} - N_{\text{null}} \quad \text{and} \quad \tilde{n}_{\text{VRB}} \bmod 4 \geq 2 \\ \tilde{n}''_{\text{PRB}} & , \text{otherwise} \end{cases},$$

$$\text{where } \tilde{n}'_{\text{PRB}} = 2N_{\text{row}} \cdot (\tilde{n}_{\text{VRB}} \bmod 2) + \lfloor \tilde{n}_{\text{VRB}} / 2 \rfloor + \tilde{N}_{\text{VRB}}^{\text{DL}} \cdot \lfloor n_{\text{VRB}} / \tilde{N}_{\text{VRB}}^{\text{DL}} \rfloor,$$

$$\text{and } \tilde{n}''_{\text{PRB}} = N_{\text{row}} \cdot (\tilde{n}_{\text{VRB}} \bmod 4) + \lfloor \tilde{n}_{\text{VRB}} / 4 \rfloor + \tilde{N}_{\text{VRB}}^{\text{DL}} \cdot \lfloor n_{\text{VRB}} / \tilde{N}_{\text{VRB}}^{\text{DL}} \rfloor,$$

where $\tilde{n}_{\text{VRB}} = n_{\text{VRB}} \bmod \tilde{N}_{\text{VRB}}^{\text{DL}}$ and n_{VRB} is obtained from the downlink scheduling assignment as described in [4].

For odd slot number n_s;

$$\tilde{n}_{\text{PRB}}(n_s) = \left(\tilde{n}_{\text{PRB}}(n_s - 1) + \tilde{N}_{\text{VRB}}^{\text{DL}} / 2 \right) \bmod \tilde{N}_{\text{VRB}}^{\text{DL}} + \tilde{N}_{\text{VRB}}^{\text{DL}} \cdot \lfloor n_{\text{VRB}} / \tilde{N}_{\text{VRB}}^{\text{DL}} \rfloor$$

Then, for all n_s;

$$n_{\text{PRB}}(n_s) = \begin{cases} \tilde{n}_{\text{PRB}}(n_s), & \tilde{n}_{\text{PRB}}(n_s) < \tilde{N}_{\text{VRB}}^{\text{DL}} / 2 \\ \tilde{n}_{\text{PRB}}(n_s) + N_{\text{gap}} - \tilde{N}_{\text{VRB}}^{\text{DL}} / 2, & \tilde{n}_{\text{PRB}}(n_s) \geq \tilde{N}_{\text{VRB}}^{\text{DL}} / 2 \end{cases}.$$

6.2.4 Resource-element groups

Resource-element groups are used for defining the mapping of control channels to resource elements.

A resource-element group is represented by the index pair (k', l') of the resource element with the lowest index k in the group with all resource elements in the group having the same value of l. The set of resource elements (k, l) in a resource-element group depends on the number of cell-specific reference signals configured as described below with $k_0 = n_{\text{PRB}} \cdot N_{\text{sc}}^{\text{RB}}$, $0 \leq n_{\text{PRB}} < N_{\text{RB}}^{\text{DL}}$.

- In the first OFDM symbol of the first slot in a subframe the two resource-element groups in physical resource block n_{PRB} consist of resource elements $(k, l = 0)$ with $k = k_0 + 0, k_0 + 1, \ldots, k_0 + 5$ and $k = k_0 + 6, k_0 + 7, \ldots, k_0 + 11$, respectively.
- In the second OFDM symbol of the first slot in a subframe in case of one or two cell-specific reference signals configured, the three resource-element groups in physical resource block n_{PRB} consist of resource elements $(k, l = 1)$ with $k = k_0 + 0, k_0 + 1, \ldots, k_0 + 3$, $k = k_0 + 4, k_0 + 5, \ldots, k_0 + 7$ and $k = k_0 + 8, k_0 + 9, \ldots, k_0 + 11$, respectively.
- In the second OFDM symbol of the first slot in a subframe in case of four cell-specific reference signals configured, the two resource-element groups in physical resource block n_{PRB} consist of resource elements $(k, l = 1)$ with $k = k_0 + 0, k_0 + 1, \ldots, k_0 + 5$ and $k = k_0 + 6, k_0 + 7, \ldots, k_0 + 11$, respectively.
- In the third OFDM symbol of the first slot in a subframe, the three resource-element groups in physical resource block n_{PRB} consist of resource elements $(k, l = 2)$ with $k = k_0 + 0, k_0 + 1, \ldots, k_0 + 3$, $k = k_0 + 4, k_0 + 5, \ldots, k_0 + 7$ and $k = k_0 + 8, k_0 + 9, \ldots, k_0 + 11$, respectively.

Petitioners' Exhibit 1003, p. 845
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- In the fourth OFDM symbol of the first slot in a subframe in case of normal cyclic prefix, the three resource-element groups in physical resource block n_{PRB} consist of resource elements $(k,l=3)$ with $k=k_0+0,k_0+1,...,k_0+3$, $k=k_0+4,k_0+5,...,k_0+7$ and $k=k_0+8,k_0+9,...,k_0+11$, respectively.
- In the fourth OFDM symbol of the first slot in a subframe in case of extended cyclic prefix, the two resource-element groups in physical resource block n_{PRB} consist of resource elements $(k,l=3)$ with $k=k_0+0,k_0+1,...,k_0+5$ and $k=k_0+6,k_0+7,...,k_0+11$, respectively.

Mapping of a symbol-quadruplet $\langle z(i),z(i+1),z(i+2),z(i+3)\rangle$ onto a resource-element group represented by resource-element (k',l') is defined such that elements $z(i)$ are mapped to resource elements (k,l) of the resource-element group not used for cell-specific reference signals in increasing order of i and k. In case a single cell-specific reference signal is configured, cell-specific reference signals shall be assumed to be present on antenna ports 0 and 1 for the purpose of mapping a symbol-quadruplet to a resource-element group, otherwise the number of cell-specific reference signals shall be assumed equal to the actual number of antenna ports used for cell-specific reference signals. The UE shall not make any assumptions about resource elements assumed to be reserved for reference signals but not used for transmission of a reference signal.

6.2.5 Guard period for half-duplex FDD operation

For half-duplex FDD operation, a guard period is created by the UE by not receiving the last part of a downlink subframe immediately preceding an uplink subframe from the same UE.

6.2.6 Guard Period for TDD Operation

For frame structure type 2, the GP field in Figure 4.2-1 serves as a guard period.

6.3 General structure for downlink physical channels

This section describes a general structure, applicable to more than one physical channel.

The baseband signal representing a downlink physical channel is defined in terms of the following steps:

- scrambling of coded bits in each of the codewords to be transmitted on a physical channel
- modulation of scrambled bits to generate complex-valued modulation symbols
- mapping of the complex-valued modulation symbols onto one or several transmission layers
- precoding of the complex-valued modulation symbols on each layer for transmission on the antenna ports
- mapping of complex-valued modulation symbols for each antenna port to resource elements
- generation of complex-valued time-domain OFDM signal for each antenna port

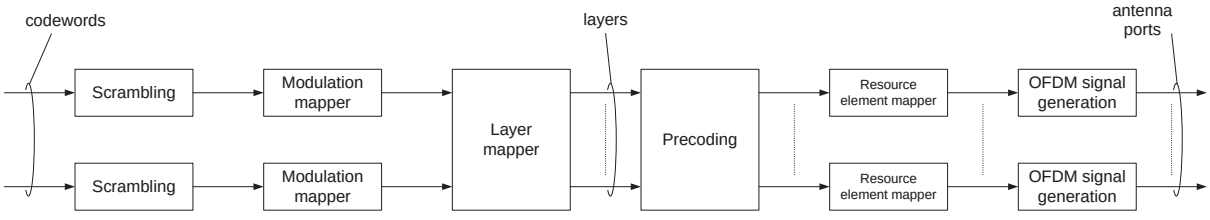


Figure 6.3-1: Overview of physical channel processing.

Petitioners' Exhibit 1003, p. 846
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.3.1 Scrambling

For each codeword q, the block of bits $b^{(q)}(0),...,b^{(q)}(M_{\text{bit}}^{(q)}-1)$, where $M_{\text{bit}}^{(q)}$ is the number of bits in codeword q transmitted on the physical channel in one subframe, shall be scrambled prior to modulation, resulting in a block of scrambled bits $\tilde{b}^{(q)}(0),...,\tilde{b}^{(q)}(M_{\text{bit}}^{(q)}-1)$ according to

$$\tilde{b}^{(q)}(i) = \left(b^{(q)}(i) + c^{(q)}(i)\right) \bmod 2$$

where the scrambling sequence $c^{(q)}(i)$ is given by Section 7.2. The scrambling sequence generator shall be initialised at the start of each subframe, where the initialisation value of c_{init} depends on the transport channel type according to

$$c_{\text{init}} = \begin{cases} n_{\text{RNTI}} \cdot 2^{14} + q \cdot 2^{13} + \lfloor n_s/2 \rfloor \cdot 2^9 + N_{\text{ID}}^{\text{cell}} & \text{for PDSCH} \\ \lfloor n_s/2 \rfloor \cdot 2^9 + N_{\text{ID}}^{\text{MBSFN}} & \text{for PMCH} \end{cases}$$

where n_{RNTI} corresponds to the RNTI associated with the PDSCH transmission as described in Section 7.1[4].

Up to two codewords can be transmitted in one subframe, i.e., $q \in \{0,1\}$. In the case of single codeword transmission, q is equal to zero.

6.3.2 Modulation

For each codeword q, the block of scrambled bits $\tilde{b}^{(q)}(0),...,\tilde{b}^{(q)}(M_{\text{bit}}^{(q)}-1)$ shall be modulated as described in Section 7.1 using one of the modulation schemes in Table 6.3.2-1, resulting in a block of complex-valued modulation symbols $d^{(q)}(0),...,d^{(q)}(M_{\text{symb}}^{(q)}-1)$.

Table 6.3.2-1: Modulation schemes.

Physical channel	Modulation schemes
PDSCH	QPSK, 16QAM, 64QAM
PMCH	QPSK, 16QAM, 64QAM

6.3.3 Layer mapping

The complex-valued modulation symbols for each of the codewords to be transmitted are mapped onto one or several layers. Complex-valued modulation symbols $d^{(q)}(0),...,d^{(q)}(M_{\text{symb}}^{(q)}-1)$ for codeword q shall be mapped onto the layers $x(i) = \left[x^{(0)}(i) \ \ ... \ \ x^{(\upsilon-1)}(i)\right]^T$, $i = 0,1,...,M_{\text{symb}}^{\text{layer}}-1$ where υ is the number of layers and $M_{\text{symb}}^{\text{layer}}$ is the number of modulation symbols per layer.

6.3.3.1 Layer mapping for transmission on a single antenna port

For transmission on a single antenna port, a single layer is used, $\upsilon = 1$, and the mapping is defined by

$$x^{(0)}(i) = d^{(0)}(i)$$

with $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$.

6.3.3.2 Layer mapping for spatial multiplexing

For spatial multiplexing, the layer mapping shall be done according to Table 6.3.3.2-1. The number of layers υ is less than or equal to the number of antenna ports P used for transmission of the physical channel. The case of a single codeword mapped to multiple layers is only applicable when the number of cell-specific reference signals is four or when the number of UE-specific reference signals is two or larger.

Petitioners' Exhibit 1003, p. 847
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.3.3.2-1: Codeword-to-layer mapping for spatial multiplexing.

Number of layers	Number of codewords	Codeword-to-layer mapping $i = 0,1,\ldots,M_{\text{symb}}^{\text{layer}}-1$	
1	1	$x^{(0)}(i) = d^{(0)}(i)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$
2	1	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/2$
2	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(i)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$
3	1	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i+1)$ $x^{(2)}(i) = d^{(0)}(3i+2)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/3$
3	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(2i)$ $x^{(2)}(i) = d^{(1)}(2i+1)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}/2$
4	1	$x^{(0)}(i) = d^{(0)}(4i)$ $x^{(1)}(i) = d^{(0)}(4i+1)$ $x^{(2)}(i) = d^{(0)}(4i+2)$ $x^{(3)}(i) = d^{(0)}(4i+3)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/4$
4	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i+1)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/2 = M_{\text{symb}}^{(1)}/2$
5	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $x^{(2)}(i) = d^{(1)}(3i)$ $x^{(3)}(i) = d^{(1)}(3i+1)$ $x^{(4)}(i) = d^{(1)}(3i+2)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/2 = M_{\text{symb}}^{(1)}/3$
6	2	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i+1)$ $x^{(2)}(i) = d^{(0)}(3i+2)$ $x^{(3)}(i) = d^{(1)}(3i)$ $x^{(4)}(i) = d^{(1)}(3i+1)$ $x^{(5)}(i) = d^{(1)}(3i+2)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/3 = M_{\text{symb}}^{(1)}/3$
7	2	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i+1)$ $x^{(2)}(i) = d^{(0)}(3i+2)$ $x^{(3)}(i) = d^{(1)}(4i)$ $x^{(4)}(i) = d^{(1)}(4i+1)$ $x^{(5)}(i) = d^{(1)}(4i+2)$ $x^{(6)}(i) = d^{(1)}(4i+3)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/3 = M_{\text{symb}}^{(1)}/4$
8	2	$x^{(0)}(i) = d^{(0)}(4i)$ $x^{(1)}(i) = d^{(0)}(4i+1)$ $x^{(2)}(i) = d^{(0)}(4i+2)$ $x^{(3)}(i) = d^{(0)}(4i+3)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/4 = M_{\text{symb}}^{(1)}/4$

Petitioners' Exhibit 1003, p. 848
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

		$x^{(4)}(i) = d^{(1)}(4i)$ $x^{(5)}(i) = d^{(1)}(4i+1)$ $x^{(6)}(i) = d^{(1)}(4i+2)$ $x^{(7)}(i) = d^{(1)}(4i+3)$	

6.3.3.3 Layer mapping for transmit diversity

For transmit diversity, the layer mapping shall be done according to Table 6.3.3.3-1. There is only one codeword and the number of layers υ is equal to the number of antenna ports P used for transmission of the physical channel.

Table 6.3.3.3-1: Codeword-to-layer mapping for transmit diversity.

Number of layers	Number of codewords	Codeword-to-layer mapping $i = 0,1,...,M_{\text{symb}}^{\text{layer}}-1$	
2	1	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/2$
4	1	$x^{(0)}(i) = d^{(0)}(4i)$ $x^{(1)}(i) = d^{(0)}(4i+1)$ $x^{(2)}(i) = d^{(0)}(4i+2)$ $x^{(3)}(i) = d^{(0)}(4i+3)$	$M_{\text{symb}}^{\text{layer}} = \begin{cases} M_{\text{symb}}^{(0)}/4 & \text{if } M_{\text{symb}}^{(0)} \bmod 4 = 0 \\ \left(M_{\text{symb}}^{(0)}+2\right)/4 & \text{if } M_{\text{symb}}^{(0)} \bmod 4 \neq 0 \end{cases}$ If $M_{\text{symb}}^{(0)} \bmod 4 \neq 0$ two null symbols shall be appended to $d^{(0)}(M_{\text{symb}}^{(0)}-1)$

6.3.4 Precoding

The precoder takes as input a block of vectors $x(i) = \left[x^{(0)}(i) \quad ... \quad x^{(\upsilon-1)}(i)\right]^T$, $i = 0,1,...,M_{\text{symb}}^{\text{layer}}-1$ from the layer mapping and generates a block of vectors $y(i) = \left[... \quad y^{(p)}(i) \quad ...\right]^T$, $i = 0,1,...,M_{\text{symb}}^{\text{ap}}-1$ to be mapped onto resources on each of the antenna ports, where $y^{(p)}(i)$ represents the signal for antenna port p.

6.3.4.1 Precoding for transmission on a single antenna port

For transmission on a single antenna port, precoding is defined by

$$y^{(p)}(i) = x^{(0)}(i)$$

where $p \in \{0,4,5,7,8\}$ is the number of the single antenna port used for transmission of the physical channel and $i = 0,1,...,M_{\text{symb}}^{\text{ap}}-1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

6.3.4.2 Precoding for spatial multiplexing using antenna ports with cell-specific reference signals

Precoding for spatial multiplexing using antenna ports with cell-specific reference signals is only used in combination with layer mapping for spatial multiplexing as described in Section 6.3.3.2. Spatial multiplexing supports two or four antenna ports and the set of antenna ports used is $p \in \{0,1\}$ or $p \in \{0,1,2,3\}$, respectively.

6.3.4.2.1 Precoding without CDD

Without cyclic delay diversity (CDD), precoding for spatial multiplexing is defined by

Petitioners' Exhibit 1003, p. 849
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$\begin{bmatrix} y^{(0)}(i) \\ \vdots \\ y^{(P-1)}(i) \end{bmatrix} = W(i) \begin{bmatrix} x^{(0)}(i) \\ \vdots \\ x^{(\upsilon-1)}(i) \end{bmatrix}$$

where the precoding matrix $W(i)$ is of size $P \times \upsilon$ and $i = 0,1,...,M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

For spatial multiplexing, the values of $W(i)$ shall be selected among the precoder elements in the codebook configured in the eNodeB and the UE. The eNodeB can further confine the precoder selection in the UE to a subset of the elements in the codebook using codebook subset restrictions. The configured codebook shall be selected from Table 6.3.4.2.3-1 or 6.3.4.2.3-2.

6.3.4.2.2 Precoding for large delay CDD

For large-delay CDD, precoding for spatial multiplexing is defined by

$$\begin{bmatrix} y^{(0)}(i) \\ \vdots \\ y^{(P-1)}(i) \end{bmatrix} = W(i)D(i)U \begin{bmatrix} x^{(0)}(i) \\ \vdots \\ x^{(\upsilon-1)}(i) \end{bmatrix}$$

where the precoding matrix $W(i)$ is of size $P \times \upsilon$ and $i = 0,1,...,M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$. The diagonal size-$\upsilon \times \upsilon$ matrix $D(i)$ supporting cyclic delay diversity and the size-$\upsilon \times \upsilon$ matrix U are both given by Table 6.3.4.2.2-1 for different numbers of layers υ.

The values of the precoding matrix $W(i)$ shall be selected among the precoder elements in the codebook configured in the eNodeB and the UE. The eNodeB can further confine the precoder selection in the UE to a subset of the elements in the codebook using codebook subset restriction. The configured codebook shall be selected from Table 6.3.4.2.3-1 or 6.3.4.2.3-2.

For 2 antenna ports, the precoder is selected according to $W(i) = C_1$ where C_1 denotes the precoding matrix corresponding to precoder index 0 in Table 6.3.4.2.3-1.

For 4 antenna ports, the UE may assume that the eNodeB cyclically assigns different precoders to different vectors $\left[x^{(0)}(i) \quad ... \quad x^{(\upsilon-1)}(i)\right]^T$ on the physical downlink shared channel as follows. A different precoder is used every υ vectors, where υ denotes the number of transmission layers in the case of spatial multiplexing. In particular, the precoder is selected according to $W(i) = C_k$, where k is the precoder index given by $k = \left(\left\lfloor \frac{i}{\upsilon} \right\rfloor \bmod 4\right) + 1 \in \{1,2,3,4\}$ and C_1, C_2, C_3, C_4 denote precoder matrices corresponding to precoder indices 12,13,14 and 15, respectively, in Table 6.3.4.2.3-2.

Petitioners' Exhibit 1003, p. 850
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.3.4.2.2-1: Large-delay cyclic delay diversity.

Number of layers υ	U	$D(i)$
2	$\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\ 1 & e^{-j2\pi/2}\end{bmatrix}$	$\begin{bmatrix}1 & 0\\ 0 & e^{-j2\pi i/2}\end{bmatrix}$
3	$\frac{1}{\sqrt{3}}\begin{bmatrix}1 & 1 & 1\\ 1 & e^{-j2\pi/3} & e^{-j4\pi/3}\\ 1 & e^{-j4\pi/3} & e^{-j8\pi/3}\end{bmatrix}$	$\begin{bmatrix}1 & 0 & 0\\ 0 & e^{-j2\pi i/3} & 0\\ 0 & 0 & e^{-j4\pi i/3}\end{bmatrix}$
4	$\frac{1}{2}\begin{bmatrix}1 & 1 & 1 & 1\\ 1 & e^{-j2\pi/4} & e^{-j4\pi/4} & e^{-j6\pi/4}\\ 1 & e^{-j4\pi/4} & e^{-j8\pi/4} & e^{-j12\pi/4}\\ 1 & e^{-j6\pi/4} & e^{-j12\pi/4} & e^{-j18\pi/4}\end{bmatrix}$	$\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & e^{-j2\pi i/4} & 0 & 0\\ 0 & 0 & e^{-j4\pi i/4} & 0\\ 0 & 0 & 0 & e^{-j6\pi i/4}\end{bmatrix}$

6.3.4.2.3 Codebook for precoding and CSI reporting

For transmission on two antenna ports, $p \in \{0,1\}$, and for the purpose of CSI reporting based on two antenna ports $p \in \{0,1\}$ or $p \in \{15,16\}$, the precoding matrix $W(i)$ shall be selected from Table 6.3.4.2.3-1 or a subset thereof. For the closed-loop spatial multiplexing transmission mode defined in [4], the codebook index 0 is not used when the number of layers is $\upsilon = 2$.

Table 6.3.4.2.3-1: Codebook for transmission on antenna ports $\{0,1\}$ and for CSI reporting based on antenna ports $\{0,1\}$ or $\{15,16\}$.

Codebook index	Number of layers υ	
	1	**2**
0	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\ 1\end{bmatrix}$	$\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}$
1	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\ -1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix}$
2	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\ j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 1\\ j & -j\end{bmatrix}$
3	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\ -j\end{bmatrix}$	-

For transmission on four antenna ports, $p \in \{0,1,2,3\}$, and for the purpose of CSI reporting based on four antenna ports $p \in \{0,1,2,3\}$ or $p \in \{15,16,17,18\}$, the precoding matrix W shall be selected from Table 6.3.4.2.3-2 or a subset thereof. The quantity $W_n^{\{s\}}$ denotes the matrix defined by the columns given by the set $\{s\}$ from the expression $W_n = I - 2u_n u_n^H / u_n^H u_n$ where I is the 4×4 identity matrix and the vector u_n is given by Table 6.3.4.2.3-2.

Petitioners' Exhibit 1003, p. 851
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.3.4.2.3-2: Codebook for transmission on antenna ports $\{0,1,2,3\}$ and for CSI reporting based on antenna ports $\{0,1,2,3\}$ or $\{15,16,17,18\}$.

Codebook index	u_n	Number of layers υ			
		1	2	3	4
0	$u_0 = \begin{bmatrix} 1 & -1 & -1 & -1 \end{bmatrix}^T$	$W_0^{\{1\}}$	$W_0^{\{14\}}/\sqrt{2}$	$W_0^{\{124\}}/\sqrt{3}$	$W_0^{\{1234\}}/2$
1	$u_1 = \begin{bmatrix} 1 & -j & 1 & j \end{bmatrix}^T$	$W_1^{\{1\}}$	$W_1^{\{12\}}/\sqrt{2}$	$W_1^{\{123\}}/\sqrt{3}$	$W_1^{\{1234\}}/2$
2	$u_2 = \begin{bmatrix} 1 & 1 & -1 & 1 \end{bmatrix}^T$	$W_2^{\{1\}}$	$W_2^{\{12\}}/\sqrt{2}$	$W_2^{\{123\}}/\sqrt{3}$	$W_2^{\{3214\}}/2$
3	$u_3 = \begin{bmatrix} 1 & j & 1 & -j \end{bmatrix}^T$	$W_3^{\{1\}}$	$W_3^{\{12\}}/\sqrt{2}$	$W_3^{\{123\}}/\sqrt{3}$	$W_3^{\{3214\}}/2$
4	$u_4 = \begin{bmatrix} 1 & (-1-j)/\sqrt{2} & -j & (1-j)/\sqrt{2} \end{bmatrix}^T$	$W_4^{\{1\}}$	$W_4^{\{14\}}/\sqrt{2}$	$W_4^{\{124\}}/\sqrt{3}$	$W_4^{\{1234\}}/2$
5	$u_5 = \begin{bmatrix} 1 & (1-j)/\sqrt{2} & j & (-1-j)/\sqrt{2} \end{bmatrix}^T$	$W_5^{\{1\}}$	$W_5^{\{14\}}/\sqrt{2}$	$W_5^{\{124\}}/\sqrt{3}$	$W_5^{\{1234\}}/2$
6	$u_6 = \begin{bmatrix} 1 & (1+j)/\sqrt{2} & -j & (-1+j)/\sqrt{2} \end{bmatrix}^T$	$W_6^{\{1\}}$	$W_6^{\{13\}}/\sqrt{2}$	$W_6^{\{134\}}/\sqrt{3}$	$W_6^{\{1324\}}/2$
7	$u_7 = \begin{bmatrix} 1 & (-1+j)/\sqrt{2} & j & (1+j)/\sqrt{2} \end{bmatrix}^T$	$W_7^{\{1\}}$	$W_7^{\{13\}}/\sqrt{2}$	$W_7^{\{134\}}/\sqrt{3}$	$W_7^{\{1324\}}/2$
8	$u_8 = \begin{bmatrix} 1 & -1 & 1 & 1 \end{bmatrix}^T$	$W_8^{\{1\}}$	$W_8^{\{12\}}/\sqrt{2}$	$W_8^{\{124\}}/\sqrt{3}$	$W_8^{\{1234\}}/2$
9	$u_9 = \begin{bmatrix} 1 & -j & -1 & -j \end{bmatrix}^T$	$W_9^{\{1\}}$	$W_9^{\{14\}}/\sqrt{2}$	$W_9^{\{134\}}/\sqrt{3}$	$W_9^{\{1234\}}/2$
10	$u_{10} = \begin{bmatrix} 1 & 1 & 1 & -1 \end{bmatrix}^T$	$W_{10}^{\{1\}}$	$W_{10}^{\{13\}}/\sqrt{2}$	$W_{10}^{\{123\}}/\sqrt{3}$	$W_{10}^{\{1324\}}/2$
11	$u_{11} = \begin{bmatrix} 1 & j & -1 & j \end{bmatrix}^T$	$W_{11}^{\{1\}}$	$W_{11}^{\{13\}}/\sqrt{2}$	$W_{11}^{\{134\}}/\sqrt{3}$	$W_{11}^{\{1324\}}/2$
12	$u_{12} = \begin{bmatrix} 1 & -1 & -1 & 1 \end{bmatrix}^T$	$W_{12}^{\{1\}}$	$W_{12}^{\{12\}}/\sqrt{2}$	$W_{12}^{\{123\}}/\sqrt{3}$	$W_{12}^{\{1234\}}/2$
13	$u_{13} = \begin{bmatrix} 1 & -1 & 1 & -1 \end{bmatrix}^T$	$W_{13}^{\{1\}}$	$W_{13}^{\{13\}}/\sqrt{2}$	$W_{13}^{\{123\}}/\sqrt{3}$	$W_{13}^{\{1324\}}/2$
14	$u_{14} = \begin{bmatrix} 1 & 1 & -1 & -1 \end{bmatrix}^T$	$W_{14}^{\{1\}}$	$W_{14}^{\{13\}}/\sqrt{2}$	$W_{14}^{\{123\}}/\sqrt{3}$	$W_{14}^{\{3214\}}/2$
15	$u_{15} = \begin{bmatrix} 1 & 1 & 1 & 1 \end{bmatrix}^T$	$W_{15}^{\{1\}}$	$W_{15}^{\{12\}}/\sqrt{2}$	$W_{15}^{\{123\}}/\sqrt{3}$	$W_{15}^{\{1234\}}/2$

For the purpose of CSI reporting for eight CSI reference signals the codebooks are given in section 7.2.4 of [4].

6.3.4.3 Precoding for transmit diversity

Precoding for transmit diversity is only used in combination with layer mapping for transmit diversity as described in Section 6.3.3.3. The precoding operation for transmit diversity is defined for two and four antenna ports.

For transmission on two antenna ports, $p \in \{0,1\}$, the output $y(i) = \begin{bmatrix} y^{(0)}(i) & y^{(1)}(i) \end{bmatrix}^T$, $i = 0,1,\ldots,M_{\text{symb}}^{\text{ap}}-1$ of the precoding operation is defined by

$$\begin{bmatrix} y^{(0)}(2i) \\ y^{(1)}(2i) \\ y^{(0)}(2i+1) \\ y^{(1)}(2i+1) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 & j & 0 \\ 0 & -1 & 0 & j \\ 0 & 1 & 0 & j \\ 1 & 0 & -j & 0 \end{bmatrix} \begin{bmatrix} \text{Re}\left(x^{(0)}(i)\right) \\ \text{Re}\left(x^{(1)}(i)\right) \\ \text{Im}\left(x^{(0)}(i)\right) \\ \text{Im}\left(x^{(1)}(i)\right) \end{bmatrix}$$

for $i = 0,1,\ldots,M_{\text{symb}}^{\text{layer}}-1$ with $M_{\text{symb}}^{\text{ap}} = 2M_{\text{symb}}^{\text{layer}}$.

For transmission on four antenna ports, $p \in \{0,1,2,3\}$, the output $y(i) = \begin{bmatrix} y^{(0)}(i) & y^{(1)}(i) & y^{(2)}(i) & y^{(3)}(i) \end{bmatrix}^T$, $i = 0,1,\ldots,M_{\text{symb}}^{\text{ap}}-1$ of the precoding operation is defined by

Petitioners' Exhibit 1003, p. 852
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$\begin{bmatrix} y^{(0)}(4i) \\ y^{(1)}(4i) \\ y^{(2)}(4i) \\ y^{(3)}(4i) \\ y^{(0)}(4i+1) \\ y^{(1)}(4i+1) \\ y^{(2)}(4i+1) \\ y^{(3)}(4i+1) \\ y^{(0)}(4i+2) \\ y^{(1)}(4i+2) \\ y^{(2)}(4i+2) \\ y^{(3)}(4i+2) \\ y^{(0)}(4i+3) \\ y^{(1)}(4i+3) \\ y^{(2)}(4i+3) \\ y^{(3)}(4i+3) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 & 0 & 0 & j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & -j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & j & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & -j & 0 \end{bmatrix} \begin{bmatrix} \mathrm{Re}\left(x^{(0)}(i)\right) \\ \mathrm{Re}\left(x^{(1)}(i)\right) \\ \mathrm{Re}\left(x^{(2)}(i)\right) \\ \mathrm{Re}\left(x^{(3)}(i)\right) \\ \mathrm{Im}\left(x^{(0)}(i)\right) \\ \mathrm{Im}\left(x^{(1)}(i)\right) \\ \mathrm{Im}\left(x^{(2)}(i)\right) \\ \mathrm{Im}\left(x^{(3)}(i)\right) \end{bmatrix}$$

for $i = 0,1,\ldots,M_{\text{symb}}^{\text{layer}}-1$ with $M_{\text{symb}}^{\text{ap}} = \begin{cases} 4M_{\text{symb}}^{\text{layer}} & \text{if } M_{\text{symb}}^{(0)} \bmod 4 = 0 \\ \left(4M_{\text{symb}}^{\text{layer}}\right)-2 & \text{if } M_{\text{symb}}^{(0)} \bmod 4 \neq 0 \end{cases}$.

6.3.4.4 Precoding for spatial multiplexing using antenna ports with UE-specific reference signals

Precoding for spatial multiplexing using antenna ports with UE-specific reference signals is only used in combination with layer mapping for spatial multiplexing as described in Section 6.3.3.2. Spatial multiplexing using antenna ports with UE-specific reference signals supports up to eight antenna ports and the set of antenna ports used is $p = 7,8,\ldots,\upsilon+6$.

For transmission on υ antenna ports, the precoding operation is defined by

$$\begin{bmatrix} y^{(7)}(i) \\ y^{(8)}(i) \\ \vdots \\ y^{(6+\upsilon)}(i) \end{bmatrix} = \begin{bmatrix} x^{(0)}(i) \\ x^{(1)}(i) \\ \vdots \\ x^{(\upsilon-1)}(i) \end{bmatrix}$$

where $i = 0,1,\ldots,M_{\text{symb}}^{\text{ap}}-1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

6.3.5 Mapping to resource elements

For each of the antenna ports used for transmission of the physical channel, the block of complex-valued symbols $y^{(p)}(0),\ldots,y^{(p)}(M_{\text{symb}}^{\text{ap}}-1)$ shall conform to the downlink power allocation specified in Section 5.2 in [4] and be mapped in sequence starting with $y^{(p)}(0)$ to resource elements (k,l) which meet all of the following criteria:

- they are in the physical resource blocks corresponding to the virtual resource blocks assigned for transmission, and
- they are not used for transmission of PBCH, synchronization signals, cell-specific reference signals, MBSFN reference signals or UE-specific reference signals, and
- they are assumed by the UE not to be used for transmission of CSI reference signals and the DCI associated with the downlink transmission uses the C-RNTI or semi-persistent C-RNTI, and

Petitioners' Exhibit 1003, p. 853
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- the index l in the first slot in a subframe fulfils $l \geq l_{\text{DataStart}}$ where $l_{\text{DataStart}}$ is given by Section 7.1.6.4 of [4].

If the DCI associated with the downlink transmission uses the C-RNTI or semi-persistent C-RNTI and transmit diversity according to section 6.3.4.3 is used, resource elements in an OFDM symbol assumed by the UE to contain CSI-RS shall be used in the mapping above if and only if all of the following criteria are fulfilled:

- there is an even number of resource elements for the OFDM symbol in each resource block assigned for transmission, and

- the complex-valued symbols $y^{(p)}(i)$ and $y^{(p)}(i+1)$, where i is an even number, can be mapped to resource elements (k,l) and $(k+n,l)$ in the same OFDM symbol with $n<3$.

The mapping to resource elements (k,l) on antenna port p not reserved for other purposes shall be in increasing order of first the index k over the assigned physical resource blocks and then the index l, starting with the first slot in a subframe.

6.4 Physical downlink shared channel

The physical downlink shared channel shall be processed and mapped to resource elements as described in Section 6.3 with the following exceptions:

- In resource blocks in which UE-specific reference signals are not transmitted, the PDSCH shall be transmitted on the same set of antenna ports as the PBCH, which is one of $\{0\}$, $\{0,1\}$, or $\{0,1,2,3\}$

- In resource blocks in which UE-specific reference signals are transmitted, the PDSCH shall be transmitted on antenna port(s) $\{5\}$, $\{7\}$, $\{8\}$, or $p \in \{7,8,...,\upsilon+6\}$, where υ is the number of layers used for transmission of the PDSCH.

- If PDSCH is transmitted in MBSFN subframes as defined in [4], the PDSCH shall be transmitted on one or several of antenna port(s) $p \in \{7,8,...,\upsilon+6\}$, where υ is the number of layers used for transmission of the PDSCH.

6.5 Physical multicast channel

The physical multicast channel shall be processed and mapped to resource elements as described in Section 6.3 with the following exceptions:

- No transmit diversity scheme is specified

- Layer mapping and precoding shall be done assuming a single antenna port and the transmission shall use antenna port 4.

- The PMCH can only be transmitted in the MBSFN region of an MBSFN subframe.

- The PMCH shall use extended cyclic prefix.

6.6 Physical broadcast channel

6.6.1 Scrambling

The block of bits $b(0),...,b(M_{\text{bit}}-1)$, where M_{bit}, the number of bits transmitted on the physical broadcast channel, equals 1920 for normal cyclic prefix and 1728 for extended cyclic prefix, shall be scrambled with a cell-specific sequence prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{bit}}-1)$ according to

$$\tilde{b}(i) = \left(b(i)+c(i)\right) \bmod 2$$

Petitioners' Exhibit 1003, p. 854
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

where the scrambling sequence $c(i)$ is given by Section 7.2. The scrambling sequence shall be initialised with $c_{\text{init}} = N_{\text{ID}}^{\text{cell}}$ in each radio frame fulfilling $n_{\text{f}} \bmod 4 = 0$.

6.6.2 Modulation

The block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{bit}}-1)$ shall be modulated as described in Section 7.1, resulting in a block of complex-valued modulation symbols $d(0),...,d(M_{\text{symb}}-1)$. Table 6.6.2-1 specifies the modulation mappings applicable for the physical broadcast channel.

Table 6.6.2-1: PBCH modulation schemes.

Physical channel	Modulation schemes
PBCH	QPSK

6.6.3 Layer mapping and precoding

The block of modulation symbols $d(0),...,d(M_{\text{symb}}-1)$ shall be mapped to layers according to one of Sections 6.3.3.1 or 6.3.3.3 with $M_{\text{symb}}^{(0)} = M_{\text{symb}}$ and precoded according to one of Sections 6.3.4.1 or 6.3.4.3, resulting in a block of vectors $y(i) = \left[y^{(0)}(i) \quad ... \quad y^{(P-1)}(i)\right]^T$, $i = 0,...,M_{\text{symb}}-1$, where $y^{(p)}(i)$ represents the signal for antenna port p and where $p = 0,...,P-1$ and the number of antenna ports for cell-specific reference signals $P \in \{1,2,4\}$.

6.6.4 Mapping to resource elements

The block of complex-valued symbols $y^{(p)}(0),...,y^{(p)}(M_{\text{symb}}-1)$ for each antenna port is transmitted during 4 consecutive radio frames starting in each radio frame fulfilling $n_{\text{f}} \bmod 4 = 0$ and shall be mapped in sequence starting with $y(0)$ to resource elements (k,l). The mapping to resource elements (k,l) not reserved for transmission of reference signals shall be in increasing order of first the index k, then the index l in slot 1 in subframe 0 and finally the radio frame number. The resource-element indices are given by

$$k = \frac{N_{\text{RB}}^{\text{DL}} N_{\text{sc}}^{\text{RB}}}{2} - 36 + k', \qquad k' = 0,1,...,71$$
$$l = 0,1,...,3$$

where resource elements reserved for reference signals shall be excluded. The mapping operation shall assume cell-specific reference signals for antenna ports 0-3 being present irrespective of the actual configuration. The UE shall assume that the resource elements assumed to be reserved for reference signals in the mapping operation above but not used for transmission of reference signal are not available for PDSCH transmission. The UE shall not make any other assumptions about these resource elements.

6.7 Physical control format indicator channel

The physical control format indicator channel carries information about the number of OFDM symbols used for transmission of PDCCHs in a subframe. The set of OFDM symbols possible to use for PDCCH in a subframe is given by Table 6.7-1.

Petitioners' Exhibit 1003, p. 855
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.7-1: Number of OFDM symbols used for PDCCH.

Subframe	Number of OFDM symbols for PDCCH when $N_{RB}^{DL} > 10$	Number of OFDM symbols for PDCCH when $N_{RB}^{DL} \le 10$
Subframe 1 and 6 for frame structure type 2	1, 2	2
MBSFN subframes on a carrier supporting PDSCH, configured with 1 or 2 cell-specific antenna ports	1, 2	2
MBSFN subframes on a carrier supporting PDSCH, configured with 4 cell-specific antenna ports	2	2
Subframes on a carrier not supporting PDSCH	0	0
Non-MBSFN subframes (except subframe 6 for frame structure type 2) configured with positioning reference signals	1, 2, 3	2, 3
All other cases	1, 2, 3	2, 3, 4

The PCFICH shall be transmitted when the number of OFDM symbols for PDCCH is greater than zero.

6.7.1 Scrambling

The block of bits $b(0),...,b(31)$ transmitted in one subframe shall be scrambled with a cell-specific sequence prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0),...,\tilde{b}(31)$ according to

$$\tilde{b}(i) = \left(b(i) + c(i)\right) \bmod 2$$

where the scrambling sequence $c(i)$ is given by Section 7.2. The scrambling sequence generator shall be initialised with $c_{init} = \left(\lfloor n_s/2 \rfloor + 1\right) \cdot \left(2N_{ID}^{cell} + 1\right) \cdot 2^9 + N_{ID}^{cell}$ at the start of each subframe.

6.7.2 Modulation

The block of scrambled bits $\tilde{b}(0),...,\tilde{b}(31)$ shall be modulated as described in Section 7.1, resulting in a block of complex-valued modulation symbols $d(0),...,d(15)$. Table 6.7.2-1 specifies the modulation mappings applicable for the physical control format indicator channel.

Table 6.7.2-1: PCFICH modulation schemes.

Physical channel	Modulation schemes
PCFICH	QPSK

6.7.3 Layer mapping and precoding

The block of modulation symbols $d(0),...,d(15)$ shall be mapped to layers according to one of Sections 6.3.3.1 or 6.3.3.3 with $M_{symb}^{(0)} = 16$ and precoded according to one of Sections 6.3.4.1 or 6.3.4.3, resulting in a block of vectors $y(i) = \left[y^{(0)}(i) \quad ... \quad y^{(P-1)}(i)\right]^T$, $i = 0,...,15$, where $y^{(p)}(i)$ represents the signal for antenna port p and where $p = 0,...,P-1$ and the number of antenna ports for cell-specific reference signals $P \in \{1,2,4\}$. The PCFICH shall be transmitted on the same set of antenna ports as the PBCH.

6.7.4 Mapping to resource elements

The mapping to resource elements is defined in terms of quadruplets of complex-valued symbols. Let $z^{(p)}(i) = \left\langle y^{(p)}(4i), y^{(p)}(4i+1), y^{(p)}(4i+2), y^{(p)}(4i+3) \right\rangle$ denote symbol quadruplet i for antenna port p. For each of the antenna ports, symbol quadruplets shall be mapped in increasing order of i to the four resource-element groups in

Petitioners' Exhibit 1003, p. 856
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

the first OFDM symbol in a downlink subframe with the representative resource-element as defined in Section 6.2.4 given by

$z^{(p)}(0)$ is mapped to the resource-element group represented by $k = \bar{k}$

$z^{(p)}(1)$ is mapped to the resource-element group represented by $k = \bar{k} + \lfloor N_{\mathrm{RB}}^{\mathrm{DL}}/2 \rfloor \cdot N_{\mathrm{sc}}^{\mathrm{RB}}/2$

$z^{(p)}(2)$ is mapped to the resource-element group represented by $k = \bar{k} + \lfloor 2N_{\mathrm{RB}}^{\mathrm{DL}}/2 \rfloor \cdot N_{\mathrm{sc}}^{\mathrm{RB}}/2$

$z^{(p)}(3)$ is mapped to the resource-element group represented by $k = \bar{k} + \lfloor 3N_{\mathrm{RB}}^{\mathrm{DL}}/2 \rfloor \cdot N_{\mathrm{sc}}^{\mathrm{RB}}/2$

where the additions are modulo $N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}$,

$$\bar{k} = \left(N_{\mathrm{sc}}^{\mathrm{RB}}/2\right) \cdot \left(N_{\mathrm{ID}}^{\mathrm{cell}} \bmod 2N_{\mathrm{RB}}^{\mathrm{DL}}\right)$$

and $N_{\mathrm{ID}}^{\mathrm{cell}}$ is the physical-layer cell identity as given by Section 6.11.

6.8 Physical downlink control channel

6.8.1 PDCCH formats

The physical downlink control channel carries scheduling assignments and other control information. A physical control channel is transmitted on an aggregation of one or several consecutive control channel elements (CCEs), where a control channel element corresponds to 9 resource element groups. The number of resource-element groups not assigned to PCFICH or PHICH is N_{REG} . The CCEs available in the system are numbered from 0 to $N_{\mathrm{CCE}} - 1$, where $N_{\mathrm{CCE}} = \lfloor N_{\mathrm{REG}}/9 \rfloor$. The PDCCH supports multiple formats as listed in Table 6.8.1-1. A PDCCH consisting of n consecutive CCEs may only start on a CCE fulfilling $i \bmod n = 0$, where i is the CCE number.

Multiple PDCCHs can be transmitted in a subframe.

Table 6.8.1-1: Supported PDCCH formats.

PDCCH format	Number of CCEs	Number of resource-element groups	Number of PDCCH bits
0	1	9	72
1	2	18	144
2	4	36	288
3	8	72	576

6.8.2 PDCCH multiplexing and scrambling

The block of bits $b^{(i)}(0),\ldots,b^{(i)}(M_{\mathrm{bit}}^{(\mathrm{i})} - 1)$ on each of the control channels to be transmitted in a subframe, where $M_{\mathrm{bit}}^{(\mathrm{i})}$ is the number of bits in one subframe to be transmitted on physical downlink control channel number i , shall be multiplexed, resulting in a block of bits $b^{(0)}(0),\ldots,b^{(0)}(M_{\mathrm{bit}}^{(0)} - 1), b^{(1)}(0),\ldots,b^{(1)}(M_{\mathrm{bit}}^{(1)} - 1),\ldots,b^{(n_{\mathrm{PDCCH}}-1)}(0),\ldots,b^{(n_{\mathrm{PDCCH}}-1)}(M_{\mathrm{bit}}^{(n_{\mathrm{PDCCH}}-1)} - 1)$, where n_{PDCCH} is the number of PDCCHs transmitted in the subframe.

The block of bits $b^{(0)}(0),\ldots,b^{(0)}(M_{\mathrm{bit}}^{(0)} - 1), b^{(1)}(0),\ldots,b^{(1)}(M_{\mathrm{bit}}^{(1)} - 1),\ldots,b^{(n_{\mathrm{PDCCH}}-1)}(0),\ldots,b^{(n_{\mathrm{PDCCH}}-1)}(M_{\mathrm{bit}}^{(n_{\mathrm{PDCCH}}-1)} - 1)$ shall be scrambled with a cell-specific sequence prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0),\ldots,\tilde{b}(M_{\mathrm{tot}} - 1)$ according to

$$\tilde{b}(i) = \left(b(i) + c(i)\right) \bmod 2$$

where the scrambling sequence $c(i)$ is given by Section 7.2. The scrambling sequence generator shall be initialised with $c_{\mathrm{init}} = \lfloor n_{\mathrm{s}}/2 \rfloor 2^9 + N_{\mathrm{ID}}^{\mathrm{cell}}$ at the start of each subframe.

Petitioners' Exhibit 1003, p. 857
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CCE number n corresponds to bits $b(72n), b(72n+1), ..., b(72n+71)$. If necessary, <NIL> elements shall be inserted in the block of bits prior to scrambling to ensure that the PDCCHs starts at the CCE positions as described in [4] and to ensure that the length $M_{\text{tot}} = 8N_{\text{REG}} \geq \sum_{i=0}^{n_{\text{PDCCH}}-1} M_{\text{bit}}^{(i)}$ of the scrambled block of bits matches the amount of resource-element groups not assigned to PCFICH or PHICH.

6.8.3 Modulation

The block of scrambled bits $\tilde{b}(0), ..., \tilde{b}(M_{\text{tot}}-1)$ shall be modulated as described in Section 7.1, resulting in a block of complex-valued modulation symbols $d(0), ..., d(M_{\text{symb}}-1)$. Table 6.8.3-1 specifies the modulation mappings applicable for the physical downlink control channel.

Table 6.8.3-1: PDCCH modulation schemes.

Physical channel	Modulation schemes
PDCCH	QPSK

6.8.4 Layer mapping and precoding

The block of modulation symbols $d(0), ..., d(M_{\text{symb}}-1)$ shall be mapped to layers according to one of Sections 6.3.3.1 or 6.3.3.3 with $M_{\text{symb}}^{(0)} = M_{\text{symb}}$ and precoded according to one of Sections 6.3.4.1 or 6.3.4.3, resulting in a block of vectors $y(i) = \left[y^{(0)}(i) \quad ... \quad y^{(P-1)}(i) \right]^T$, $i = 0, ..., M_{\text{symb}}-1$ to be mapped onto resources on the antenna ports used for transmission, where $y^{(p)}(i)$ represents the signal for antenna port p. The PDCCH shall be transmitted on the same set of antenna ports as the PBCH.

6.8.5 Mapping to resource elements

The mapping to resource elements is defined by operations on quadruplets of complex-valued symbols. Let $z^{(p)}(i) = \left\langle y^{(p)}(4i), y^{(p)}(4i+1), y^{(p)}(4i+2), y^{(p)}(4i+3) \right\rangle$ denote symbol quadruplet i for antenna port p.

The block of quadruplets $z^{(p)}(0), ..., z^{(p)}(M_{\text{quad}}-1)$, where $M_{\text{quad}} = M_{\text{symb}}/4$, shall be permuted resulting in $w^{(p)}(0), ..., w^{(p)}(M_{\text{quad}}-1)$. The permutation shall be according to the sub-block interleaver in Section 5.1.4.2.1 of [3] with the following exceptions:

- the input and output to the interleaver is defined by symbol quadruplets instead of bits
- interleaving is performed on symbol quadruplets instead of bits by substituting the terms “bit”, “bits” and “bit sequence” in Section 5.1.4.2.1 of [3] by “symbol quadruplet”, “symbol quadruplets” and “symbol-quadruplet sequence”, respectively

<NULL> elements at the output of the interleaver in [3] shall be removed when forming $w^{(p)}(0), ..., w^{(p)}(M_{\text{quad}}-1)$. Note that the removal of <NULL> elements does not affect any <NIL> elements inserted in Section 6.8.2.

The block of quadruplets $w^{(p)}(0), ..., w^{(p)}(M_{\text{quad}}-1)$ shall be cyclically shifted, resulting in $\overline{w}^{(p)}(0), ..., \overline{w}^{(p)}(M_{\text{quad}}-1)$ where $\overline{w}^{(p)}(i) = w^{(p)}\left((i + N_{\text{ID}}^{\text{cell}}) \bmod M_{\text{quad}} \right)$.

Mapping of the block of quadruplets $\overline{w}^{(p)}(0), ..., \overline{w}^{(p)}(M_{\text{quad}}-1)$ is defined in terms of resource-element groups, specified in Section 6.2.4, according to steps 1–10 below:

1) Initialize $m' = 0$ (resource-element group number)
2) Initialize $k' = 0$

Petitioners' Exhibit 1003, p. 858
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

3) Initialize $l'=0$

4) If the resource element (k',l') represents a resource-element group and the resource-element group is not assigned to PCFICH or PHICH then perform step 5 and 6, else go to step 7

5) Map symbol-quadruplet $\overline{w}^{(p)}(m')$ to the resource-element group represented by (k',l') for each antenna port p

6) Increase m' by 1

7) Increase l' by 1

8) Repeat from step 4 if $l'<L$, where L corresponds to the number of OFDM symbols used for PDCCH transmission as indicated by the sequence transmitted on the PCFICH

9) Increase k' by 1

10) Repeat from step 3 if $k'<N_{\mathrm{RB}}^{\mathrm{DL}}\cdot N_{\mathrm{sc}}^{\mathrm{RB}}$

6.9 Physical hybrid ARQ indicator channel

The PHICH carries the hybrid-ARQ ACK/NACK. Multiple PHICHs mapped to the same set of resource elements constitute a PHICH group, where PHICHs within the same PHICH group are separated through different orthogonal sequences. A PHICH resource is identified by the index pair $\left(n_{\mathrm{PHICH}}^{\mathrm{group}}, n_{\mathrm{PHICH}}^{\mathrm{seq}}\right)$, where $n_{\mathrm{PHICH}}^{\mathrm{group}}$ is the PHICH group number and $n_{\mathrm{PHICH}}^{\mathrm{seq}}$ is the orthogonal sequence index within the group.

For frame structure type 1, the number of PHICH groups $N_{\mathrm{PHICH}}^{\mathrm{group}}$ is constant in all subframes and given by

$$N_{\mathrm{PHICH}}^{\mathrm{group}}=\begin{cases}\left\lceil N_{\mathrm{g}}\left(N_{\mathrm{RB}}^{\mathrm{DL}}/8\right)\right\rceil & \text{for normal cyclic prefix}\\ 2\cdot\left\lceil N_{\mathrm{g}}\left(N_{\mathrm{RB}}^{\mathrm{DL}}/8\right)\right\rceil & \text{for extended cyclic prefix}\end{cases}$$

where $N_{\mathrm{g}}\in\{1/6,1/2,1,2\}$ is provided by higher layers. The index $n_{\mathrm{PHICH}}^{\mathrm{group}}$ ranges from 0 to $N_{\mathrm{PHICH}}^{\mathrm{group}}-1$.

For frame structure type 2, the number of PHICH groups may vary between downlink subframes and is given by $m_i\cdot N_{\mathrm{PHICH}}^{\mathrm{group}}$ where m_i is given by Table 6.9-1 and $N_{\mathrm{PHICH}}^{\mathrm{group}}$ by the expression above. The index $n_{\mathrm{PHICH}}^{\mathrm{group}}$ in a downlink subframe with non-zero PHICH resources ranges from 0 to $m_i\cdot N_{\mathrm{PHICH}}^{\mathrm{group}}-1$.

Table 6.9-1: The factor m_i for frame structure type 2.

Uplink-downlink configuration	Subframe number i									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	2	1	-	-	-	2	1	-	-	-
1	0	1	-	-	1	0	1	-	-	1
2	0	0	-	1	0	0	0	-	1	0
3	1	0	-	-	-	0	0	0	1	1
4	0	0	-	-	0	0	0	0	1	1
5	0	0	-	0	0	0	0	0	1	0
6	1	1	-	-	-	1	1	-	-	1

6.9.1 Modulation

The block of bits $b(0),\ldots,b(M_{\mathrm{bit}}-1)$ transmitted on one PHICH in one subframe shall be modulated as described in Section 7.1, resulting in a block of complex-valued modulation symbols $z(0),\ldots,z(M_{\mathrm{s}}-1)$, where $M_{\mathrm{s}}=M_{\mathrm{bit}}$. Table 6.9.1-1 specifies the modulation mappings applicable for the physical hybrid ARQ indicator channel.

Petitioners' Exhibit 1003, p. 859
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.9.1-1: PHICH modulation schemes.

Physical channel	Modulation schemes
PHICH	BPSK

The block of modulation symbols $z(0),...,z(M_{\text{s}}-1)$ shall be symbol-wise multiplied with an orthogonal sequence and scrambled, resulting in a sequence of modulation symbols $d(0),...,d(M_{\text{symb}}-1)$ according to

$$d(i) = w\left(i \bmod N_{\text{SF}}^{\text{PHICH}}\right)\cdot\left(1-2c(i)\right)\cdot z\left(\left\lfloor i/N_{\text{SF}}^{\text{PHICH}}\right\rfloor\right)$$

where

$$i = 0,...,M_{\text{symb}}-1$$
$$M_{\text{symb}} = N_{\text{SF}}^{\text{PHICH}}\cdot M_{\text{s}}$$
$$N_{\text{SF}}^{\text{PHICH}} = \begin{cases}4 & \text{normal cyclic prefix}\\ 2 & \text{extended cyclic prefix}\end{cases}$$

and $c(i)$ is a cell-specific scrambling sequence generated according to Section 7.2. The scrambling sequence generator shall be initialised with $c_{\text{init}} = \left(\lfloor n_{\text{s}}/2\rfloor+1\right)\cdot\left(2N_{\text{ID}}^{\text{cell}}+1\right)\cdot 2^9 + N_{\text{ID}}^{\text{cell}}$ at the start of each subframe.

The sequence $\left[w(0) \quad \cdots \quad w(N_{\text{SF}}^{\text{PHICH}}-1)\right]$ is given by Table 6.9.1-2 where the sequence index $n_{\text{PHICH}}^{\text{seq}}$ corresponds to the PHICH number within the PHICH group.

Table 6.9.1-2: Orthogonal sequences $\left[w(0) \quad \cdots \quad w(N_{\text{SF}}^{\text{PHICH}}-1)\right]$ for PHICH.

Sequence index	Orthogonal sequence	
$n_{\text{PHICH}}^{\text{seq}}$	Normal cyclic prefix $N_{\text{SF}}^{\text{PHICH}}=4$	Extended cyclic prefix $N_{\text{SF}}^{\text{PHICH}}=2$
0	$[+1 \quad +1 \quad +1 \quad +1]$	$[+1 \quad +1]$
1	$[+1 \quad -1 \quad +1 \quad -1]$	$[+1 \quad -1]$
2	$[+1 \quad +1 \quad -1 \quad -1]$	$[+j \quad +j]$
3	$[+1 \quad -1 \quad -1 \quad +1]$	$[+j \quad -j]$
4	$[+j \quad +j \quad +j \quad +j]$	-
5	$[+j \quad -j \quad +j \quad -j]$	-
6	$[+j \quad +j \quad -j \quad -j]$	-
7	$[+j \quad -j \quad -j \quad +j]$	-

6.9.2 Resource group alignment, layer mapping and precoding

The block of symbols $d(0),...,d(M_{\text{symb}}-1)$ should be first aligned with resource element group size, resulting in a block of symbols $d^{(0)}(0),...,d^{(0)}(c\cdot M_{\text{symb}}-1)$, where $c=1$ for normal cyclic prefix; and $c=2$ for extended cyclic prefix.

For normal cyclic prefix, $d^{(0)}(i) = d(i)$, for $i = 0,...,M_{\text{symb}}-1$.

For extended cyclic prefix,

$$\left[d^{(0)}(4i) \quad d^{(0)}(4i+1) \quad d^{(0)}(4i+2) \quad d^{(0)}(4i+3)\right]^T = \begin{cases}\left[d(2i) \quad d(2i+1) \quad 0 \quad 0\right]^T & n_{\text{PHICH}}^{\text{group}} \bmod 2 = 0\\ \left[0 \quad 0 \quad d(2i) \quad d(2i+1)\right]^T & n_{\text{PHICH}}^{\text{group}} \bmod 2 = 1\end{cases}$$

Petitioners' Exhibit 1003, p. 860
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

for $i = 0,...,\left(M_{\text{symb}}/2\right)-1$.

The block of symbols $d^{(0)}(0),...,d^{(0)}(c\cdot M_{\text{symb}}-1)$ shall be mapped to layers and precoded, resulting in a block of vectors $y(i)=\left[y^{(0)}(i) \quad ... \quad y^{(P-1)}(i)\right]^T$, $i = 0,...,c\cdot M_{\text{symb}}-1$, where $y^{(p)}(i)$ represents the signal for antenna port p, $p = 0,...,P-1$ and the number of cell-specific reference signals $P \in \{1,2,4\}$. The layer mapping and precoding operation depends on the cyclic prefix length and the number of antenna ports used for transmission of the PHICH. The PHICH shall be transmitted on the same set of antenna ports as the PBCH.

For transmission on a single antenna port, $P = 1$, layer mapping and precoding are defined by Sections 6.3.3.1 and 6.3.4.1, respectively, with $M_{\text{symb}}^{(0)} = c\cdot M_{\text{symb}}$.

For transmission on two antenna ports, $P = 2$, layer mapping and precoding are defined by Sections 6.3.3.3 and 6.3.4.3, respectively, with $M_{\text{symb}}^{(0)} = c\cdot M_{\text{symb}}$.

For transmission on four antenna ports, $P = 4$, layer mapping is defined by Section 6.3.3.3 with $M_{\text{symb}}^{(0)} = c\cdot M_{\text{symb}}$ and precoding by

$$\begin{bmatrix} y^{(0)}(4i) \\ y^{(1)}(4i) \\ y^{(2)}(4i) \\ y^{(3)}(4i) \\ y^{(0)}(4i+1) \\ y^{(1)}(4i+1) \\ y^{(2)}(4i+1) \\ y^{(3)}(4i+1) \\ y^{(0)}(4i+2) \\ y^{(1)}(4i+2) \\ y^{(2)}(4i+2) \\ y^{(3)}(4i+2) \\ y^{(0)}(4i+3) \\ y^{(1)}(4i+3) \\ y^{(2)}(4i+3) \\ y^{(3)}(4i+3) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 & 0 & 0 & j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & -j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & j & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & -j & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \text{Re}\left(x^{(0)}(i)\right) \\ \text{Re}\left(x^{(1)}(i)\right) \\ \text{Re}\left(x^{(2)}(i)\right) \\ \text{Re}\left(x^{(3)}(i)\right) \\ \text{Im}\left(x^{(0)}(i)\right) \\ \text{Im}\left(x^{(1)}(i)\right) \\ \text{Im}\left(x^{(2)}(i)\right) \\ \text{Im}\left(x^{(3)}(i)\right) \end{bmatrix}$$

if $(i+n_{\text{PHICH}}^{\text{group}}) \bmod 2 = 0$ for normal cyclic prefix, or $(i+\lfloor n_{\text{PHICH}}^{\text{group}}/2 \rfloor) \bmod 2 = 0$ for extended cyclic prefix, where $n_{\text{PHICH}}^{\text{group}}$ is the PHICH group number and $i = 0,1,2$, and by

Petitioners' Exhibit 1003, p. 861
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$\begin{bmatrix} y^{(0)}(4i) \\ y^{(1)}(4i) \\ y^{(2)}(4i) \\ y^{(3)}(4i) \\ y^{(0)}(4i+1) \\ y^{(1)}(4i+1) \\ y^{(2)}(4i+1) \\ y^{(3)}(4i+1) \\ y^{(0)}(4i+2) \\ y^{(1)}(4i+2) \\ y^{(2)}(4i+2) \\ y^{(3)}(4i+2) \\ y^{(0)}(4i+3) \\ y^{(1)}(4i+3) \\ y^{(2)}(4i+3) \\ y^{(3)}(4i+3) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & -j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & j & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & -j & 0 \end{bmatrix} \begin{bmatrix} \mathrm{Re}\left(x^{(0)}(i)\right) \\ \mathrm{Re}\left(x^{(1)}(i)\right) \\ \mathrm{Re}\left(x^{(2)}(i)\right) \\ \mathrm{Re}\left(x^{(3)}(i)\right) \\ \mathrm{Im}\left(x^{(0)}(i)\right) \\ \mathrm{Im}\left(x^{(1)}(i)\right) \\ \mathrm{Im}\left(x^{(2)}(i)\right) \\ \mathrm{Im}\left(x^{(3)}(i)\right) \end{bmatrix}$$

otherwise for $i = 0,1,2$.

6.9.3 Mapping to resource elements

The sequence $\bar{y}^{(p)}(0),\ldots,\bar{y}^{(p)}(M_{\mathrm{symb}}^{(0)}-1)$ for each of the PHICH groups is defined by

$$\bar{y}^{(p)}(n) = \sum y_i^{(p)}(n)$$

where the sum is over all PHICHs in the PHICH group and $y_i^{(p)}(n)$ represents the symbol sequence from the i:th PHICH in the PHICH group.

PHICH groups are mapped to PHICH mapping units.

For normal cyclic prefix, the mapping of PHICH group m to PHICH mapping unit m' is defined by

$$\tilde{y}_{m'}^{(p)}(n) = \bar{y}_m^{(p)}(n)$$

where

$$m' = m = \begin{cases} 0,1,\ldots,N_{\mathrm{PHICH}}^{\mathrm{group}}-1 & \text{for frame structure type1} \\ 0,1,\ldots,m_i \cdot N_{\mathrm{PHICH}}^{\mathrm{group}}-1 & \text{for frame structure type2} \end{cases},$$

and where m_i is given by Table 6.9-1.

For extended cyclic prefix, the mapping of PHICH group m and $m+1$ to PHICH mapping unit m' is defined by

$$\tilde{y}_{m'}^{(p)}(n) = \bar{y}_m^{(p)}(n) + \bar{y}_{m+1}^{(p)}(n)$$

where

$$m' = m/2$$

$$m = \begin{cases} 0,2,\ldots,N_{\mathrm{PHICH}}^{\mathrm{group}}-2 & \text{for frame structure type1} \\ 0,2,\ldots,m_i \cdot N_{\mathrm{PHICH}}^{\mathrm{group}}-2 & \text{for frame structure type2} \end{cases}$$

Petitioners' Exhibit 1003, p. 862
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

and where m_i is given by Table 6.9-1.

Let $z^{(p)}(i) = \left\langle \tilde{y}^{(p)}(4i), \tilde{y}^{(p)}(4i+1), \tilde{y}^{(p)}(4i+2), \tilde{y}^{(p)}(4i+3) \right\rangle$, $i = 0,1,2$ denote symbol quadruplet i for antenna port p. Mapping to resource elements is defined in terms of symbol quadruplets according to steps 1–10 below:

1) For each value of l'

   2) Let $n_{l'}$ denote the number of resource element groups not assigned to PCFICH in OFDM symbol l'

   3) Number the resource-element groups not assigned to PCFICH in OFDM symbol l' from 0 to $n_{l'} - 1$, starting from the resource-element group with the lowest frequency-domain index.

4) Initialize $m' = 0$ (PHICH mapping unit number)

5) For each value of $i = 0,1,2$

   6) Symbol-quadruplet $z^{(p)}(i)$ from PHICH mapping unit m' is mapped to the resource-element group represented by $(k', l')_i$ as defined in Section 6.2.4 where the indices k_i' and l_i' are given by steps 7 and 8 below:

      7) The time-domain index l_i' is given by

$$l_i' = \begin{cases} 0 & \text{normal PHICH duration, all subframes} \\ (\lfloor m'/2 \rfloor + i + 1) \bmod 2 & \text{extended PHICH duration, MBSFN subframes} \\ (\lfloor m'/2 \rfloor + i + 1) \bmod 2 & \text{extended PHICH duration, subframe 1 and 6 in frame structure type 2} \\ i & \text{otherwise} \end{cases}$$

      8) Set the frequency-domain index k_i' to the resource-element group assigned the number $\bar{n}_i$ in step 3 above, where $\bar{n}_i$ is given by

$$\bar{n}_i = \begin{cases} \left(\lfloor N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l_i'} / n_1 \rfloor + m'\right) \bmod n_{l_i'} & i = 0 \\ \left(\lfloor N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l_i'} / n_1 \rfloor + m' + \lfloor n_{l_i'} / 3 \rfloor\right) \bmod n_{l_i'} & i = 1 \\ \left(\lfloor N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l_i'} / n_1 \rfloor + m' + \lfloor 2 n_{l_i'} / 3 \rfloor\right) \bmod n_{l_i'} & i = 2 \end{cases}$$

      in case of extended PHICH duration in MBSFN subframes, or extended PHICH duration in subframes 1 and 6 for frame structure type 2 and by

$$\bar{n}_i = \begin{cases} \left(\lfloor N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l_i'} / n_0 \rfloor + m'\right) \bmod n_{l_i'} & i = 0 \\ \left(\lfloor N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l_i'} / n_0 \rfloor + m' + \lfloor n_{l_i'} / 3 \rfloor\right) \bmod n_{l_i'} & i = 1 \\ \left(\lfloor N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l_i'} / n_0 \rfloor + m' + \lfloor 2 n_{l_i'} / 3 \rfloor\right) \bmod n_{l_i'} & i = 2 \end{cases}$$

      otherwise.

9) Increase m' by 1.

10) Repeat from step 5 until all PHICH mapping units have been assigned.

The PHICH duration is configurable by higher layers according to Table 6.9.3-1.

Petitioners' Exhibit 1003, p. 863
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.9.3-1: PHICH duration in MBSFN and non-MBSFN subframes.

PHICH duration	Non-MBSFN subframes		MBSFN subframes on a carrier supporting PDSCH
	Subframes 1 and 6 in case of frame structure type 2	All other cases	
Normal	1	1	1
Extended	2	3	2

6.10 Reference signals

Five types of downlink reference signals are defined:

- Cell-specific reference signals (CRS)
- MBSFN reference signals
- UE-specific reference signals (DM-RS)
- Positioning reference signals (PRS)
- CSI reference signals (CSI-RS)

There is one reference signal transmitted per downlink antenna port.

6.10.1 Cell-specific reference signals

Cell-specific reference signals shall be transmitted in all downlink subframes in a cell supporting PDSCH transmission.

Cell-specific reference signals are transmitted on one or several of antenna ports 0 to 3.

Cell-specific reference signals are defined for $\Delta f = 15\,\text{kHz}$ only.

6.10.1.1 Sequence generation

The reference-signal sequence $r_{l,n_s}(m)$ is defined by

$$r_{l,n_s}(m) = \frac{1}{\sqrt{2}}\left(1-2\cdot c(2m)\right) + j\frac{1}{\sqrt{2}}\left(1-2\cdot c(2m+1)\right), \quad m = 0,1,\ldots,2N_{\text{RB}}^{\max,\text{DL}}-1$$

where n_s is the slot number within a radio frame and l is the OFDM symbol number within the slot. The pseudo-random sequence $c(i)$ is defined in Section 7.2. The pseudo-random sequence generator shall be initialised with $c_{\text{init}} = 2^{10}\cdot\left(7\cdot\left(n_s+1\right)+l+1\right)\cdot\left(2\cdot N_{\text{ID}}^{\text{cell}}+1\right)+2\cdot N_{\text{ID}}^{\text{cell}}+N_{\text{CP}}$ at the start of each OFDM symbol where

$$N_{\text{CP}} = \begin{cases} 1 & \text{for normal CP} \\ 0 & \text{for extended CP} \end{cases}$$

6.10.1.2 Mapping to resource elements

The reference signal sequence $r_{l,n_s}(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ used as reference symbols for antenna port p in slot n_s according to

$$a_{k,l}^{(p)} = r_{l,n_s}(m')$$

where

Petitioners' Exhibit 1003, p. 864
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$k = 6m + (v + v_{\text{shift}}) \bmod 6$$
$$l = \begin{cases} 0, N_{\text{symb}}^{\text{DL}} - 3 & \text{if } p \in \{0,1\} \\ 1 & \text{if } p \in \{2,3\} \end{cases}$$
$$m = 0,1,\ldots,2 \cdot N_{\text{RB}}^{\text{DL}} - 1$$
$$m' = m + N_{\text{RB}}^{\text{max,DL}} - N_{\text{RB}}^{\text{DL}}$$

The variables v and v_{shift} define the position in the frequency domain for the different reference signals where v is given by

$$v = \begin{cases} 0 & \text{if } p = 0 \text{ and } l = 0 \\ 3 & \text{if } p = 0 \text{ and } l \neq 0 \\ 3 & \text{if } p = 1 \text{ and } l = 0 \\ 0 & \text{if } p = 1 \text{ and } l \neq 0 \\ 3(n_{\text{s}} \bmod 2) & \text{if } p = 2 \\ 3 + 3(n_{\text{s}} \bmod 2) & \text{if } p = 3 \end{cases}$$

The cell-specific frequency shift is given by $v_{\text{shift}} = N_{\text{ID}}^{\text{cell}} \bmod 6$.

Resource elements (k,l) used for transmission of cell-specific reference signals on any of the antenna ports in a slot shall not be used for any transmission on any other antenna port in the same slot and set to zero.

In an MBSFN subframe, cell-specific reference signals shall only be transmitted in the non-MBSFN region of the MBSFN subframe.

Figures 6.10.1.2-1 and 6.10.1.2-2 illustrate the resource elements used for reference signal transmission according to the above definition. The notation R_p is used to denote a resource element used for reference signal transmission on antenna port p.

Petitioners' Exhibit 1003, p. 865
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

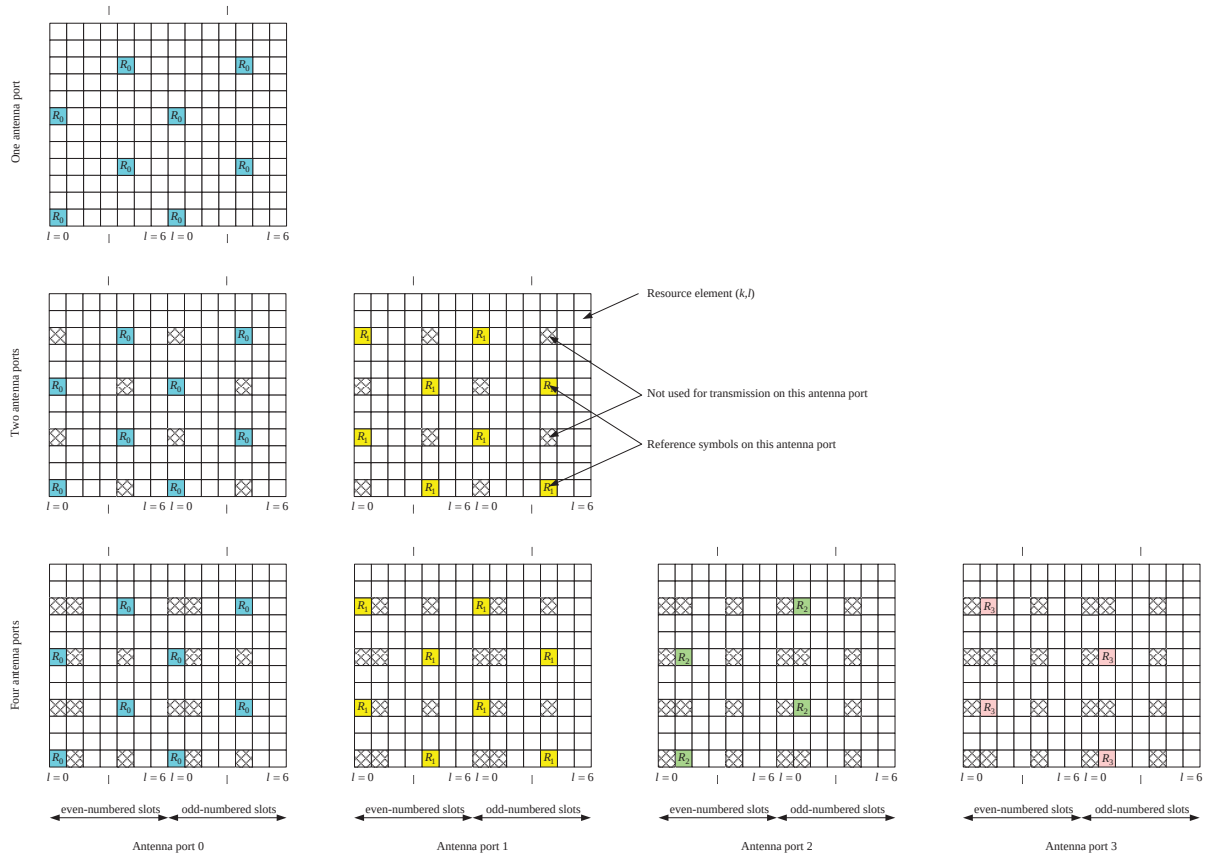


Figure 6.10.1.2-1. Mapping of downlink reference signals (normal cyclic prefix).

Petitioners' Exhibit 1003, p. 866
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

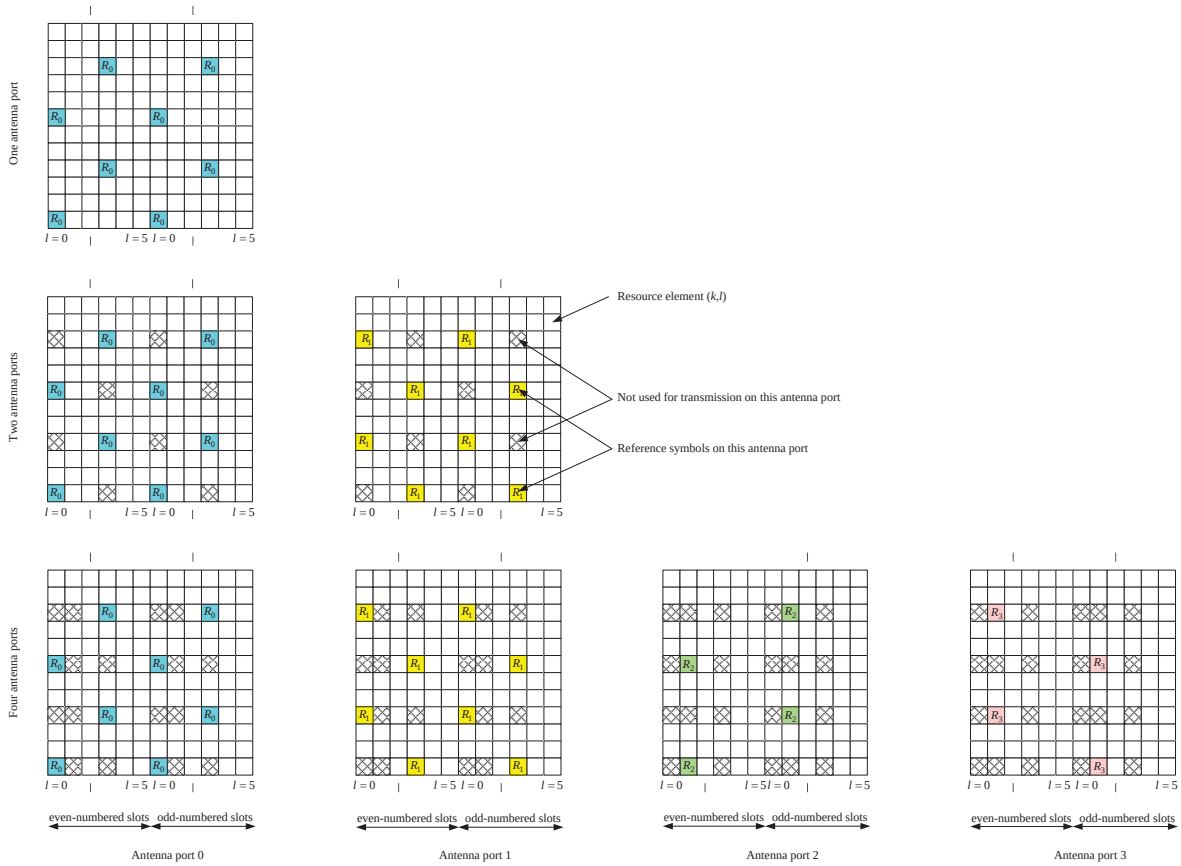


Figure 6.10.1.2-2. Mapping of downlink reference signals (extended cyclic prefix).

6.10.2 MBSFN reference signals

MBSFN reference signals shall be transmitted in the MBSFN region of MBSFN subframes only when the PMCH is transmitted. MBSFN reference signals are transmitted on antenna port 4.

MBSFN reference signals are defined for extended cyclic prefix only.

6.10.2.1 Sequence generation

The MBSFN reference-signal sequence $r_{l,n_s}(m)$ is defined by

$$r_{l,n_s}(m) = \frac{1}{\sqrt{2}}\left(1-2\cdot c(2m)\right) + j\frac{1}{\sqrt{2}}\left(1-2\cdot c(2m+1)\right), \quad m = 0,1,\ldots,6N_{\mathrm{RB}}^{\max,\mathrm{DL}}-1$$

where n_s is the slot number within a radio frame and l is the OFDM symbol number within the slot. The pseudo-random sequence $c(i)$ is defined in Section 7.2. The pseudo-random sequence generator shall be initialised with $c_{\mathrm{init}} = 2^9\cdot\left(7\cdot\left(n_s+1\right)+l+1\right)\cdot\left(2\cdot N_{\mathrm{ID}}^{\mathrm{MBSFN}}+1\right)+N_{\mathrm{ID}}^{\mathrm{MBSFN}}$ at the start of each OFDM symbol.

6.10.2.2 Mapping to resource elements

The reference-signal sequence $r_{l,n_s}(m')$ in OFDM symbol l shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ with $p=4$ according to

$$a_{k,l}^{(p)} = r_{l,n_s}(m')$$

Petitioners' Exhibit 1003, p. 867
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

where

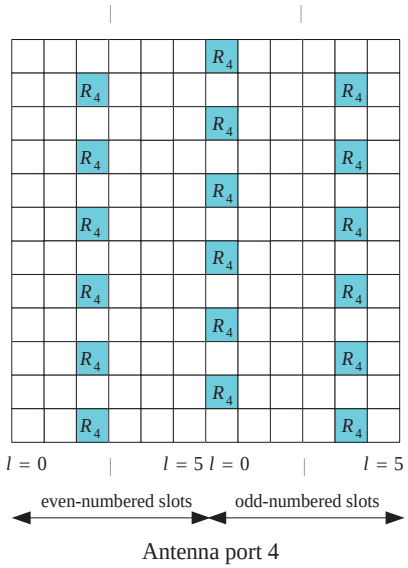
$$k = \begin{cases} 2m & \text{if } l \neq 0 \text{ and } \Delta f = 15\,\text{kHz} \\ 2m+1 & \text{if } l = 0 \text{ and } \Delta f = 15\,\text{kHz} \\ 4m & \text{if } l \neq 0 \text{ and } \Delta f = 7.5\,\text{kHz} \\ 4m+2 & \text{if } l = 0 \text{ and } \Delta f = 7.5\,\text{kHz} \end{cases}$$

$$l = \begin{cases} 2 & \text{if } n_s \bmod 2 = 0 \text{ and } \Delta f = 15\,\text{kHz} \\ 0,4 & \text{if } n_s \bmod 2 = 1 \text{ and } \Delta f = 15\,\text{kHz} \\ 1 & \text{if } n_s \bmod 2 = 0 \text{ and } \Delta f = 7.5\,\text{kHz} \\ 0,2 & \text{if } n_s \bmod 2 = 1 \text{ and } \Delta f = 7.5\,\text{kHz} \end{cases}$$

$$m = 0,1,\ldots,6N_{\text{RB}}^{\text{DL}} - 1$$

$$m' = m + 3\left(N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{DL}}\right)$$

Figure 6.10.2.2-1 illustrates the resource elements used for MBSFN reference signal transmission in case of $\Delta f = 15\,\text{kHz}$. In case of $\Delta f = 7.5\,\text{kHz}$ for a MBSFN-dedicated cell, the MBSFN reference signal shall be mapped to resource elements according to Figure 6.10.2.2-3. The notation R_p is used to denote a resource element used for reference signal transmission on antenna port p.



Antenna port 4

Figure 6.10.2.2-1: Mapping of MBSFN reference signals (extended cyclic prefix, $\Delta f = 15\,\text{kHz}$).

Petitioners' Exhibit 1003, p. 868
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

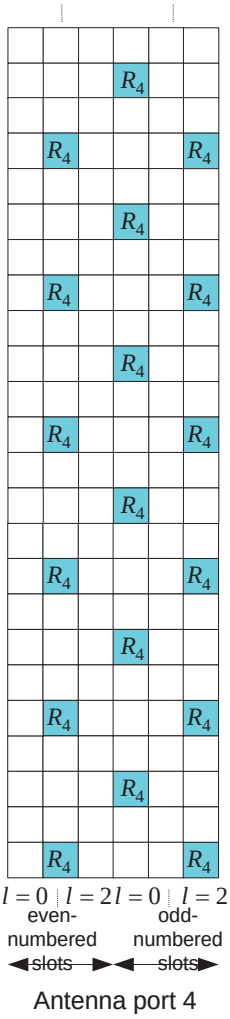


Figure 6.10.2.2-3: Mapping of MBSFN reference signals (extended cyclic prefix, $\Delta f = 7.5\,\text{kHz}$).

6.10.3 UE-specific reference signals

UE-specific reference signals are supported for transmission of PDSCH and are transmitted on antenna port(s) $p = 5$, $p = 7$, $p = 8$ or $p = 7,8,...,\upsilon + 6$, where υ is the number of layers used for transmission of the PDSCH. UE-specific reference signals are present and are a valid reference for PDSCH demodulation only if the PDSCH transmission is associated with the corresponding antenna port according to Section 7.1 of [4]. UE-specific reference signals are transmitted only on the resource blocks upon which the corresponding PDSCH is mapped. The UE-specific reference signal is not transmitted in resource elements (k,l) in which one of the physical channels or physical signals other than UE-specific reference signal defined in 6.1 are transmitted using resource elements with the same index pair (k,l) regardless of their antenna port p.

6.10.3.1 Sequence generation

For antenna port 5, the UE-specific reference-signal sequence $r_{n_s}(m)$ is defined by

$$r_{n_s}(m) = \frac{1}{\sqrt{2}}\left(1 - 2 \cdot c(2m)\right) + j\frac{1}{\sqrt{2}}\left(1 - 2 \cdot c(2m+1)\right), \qquad m = 0,1,...,12N_{\text{RB}}^{\text{PDSCH}} - 1$$

Petitioners' Exhibit 1003, p. 869
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

where N_{RB}^{PDSCH} denotes the bandwidth in resource blocks of the corresponding PDSCH transmission. The pseudo-random sequence $c(i)$ is defined in Section 7.2. The pseudo-random sequence generator shall be initialised with $c_{init} = (\lfloor n_s/2 \rfloor + 1) \cdot (2N_{ID}^{cell} + 1) \cdot 2^{16} + n_{RNTI}$ at the start of each subframe where n_{RNTI} is as described in Section 7.1[4].

For any of the antenna ports $p \in \{7,8,...,\upsilon+6\}$, the reference-signal sequence $r(m)$ is defined by

$$r(m) = \frac{1}{\sqrt{2}}(1-2\cdot c(2m)) + j\frac{1}{\sqrt{2}}(1-2\cdot c(2m+1)), \qquad m = \begin{cases} 0,1,...,12N_{RB}^{max,DL}-1 & \text{normal cyclic prefix} \\ 0,1,...,16N_{RB}^{max,DL}-1 & \text{extended cyclic prefix} \end{cases}.$$

The pseudo-random sequence $c(i)$ is defined in Section 7.2. The pseudo-random sequence generator shall be initialised with $c_{init} = (\lfloor n_s/2 \rfloor + 1) \cdot (2N_{ID}^{cell} + 1) \cdot 2^{16} + n_{SCID}$ at the start of each subframe. The value of n_{SCID} is zero unless specified otherwise. For a PDSCH transmission on ports 7 or 8, n_{SCID} is given by the DCI format 2B or 2C [3] associated with the PDSCH transmission. In the case of DCI format 2B, n_{SCID} is indicated by the scrambling identity field according to Table 6.10.3.1-1. In the case of DCI format 2C, n_{SCID} is given by Table 5.3.3.1.5C-1 in [3].

Table 6.10.3.1-1: Mapping of scrambling identity field in DCI format 2B to n_{SCID} values for antenna ports 7 and 8.

Scrambling identity field in DCI format 2B [3]	n_{SCID}
0	0
1	1

6.10.3.2 Mapping to resource elements

For antenna port 5, in a physical resource block with frequency-domain index n_{PRB} assigned for the corresponding PDSCH transmission, the reference signal sequence $r_{n_s}(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ with $p = 5$ in a subframe according to:

Normal cyclic prefix:

$$a_{k,l}^{(p)} = r_{n_s}(3\cdot l' \cdot N_{RB}^{PDSCH} + m')$$

$$k = (k') \bmod N_{sc}^{RB} + N_{sc}^{RB} \cdot n_{PRB}$$

$$k' = \begin{cases} 4m' + v_{shift} & \text{if } l \in \{2,3\} \\ 4m' + (2+v_{shift}) \bmod 4 & \text{if } l \in \{5,6\} \end{cases}$$

$$l = \begin{cases} 3 & l' = 0 \\ 6 & l' = 1 \\ 2 & l' = 2 \\ 5 & l' = 3 \end{cases}$$

$$l' = \begin{cases} 0,1 & \text{if } n_s \bmod 2 = 0 \\ 2,3 & \text{if } n_s \bmod 2 = 1 \end{cases}$$

$$m' = 0,1,...,3N_{RB}^{PDSCH} - 1$$

Extended cyclic prefix:

$$a_{k,l}^{(p)} = r_{n_s}(4\cdot l' \cdot N_{RB}^{PDSCH} + m')$$

Petitioners' Exhibit 1003, p. 870
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$k = (k') \bmod N_{sc}^{RB} + N_{sc}^{RB} \cdot n_{PRB}$$

$$k' = \begin{cases} 3m' + v_{shift} & \text{if } l = 4 \\ 3m' + (2 + v_{shift}) \bmod 3 & \text{if } l = 1 \end{cases}$$

$$l = \begin{cases} 4 & l' \in \{0,2\} \\ 1 & l' = 1 \end{cases}$$

$$l' = \begin{cases} 0 & \text{if } n_s \bmod 2 = 0 \\ 1,2 & \text{if } n_s \bmod 2 = 1 \end{cases}$$

$$m' = 0,1,\ldots,4N_{RB}^{PDSCH} - 1$$

where m' is the counter of UE-specific reference signal resource elements within a respective OFDM symbol of the PDSCH transmission.

The cell-specific frequency shift is given by $v_{shift} = N_{ID}^{cell} \bmod 3$.

The mapping shall be in increasing order of the frequency-domain index n_{PRB} of the physical resource blocks assigned for the corresponding PDSCH transmission. The quantity N_{RB}^{PDSCH} denotes the bandwidth in resource blocks of the corresponding PDSCH transmission.

Figure 6.10.3.2-1 illustrates the resource elements used for UE-specific reference signals for normal cyclic prefix for antenna port 5.

Figure 6.10.3.2-2 illustrates the resource elements used for UE-specific reference signals for extended cyclic prefix for antenna port 5.

The notation R_p is used to denote a resource element used for reference signal transmission on antenna port p.

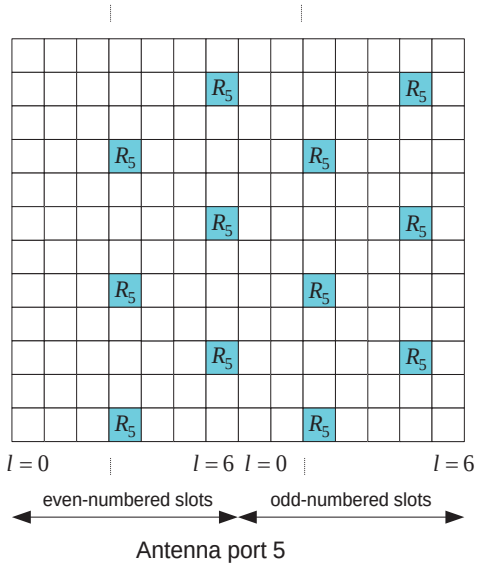


Figure 6.10.3.2-1: Mapping of UE-specific reference signals, antenna port 5 (normal cyclic prefix).

Petitioners' Exhibit 1003, p. 871
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

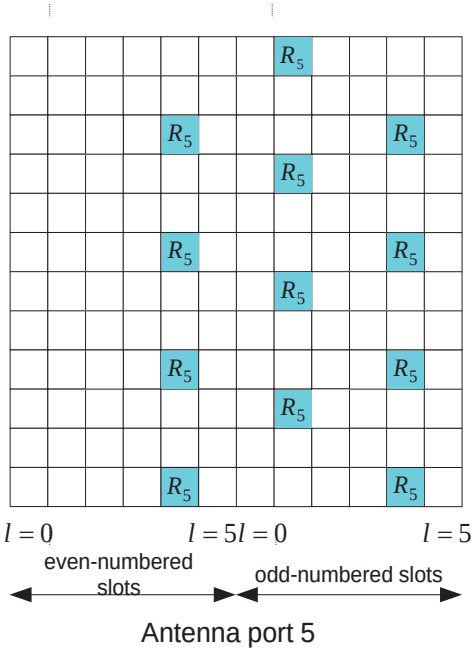


Figure 6.10.3.2-2: Mapping of UE-specific reference signals, antenna port 5 (extended cyclic prefix).

For antenna ports $p = 7$, $p = 8$ or $p = 7,8,\ldots,\upsilon+6$, in a physical resource block with frequency-domain index n_{PRB} assigned for the corresponding PDSCH transmission, a part of the reference signal sequence $r(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ in a subframe according to

Normal cyclic prefix:

$$a_{k,l}^{(p)} = w_p(l') \cdot r(3 \cdot l' \cdot N_{\text{RB}}^{\max,\text{DL}} + 3 \cdot n_{\text{PRB}} + m')$$

where

$$w_p(i) = \begin{cases} \overline{w}_p(i) & (m' + n_{\text{PRB}}) \bmod 2 = 0 \\ \overline{w}_p(3-i) & (m' + n_{\text{PRB}}) \bmod 2 = 1 \end{cases}$$

$$k = 5m' + N_{\text{sc}}^{\text{RB}} n_{\text{PRB}} + k'$$

$$k' = \begin{cases} 1 & p \in \{7,8,11,13\} \\ 0 & p \in \{9,10,12,14\} \end{cases}$$

$$l = \begin{cases} l' \bmod 2 + 2 & \text{if in a special subframe with configuration 3, 4, or 8 (see Table 4.2-1)} \\ l' \bmod 2 + 2 + 3\lfloor l'/2 \rfloor & \text{if in a special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \\ l' \bmod 2 + 5 & \text{if not in a special subframe} \end{cases}$$

$$l' = \begin{cases} 0,1,2,3 & \text{if } n_s \bmod 2 = 0 \text{ and in a special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \\ 0,1 & \text{if } n_s \bmod 2 = 0 \text{ and not in special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \\ 2,3 & \text{if } n_s \bmod 2 = 1 \text{ and not in special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \end{cases}$$

$$m' = 0,1,2$$

The sequence $\overline{w}_p(i)$ is given by Table 6.10.3.2-1.

Petitioners' Exhibit 1003, p. 872
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.10.3.2-1: The sequence $\overline{w}_p(i)$ for normal cyclic prefix.

Antenna port p	$\left[\overline{w}_p(0) \quad \overline{w}_p(1) \quad \overline{w}_p(2) \quad \overline{w}_p(3)\right]$
7	$\left[+1 \quad +1 \quad +1 \quad +1\right]$
8	$\left[+1 \quad -1 \quad +1 \quad -1\right]$
9	$\left[+1 \quad +1 \quad +1 \quad +1\right]$
10	$\left[+1 \quad -1 \quad +1 \quad -1\right]$
11	$\left[+1 \quad +1 \quad -1 \quad -1\right]$
12	$\left[-1 \quad -1 \quad +1 \quad +1\right]$
13	$\left[+1 \quad -1 \quad -1 \quad +1\right]$
14	$\left[-1 \quad +1 \quad +1 \quad -1\right]$

Extended cyclic prefix:

$$a_{k,l}^{(p)} = w_p(l' \bmod 2) \cdot r(4 \cdot l' \cdot N_{\mathrm{RB}}^{\max,\mathrm{DL}} + 4 \cdot n_{\mathrm{PRB}} + m')$$

where

$$w_p(i) = \begin{cases} \overline{w}_p(i) & m' \bmod 2 = 0 \\ \overline{w}_p(1-i) & m' \bmod 2 = 1 \end{cases}$$

$$k = 3m' + N_{\mathrm{sc}}^{\mathrm{RB}} n_{\mathrm{PRB}} + k'$$

$$k' = \begin{cases} 1 & \text{if } n_s \bmod 2 = 0 \text{ and } p \in \{7,8\} \\ 2 & \text{if } n_s \bmod 2 = 1 \text{ and } p \in \{7,8\} \end{cases}$$

$$l = l' \bmod 2 + 4$$

$$l' = \begin{cases} 0,1 & \text{if } n_s \bmod 2 = 0 \text{ and in a special subframe with configuration 1, 2, 3, 5 or 6 (see Table 4.2-1)} \\ 0,1 & \text{if } n_s \bmod 2 = 0 \text{ and not in a special subframe} \\ 2,3 & \text{if } n_s \bmod 2 = 1 \text{ and not in a special subframe} \end{cases}$$

$$m' = 0,1,2,3$$

The sequence $\overline{w}_p(i)$ is given by Table 6.10.3.2-2.

Table 6.10.3.2-2: The sequence $\overline{w}_p(i)$ for extended cyclic prefix.

Antenna port p	$\left[\overline{w}_p(0) \quad \overline{w}_p(1)\right]$
7	$\left[+1 \quad +1\right]$
8	$\left[-1 \quad +1\right]$

For extended cyclic prefix, UE-specific reference signals are not supported on antenna ports 9 to 14.

Resource elements (k,l) used for transmission of UE-specific reference signals to one UE on any of the antenna ports in the set S, where $S = \{7,8,11,13\}$ or $S = \{9,10,12,14\}$ shall

- not be used for transmission of PDSCH on any antenna port in the same slot, and
- not be used for UE-specific reference signals to the same UE on any antenna port other than those in S in the same slot.

Figure 6.10.3.2-3 illustrates the resource elements used for UE-specific reference signals for normal cyclic prefix for antenna ports 7, 8, 9 and 10. Figure 6.10.3.2-4 illustrates the resource elements used for UE-specific reference signals for extended cyclic prefix for antenna ports 7, 8.

Petitioners' Exhibit 1003, p. 873
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

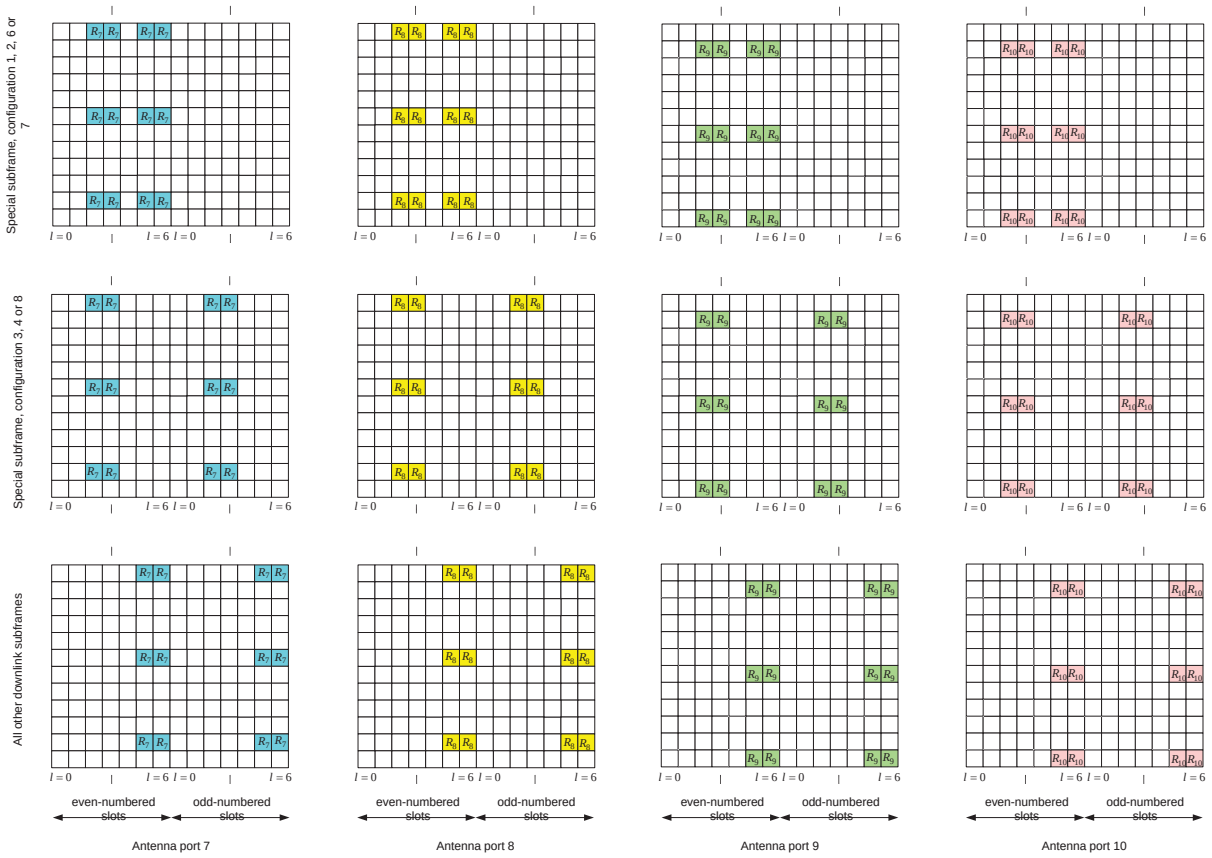


Figure 6.10.3.2-3: Mapping of UE-specific reference signals, antenna ports 7, 8, 9 and 10 (normal cyclic prefix).

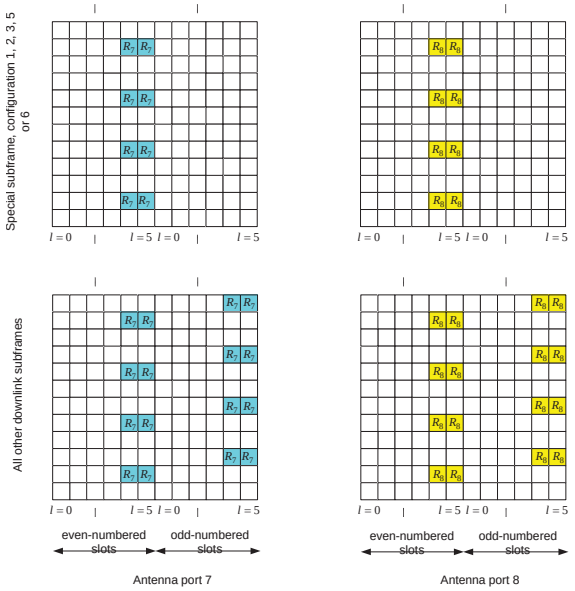


Figure 6.10.3.2-4: Mapping of UE-specific reference signals, antenna ports 7 and 8 (extended cyclic prefix).

Petitioners' Exhibit 1003, p. 874
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.10.4 Positioning reference signals

Positioning reference signals shall only be transmitted in resource blocks in downlink subframes configured for positioning reference signal transmission. If both normal and MBSFN subframes are configured as positioning subframes within a cell, the OFDM symbols in a MBSFN subframe configured for positioning reference signal transmission shall use the same cyclic prefix as used for subframe #0. If only MBSFN subframes are configured as positioning subframes within a cell, the OFDM symbols configured for positioning reference signals in the MBSFN region of these subframes shall use extended cyclic prefix length. In a subframe configured for positioning reference signal transmission, the starting positions of the OFDM symbols configured for positioning reference signal transmission shall be identical to those in a subframe in which all OFDM symbols have the same cyclic prefix length as the OFDM symbols configured for positioning reference signal transmission.

Positioning reference signals are transmitted on antenna port 6.

The positioning reference signals shall not be mapped to resource elements (k,l) allocated to PBCH, PSS or SSS regardless of their antenna port p.

Positioning reference signals are defined for $\Delta f = 15\,\text{kHz}$ only.

6.10.4.1 Sequence generation

The reference-signal sequence $r_{l,n_s}(m)$ is defined by

$$r_{l,n_s}(m) = \frac{1}{\sqrt{2}}(1-2\cdot c(2m)) + j\frac{1}{\sqrt{2}}(1-2\cdot c(2m+1)), \quad m = 0,1,\ldots,2N_{\text{RB}}^{\max,\text{DL}}-1$$

where n_s is the slot number within a radio frame, l is the OFDM symbol number within the slot. The pseudo-random sequence $c(i)$ is defined in Section 7.2. The pseudo-random sequence generator shall be initialised with $c_{\text{init}} = 2^{10}\cdot(7\cdot(n_s+1)+l+1)\cdot(2\cdot N_{\text{ID}}^{\text{cell}}+1)+2\cdot N_{\text{ID}}^{\text{cell}}+N_{\text{CP}}$ at the start of each OFDM symbol where

$$N_{\text{CP}} = \begin{cases} 1 & \text{for normal CP} \\ 0 & \text{for extended CP} \end{cases}$$

6.10.4.2 Mapping to resource elements

The reference signal sequence $r_{l,n_s}(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ used as reference signal for antenna port $p=6$ in slot n_s according to

$$a_{k,l}^{(p)} = r_{l,n_s}(m')$$

where

Normal cyclic prefix:

$$k = 6(m + N_{\text{RB}}^{\text{DL}} - N_{\text{RB}}^{\text{PRS}}) + (6 - l + v_{\text{shift}}) \bmod 6$$

$$l = \begin{cases} 3,5,6 & \text{if } n_s \bmod 2 = 0 \\ 1,2,3,5,6 & \text{if } n_s \bmod 2 = 1 \text{ and } (1 \text{ or } 2 \text{ PBCH antenna ports}) \\ 2,3,5,6 & \text{if } n_s \bmod 2 = 1 \text{ and } (4 \text{ PBCH antenna ports}) \end{cases}$$

$$m = 0,1,\ldots,2\cdot N_{\text{RB}}^{\text{PRS}} - 1$$

$$m' = m + N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{PRS}}$$

Extended cyclic prefix:

Petitioners' Exhibit 1003, p. 875
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$k = 6\left(m + N_{\mathrm{RB}}^{\mathrm{DL}} - N_{\mathrm{RB}}^{\mathrm{PRS}}\right) + \left(5 - l + v_{\mathrm{shift}}\right) \bmod 6$$

$$l = \begin{cases} 4,5 & \text{if } n_s \bmod 2 = 0 \\ 1,2,4,5 & \text{if } n_s \bmod 2 = 1 \text{ and } (1 \text{ or } 2 \text{ PBCH antenna ports}) \\ 2,4,5 & \text{if } n_s \bmod 2 = 1 \text{ and } (4 \text{ PBCH antenna ports}) \end{cases}$$

$$m = 0,1,\ldots,2 \cdot N_{\mathrm{RB}}^{\mathrm{PRS}} - 1$$

$$m' = m + N_{\mathrm{RB}}^{\max,\mathrm{DL}} - N_{\mathrm{RB}}^{\mathrm{PRS}}$$

The bandwidth for positioning reference signals and $N_{\mathrm{RB}}^{\mathrm{PRS}}$ is configured by higher layers and the cell-specific frequency shift is given by $v_{\mathrm{shift}} = N_{\mathrm{ID}}^{\mathrm{cell}} \bmod 6$.

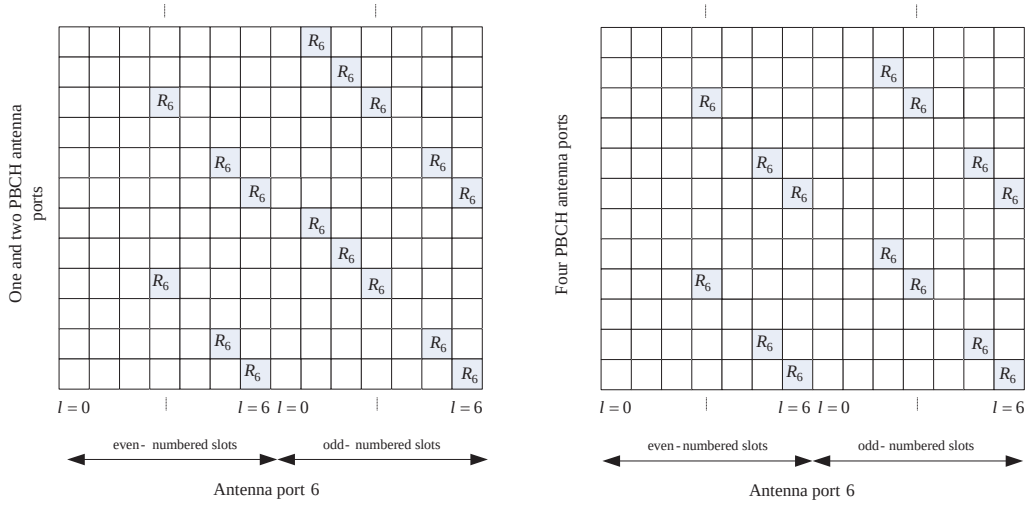


Figure 6.10.4.2-1: Mapping of positioning reference signals (normal cyclic prefix)

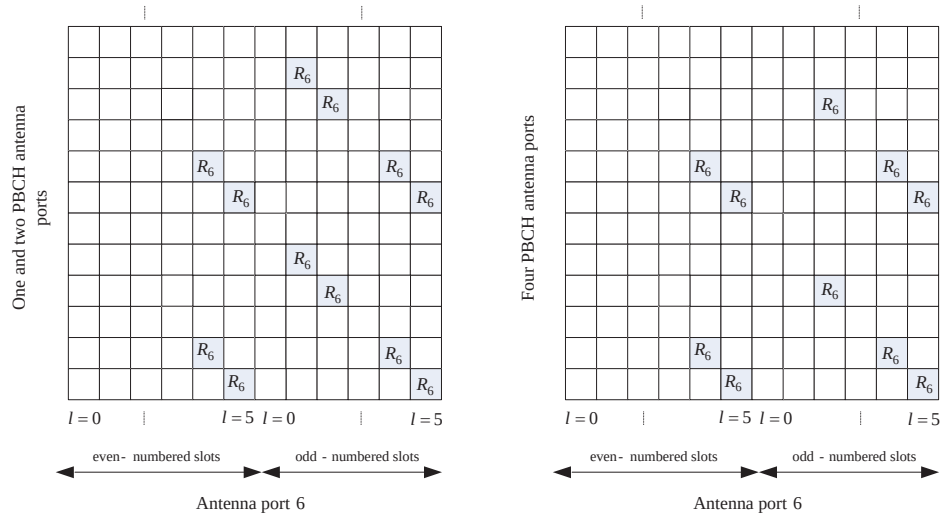


Figure 6.10.4.2-2: Mapping of positioning reference signals (extended cyclic prefix)

6.10.4.3 Positioning reference signal subframe configuration

The cell specific subframe configuration period T_{PRS} and the cell specific subframe offset Δ_{PRS} for the transmission of positioning reference signals are listed in Table 6.10.4.3-1. The PRS configuration index I_{PRS} is configured by higher layers. Positioning reference signals are transmitted only in configured DL subframes. Positioning reference signals

Petitioners' Exhibit 1003, p. 876
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

shall not be transmitted in special subframes. Positioning reference signals shall be transmitted in N_{PRS} consecutive downlink subframes, where N_{PRS} is configured by higher layers.

The positioning reference signal instances, for the first subframe of the N_{PRS} downlink subframes, shall satisfy $(10\times n_{\mathrm{f}} + \lfloor n_{\mathrm{s}}/2 \rfloor - \Delta_{\mathrm{PRS}}) \bmod T_{\mathrm{PRS}} = 0$.

Table 6.10.4.3-1: Positioning reference signal subframe configuration

PRS configuration Index I_{PRS}	PRS periodicity T_{PRS} (subframes)	PRS subframe offset Δ_{PRS} (subframes)
0 – 159	160	I_{PRS}
160 – 479	320	$I_{\mathrm{PRS}} - 160$
480 – 1119	640	$I_{\mathrm{PRS}} - 480$
1120 – 2399	1280	$I_{\mathrm{PRS}} - 1120$
2400-4095	Reserved	

6.10.5 CSI reference signals

CSI reference signals are transmitted on one, two, four or eight antenna ports using $p=15$, $p=15,16$, $p=15,...,18$ and $p=15,...,22$, respectively.

CSI reference signals are defined for $\Delta f = 15\,\mathrm{kHz}$ only.

6.10.5.1 Sequence generation

The reference-signal sequence $r_{l,n_{\mathrm{s}}}(m)$ is defined by

$$r_{l,n_{\mathrm{s}}}(m) = \frac{1}{\sqrt{2}}\left(1-2\cdot c(2m)\right) + j\frac{1}{\sqrt{2}}\left(1-2\cdot c(2m+1)\right), \quad m = 0,1,...,N_{\mathrm{RB}}^{\max,\mathrm{DL}} - 1$$

where n_{s} is the slot number within a radio frame and l is the OFDM symbol number within the slot. The pseudo-random sequence $c(i)$ is defined in Section 7.2. The pseudo-random sequence generator shall be initialised with $c_{\mathrm{init}} = 2^{10}\cdot(7\cdot(n_{\mathrm{s}}+1)+l+1)\cdot(2\cdot N_{\mathrm{ID}}^{\mathrm{cell}}+1)+2\cdot N_{\mathrm{ID}}^{\mathrm{cell}}+N_{\mathrm{CP}}$ at the start of each OFDM symbol where

$$N_{\mathrm{CP}} = \begin{cases} 1 & \text{for normal CP} \\ 0 & \text{for extended CP} \end{cases}$$

6.10.5.2 Mapping to resource elements

In subframes configured for CSI reference signal transmission, the reference signal sequence $r_{l,n_{\mathrm{s}}}(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ used as reference symbols on antenna port p according to

$$a_{k,l}^{(p)} = w_{l''}\cdot r_{l,n_{\mathrm{s}}}(m')$$

where

Petitioners' Exhibit 1003, p. 877
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$k = k' + 12m + \begin{cases} -0 & \text{for } p \in \{15,16\}, \text{normal cyclic prefix} \\ -6 & \text{for } p \in \{17,18\}, \text{normal cyclic prefix} \\ -1 & \text{for } p \in \{19,20\}, \text{normal cyclic prefix} \\ -7 & \text{for } p \in \{21,22\}, \text{normal cyclic prefix} \\ -0 & \text{for } p \in \{15,16\}, \text{extended cyclic prefix} \\ -3 & \text{for } p \in \{17,18\}, \text{extended cyclic prefix} \\ -6 & \text{for } p \in \{19,20\}, \text{extended cyclic prefix} \\ -9 & \text{for } p \in \{21,22\}, \text{extended cyclic prefix} \end{cases}$$

$$l = l' + \begin{cases} l'' & \text{CSI reference signal configurations } 0\text{-}19, \text{normal cyclic prefix} \\ 2l'' & \text{CSI reference signal configurations } 20\text{-}31, \text{normal cyclic prefix} \\ l'' & \text{CSI reference signal configurations } 0\text{-}27, \text{extended cyclic prefix} \end{cases}$$

$$w_{l''} = \begin{cases} 1 & p \in \{15,17,19,21\} \\ (-1)^{l''} & p \in \{16,18,20,22\} \end{cases}$$

$$l'' = 0,1$$

$$m = 0,1,\ldots,N_{\text{RB}}^{\text{DL}} - 1$$

$$m' = m + \left\lfloor \frac{N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{DL}}}{2} \right\rfloor$$

The quantity (k',l') and the necessary conditions on n_s are given by Tables 6.10.5.2-1 and 6.10.5.2-2 for normal and extended cyclic prefix, respectively.

Multiple CSI reference signal configurations can be used in a given cell,

- zero or one configuration for which the UE shall assume non-zero transmission power for the CSI-RS, and
- zero or more configurations for which the UE shall assume zero transmission power.

For each bit set to one in the 16-bit bitmap *ZeroPowerCSI-RS* configured by higher layers, the UE shall assume zero transmission power for the resource elements corresponding to the four CSI reference signal column in Tables 6.10.5.2-1 and 6.10.5.2-2 for normal and extended cyclic prefix, respectively, except for resource elements that overlap with those for which the UE shall assume non-zero transmission power CSI-RS as configured by higher layers. The most significant bit corresponds to the lowest CSI reference signal configuration index and subsequent bits in the bitmap correspond to configurations with indices in increasing order.

CSI reference signals can only occur in

- downlink slots where $n_s \bmod 2$ fulfils the condition in Tables 6.10.5.2-1 and 6.10.5.2-2 for normal and extended cyclic prefix, respectively, and
- where the subframe number fulfils the conditions in Section 6.10.5.3.

The UE shall assume that CSI reference signals are not transmitted

- in the special subframe(s) in case of frame structure type 2,
- in subframes where transmission of a CSI-RS would collide with *SystemInformationBlockType1* messages,
- in the primary cell in subframes configured for transmission of paging messages in the primary cell for any UE with the cell-specific paging configuration.

The UE shall assume that none of the CSI reference signals corresponding to a CSI reference signal configuration are transmitted in subframes where transmission of any of those CSI reference signals would collide with transmission of synchronization signals or PBCH.

Petitioners' Exhibit 1003, p. 878
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Resource elements (k,l) used for transmission of CSI reference signals on any of the antenna ports in the set S, where $S=\{15\}$, $S=\{15,16\}$, $S=\{17,18\}$, $S=\{19,20\}$ or $S=\{21,22\}$ shall not be used for transmission of PDSCH on any antenna port in the same slot.

The mapping for CSI reference signal configuration 0 is illustrated in Figures 6.10.5.2-1 and 6.10.5.2-2.

Table 6.10.5.2-1: Mapping from CSI reference signal configuration to (k',l') for normal cyclic prefix.

	CSI reference signal configuration	Number of CSI reference signals configured					
		1 or 2		4		8	
		(k',l')	$n_s \bmod 2$	(k',l')	$n_s \bmod 2$	(k',l')	$n_s \bmod 2$
Frame structure type 1 and 2	0	(9,5)	0	(9,5)	0	(9,5)	0
	1	(11,2)	1	(11,2)	1	(11,2)	1
	2	(9,2)	1	(9,2)	1	(9,2)	1
	3	(7,2)	1	(7,2)	1	(7,2)	1
	4	(9,5)	1	(9,5)	1	(9,5)	1
	5	(8,5)	0	(8,5)	0		
	6	(10,2)	1	(10,2)	1		
	7	(8,2)	1	(8,2)	1		
	8	(6,2)	1	(6,2)	1		
	9	(8,5)	1	(8,5)	1		
	10	(3,5)	0				
	11	(2,5)	0				
	12	(5,2)	1				
	13	(4,2)	1				
	14	(3,2)	1				
	15	(2,2)	1				
	16	(1,2)	1				
	17	(0,2)	1				
	18	(3,5)	1				
	19	(2,5)	1				
Frame structure type 2 only	20	(11,1)	1	(11,1)	1	(11,1)	1
	21	(9,1)	1	(9,1)	1	(9,1)	1
	22	(7,1)	1	(7,1)	1	(7,1)	1
	23	(10,1)	1	(10,1)	1		
	24	(8,1)	1	(8,1)	1		
	25	(6,1)	1	(6,1)	1		
	26	(5,1)	1				
	27	(4,1)	1				
	28	(3,1)	1				
	29	(2,1)	1				
	30	(1,1)	1				
	31	(0,1)	1				

Table 6.10.5.2-2: Mapping from CSI reference signal configuration to (k',l') for extended cyclic prefix.

	CSI reference signal configuration	Number of CSI reference signals configured					
		1 or 2		4		8	
		(k',l')	$n_s \bmod 2$	(k',l')	$n_s \bmod 2$	(k',l')	$n_s \bmod 2$
Frame structure type 1 and 2	0	(11,4)	0	(11,4)	0	(11,4)	0
	1	(9,4)	0	(9,4)	0	(9,4)	0
	2	(10,4)	1	(10,4)	1	(10,4)	1
	3	(9,4)	1	(9,4)	1	(9,4)	1
	4	(5,4)	0	(5,4)	0		
	5	(3,4)	0	(3,4)	0		
	6	(4,4)	1	(4,4)	1		
	7	(3,4)	1	(3,4)	1		
	8	(8,4)	0				
	9	(6,4)	0				
	10	(2,4)	0				
	11	(0,4)	0				
	12	(7,4)	1				

Petitioners' Exhibit 1003, p. 879
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

	13	(6,4)	1				
	14	(1,4)	1				
	15	(0,4)	1				
Frame structure type 2 only	16	(11,1)	1	(11,1)	1	(11,1)	1
	17	(10,1)	1	(10,1)	1	(10,1)	1
	18	(9,1)	1	(9,1)	1	(9,1)	1
	19	(5,1)	1	(5,1)	1		
	20	(4,1)	1	(4,1)	1		
	21	(3,1)	1	(3,1)	1		
	22	(8,1)	1				
	23	(7,1)	1				
	24	(6,1)	1				
	25	(2,1)	1				
	26	(1,1)	1				
	27	(0,1)	1				

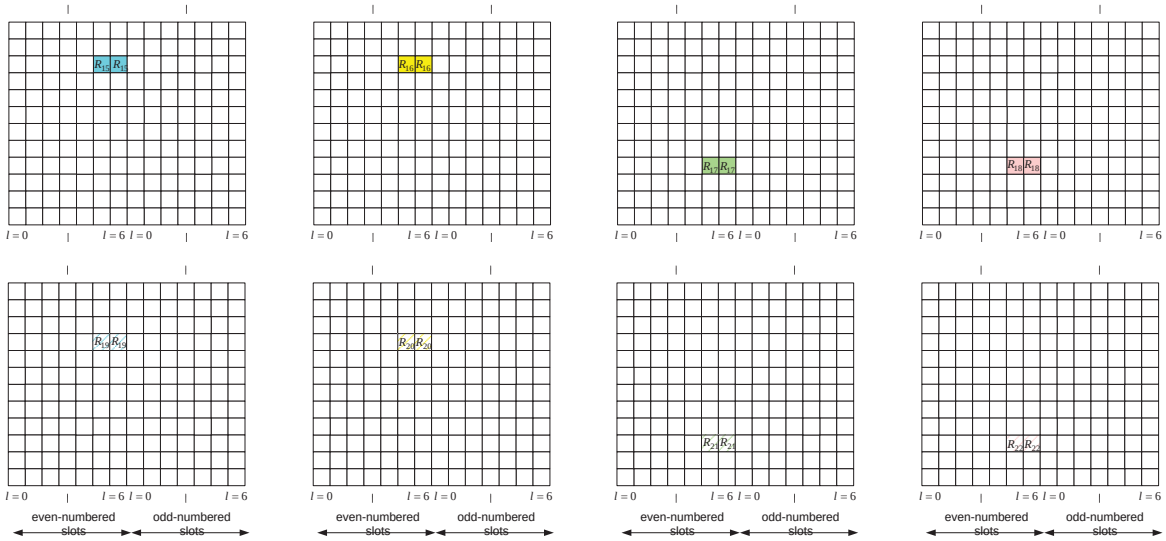


Figure 6.10.5.2-1: Mapping of CSI reference signals (CSI configuration 0, normal cyclic prefix).

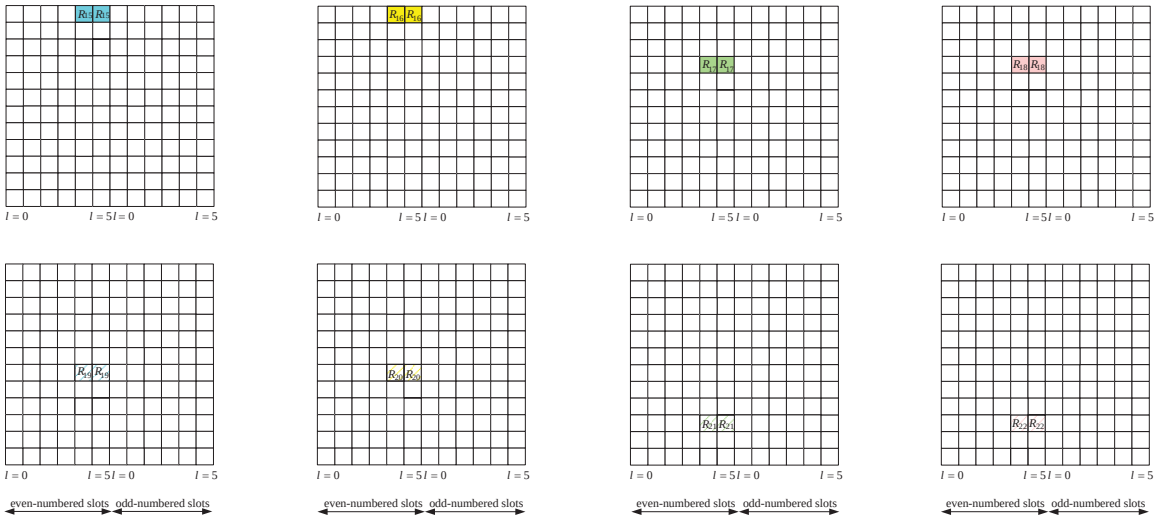


Figure 6.10.5.2-2: Mapping of CSI reference signals (CSI configuration 0, extended cyclic prefix).

Petitioners' Exhibit 1003, p. 880
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.10.5.3 CSI reference signal subframe configuration

The subframe configuration period $T_{\text{CSI-RS}}$ and the subframe offset $\Delta_{\text{CSI-RS}}$ for the occurence of CSI reference signals are listed in Table 6.10.5.3-1. The parameter $I_{\text{CSI-RS}}$ can be configured separately for CSI reference signals for which the UE shall assume non-zero and zero transmission power. Subframes containing CSI reference signals shall satisfy $(10n_{\text{f}} + \lfloor n_{\text{s}}/2 \rfloor - \Delta_{\text{CSI-RS}}) \bmod T_{\text{CSI-RS}} = 0$.

Table 6.10.5.3-1: CSI reference signal subframe configuration.

CSI-RS-SubframeConfig $I_{\text{CSI-RS}}$	CSI-RS periodicity $T_{\text{CSI-RS}}$ (subframes)	CSI-RS subframe offset $\Delta_{\text{CSI-RS}}$ (subframes)
0 – 4	5	$I_{\text{CSI-RS}}$
5 – 14	10	$I_{\text{CSI-RS}} - 5$
15 – 34	20	$I_{\text{CSI-RS}} - 15$
35 – 74	40	$I_{\text{CSI-RS}} - 35$
75 – 154	80	$I_{\text{CSI-RS}} - 75$

6.11 Synchronization signals

There are 504 unique physical-layer cell identities. The physical-layer cell identities are grouped into 168 unique physical-layer cell-identity groups, each group containing three unique identities. The grouping is such that each physical-layer cell identity is part of one and only one physical-layer cell-identity group. A physical-layer cell identity $N_{\text{ID}}^{\text{cell}} = 3N_{\text{ID}}^{(1)} + N_{\text{ID}}^{(2)}$ is thus uniquely defined by a number $N_{\text{ID}}^{(1)}$ in the range of 0 to 167, representing the physical-layer cell-identity group, and a number $N_{\text{ID}}^{(2)}$ in the range of 0 to 2, representing the physical-layer identity within the physical-layer cell-identity group.

6.11.1 Primary synchronization signal

6.11.1.1 Sequence generation

The sequence $d(n)$ used for the primary synchronization signal is generated from a frequency-domain Zadoff-Chu sequence according to

$$d_u(n) = \begin{cases} e^{-j\frac{\pi un(n+1)}{63}} & n = 0,1,\ldots,30 \\ e^{-j\frac{\pi u(n+1)(n+2)}{63}} & n = 31,32,\ldots,61 \end{cases}$$

where the Zadoff-Chu root sequence index u is given by Table 6.11.1.1-1.

Table 6.11.1.1-1: Root indices for the primary synchronization signal.

$N_{\text{ID}}^{(2)}$	Root index u
0	25
1	29
2	34

6.11.1.2 Mapping to resource elements

The mapping of the sequence to resource elements depends on the frame structure. The UE shall not assume that the primary synchronization signal is transmitted on the same antenna port as any of the downlink reference signals. The UE shall not assume that any transmission instance of the primary synchronization signal is transmitted on the same antenna port, or ports, used for any other transmission instance of the primary synchronization signal.

Petitioners' Exhibit 1003, p. 881
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The sequence $d(n)$ shall be mapped to the resource elements according to

$$a_{k,l} = d(n), \qquad n = 0,...,61$$
$$k = n - 31 + \frac{N_{\text{RB}}^{\text{DL}} N_{\text{sc}}^{\text{RB}}}{2}$$

For frame structure type 1, the primary synchronization signal shall be mapped to the last OFDM symbol in slots 0 and 10.

For frame structure type 2, the primary synchronization signal shall be mapped to the third OFDM symbol in subframes 1 and 6. Resource elements (k,l) in the OFDM symbols used for transmission of the primary synchronization signal where

$$k = n - 31 + \frac{N_{\text{RB}}^{\text{DL}} N_{\text{sc}}^{\text{RB}}}{2}$$
$$n = -5,-4,...,-1,62,63,...66$$

are reserved and not used for transmission of the primary synchronization signal.

6.11.2 Secondary synchronization signal

6.11.2.1 Sequence generation

The sequence $d(0),...,d(61)$ used for the second synchronization signal is an interleaved concatenation of two length-31 binary sequences. The concatenated sequence is scrambled with a scrambling sequence given by the primary synchronization signal.

The combination of two length-31 sequences defining the secondary synchronization signal differs between subframe 0 and subframe 5 according to

$$d(2n) = \begin{cases} s_0^{(m_0)}(n)c_0(n) & \text{in subframe 0} \\ s_1^{(m_1)}(n)c_0(n) & \text{in subframe 5} \end{cases}$$
$$d(2n+1) = \begin{cases} s_1^{(m_1)}(n)c_1(n)z_1^{(m_0)}(n) & \text{in subframe 0} \\ s_0^{(m_0)}(n)c_1(n)z_1^{(m_1)}(n) & \text{in subframe 5} \end{cases}$$

where $0 \le n \le 30$. The indices m_0 and m_1 are derived from the physical-layer cell-identity group $N_{\text{ID}}^{(1)}$ according to

$$m_0 = m' \bmod 31$$
$$m_1 = (m_0 + \lfloor m'/31 \rfloor + 1) \bmod 31$$
$$m' = N_{\text{ID}}^{(1)} + q(q+1)/2, \quad q = \left\lfloor \frac{N_{\text{ID}}^{(1)} + q'(q'+1)/2}{30} \right\rfloor, \quad q' = \lfloor N_{\text{ID}}^{(1)}/30 \rfloor$$

where the output of the above expression is listed in Table 6.11.2.1-1.

The two sequences $s_0^{(m_0)}(n)$ and $s_1^{(m_1)}(n)$ are defined as two different cyclic shifts of the m-sequence $\tilde{s}(n)$ according to

$$s_0^{(m_0)}(n) = \tilde{s}((n + m_0) \bmod 31)$$
$$s_1^{(m_1)}(n) = \tilde{s}((n + m_1) \bmod 31)$$

where $\tilde{s}(i) = 1 - 2x(i)$, $0 \le i \le 30$, is defined by

$$x(\bar{i}+5) = (x(\bar{i}+2) + x(\bar{i})) \bmod 2, \qquad 0 \le \bar{i} \le 25$$

with initial conditions $x(0) = 0, \quad x(1) = 0, \quad x(2) = 0, \quad x(3) = 0, \quad x(4) = 1.$

Petitioners' Exhibit 1003, p. 882
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The two scrambling sequences $c_0(n)$ and $c_1(n)$ depend on the primary synchronization signal and are defined by two different cyclic shifts of the m-sequence $\tilde{c}(n)$ according to

$$c_0(n) = \tilde{c}((n + N_{\mathrm{ID}}^{(2)}) \bmod 31)$$
$$c_1(n) = \tilde{c}((n + N_{\mathrm{ID}}^{(2)} + 3) \bmod 31)$$

where $N_{\mathrm{ID}}^{(2)} \in \{0,1,2\}$ is the physical-layer identity within the physical-layer cell identity group $N_{\mathrm{ID}}^{(1)}$ and $\tilde{c}(i) = 1 - 2x(i)$, $0 \le i \le 30$, is defined by

$$x(\bar{i} + 5) = \left(x(\bar{i} + 3) + x(\bar{i})\right) \bmod 2, \qquad 0 \le \bar{i} \le 25$$

with initial conditions $x(0) = 0, \quad x(1) = 0, \quad x(2) = 0, \quad x(3) = 0, \quad x(4) = 1.$

The scrambling sequences $z_1^{(m_0)}(n)$ and $z_1^{(m_1)}(n)$ are defined by a cyclic shift of the m-sequence $\tilde{z}(n)$ according to

$$z_1^{(m_0)}(n) = \tilde{z}((n + (m_0 \bmod 8)) \bmod 31)$$

$$z_1^{(m_1)}(n) = \tilde{z}((n + (m_1 \bmod 8)) \bmod 31)$$

where m_0 and m_1 are obtained from Table 6.11.2.1-1 and $\tilde{z}(i) = 1 - 2x(i)$, $0 \le i \le 30$, is defined by

$$x(\bar{i} + 5) = \left(x(\bar{i} + 4) + x(\bar{i} + 2) + x(\bar{i} + 1) + x(\bar{i})\right) \bmod 2, \qquad 0 \le \bar{i} \le 25$$

with initial conditions $x(0) = 0, \quad x(1) = 0, \quad x(2) = 0, \quad x(3) = 0, \quad x(4) = 1.$

Petitioners' Exhibit 1003, p. 883
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.11.2.1-1: Mapping between physical-layer cell-identity group $N_{\mathrm{ID}}^{(1)}$ and the indices m_0 and m_1.

$N_{\mathrm{ID}}^{(1)}$	m_0	m_1	$N_{\mathrm{ID}}^{(1)}$	m_0	m_1	$N_{\mathrm{ID}}^{(1)}$	m_0	m_1	$N_{\mathrm{ID}}^{(1)}$	m_0	m_1	$N_{\mathrm{ID}}^{(1)}$	m_0	m_1
0	0	1	34	4	6	68	9	12	102	15	19	136	22	27
1	1	2	35	5	7	69	10	13	103	16	20	137	23	28
2	2	3	36	6	8	70	11	14	104	17	21	138	24	29
3	3	4	37	7	9	71	12	15	105	18	22	139	25	30
4	4	5	38	8	10	72	13	16	106	19	23	140	0	6
5	5	6	39	9	11	73	14	17	107	20	24	141	1	7
6	6	7	40	10	12	74	15	18	108	21	25	142	2	8
7	7	8	41	11	13	75	16	19	109	22	26	143	3	9
8	8	9	42	12	14	76	17	20	110	23	27	144	4	10
9	9	10	43	13	15	77	18	21	111	24	28	145	5	11
10	10	11	44	14	16	78	19	22	112	25	29	146	6	12
11	11	12	45	15	17	79	20	23	113	26	30	147	7	13
12	12	13	46	16	18	80	21	24	114	0	5	148	8	14
13	13	14	47	17	19	81	22	25	115	1	6	149	9	15
14	14	15	48	18	20	82	23	26	116	2	7	150	10	16
15	15	16	49	19	21	83	24	27	117	3	8	151	11	17
16	16	17	50	20	22	84	25	28	118	4	9	152	12	18
17	17	18	51	21	23	85	26	29	119	5	10	153	13	19
18	18	19	52	22	24	86	27	30	120	6	11	154	14	20
19	19	20	53	23	25	87	0	4	121	7	12	155	15	21
20	20	21	54	24	26	88	1	5	122	8	13	156	16	22
21	21	22	55	25	27	89	2	6	123	9	14	157	17	23
22	22	23	56	26	28	90	3	7	124	10	15	158	18	24
23	23	24	57	27	29	91	4	8	125	11	16	159	19	25
24	24	25	58	28	30	92	5	9	126	12	17	160	20	26
25	25	26	59	0	3	93	6	10	127	13	18	161	21	27
26	26	27	60	1	4	94	7	11	128	14	19	162	22	28
27	27	28	61	2	5	95	8	12	129	15	20	163	23	29
28	28	29	62	3	6	96	9	13	130	16	21	164	24	30
29	29	30	63	4	7	97	10	14	131	17	22	165	0	7
30	0	2	64	5	8	98	11	15	132	18	23	166	1	8
31	1	3	65	6	9	99	12	16	133	19	24	167	2	9
32	2	4	66	7	10	100	13	17	134	20	25	-	-	-
33	3	5	67	8	11	101	14	18	135	21	26	-	-	-

6.11.2.2 Mapping to resource elements

The mapping of the sequence to resource elements depends on the frame structure. In a subframe for frame structure type 1 and in a half-frame for frame structure type 2, the same antenna port as for the primary synchronization signal shall be used for the secondary synchronization signal.

The sequence $d(n)$ shall be mapped to resource elements according to

$$a_{k,l} = d(n), \qquad n = 0,\ldots,61$$

$$k = n - 31 + \frac{N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}}{2}$$

$$l = \begin{cases} N_{\mathrm{symb}}^{\mathrm{DL}} - 2 & \text{in slots } 0 \text{ and } 10 \quad \text{for frame structure type 1} \\ N_{\mathrm{symb}}^{\mathrm{DL}} - 1 & \text{in slots } 1 \text{ and } 11 \quad \text{for frame structure type 2} \end{cases}$$

Resource elements (k,l) where

Petitioners' Exhibit 1003, p. 884
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$k = n - 31 + \frac{N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}}{2}$$

$$l = \begin{cases} N_{\mathrm{symb}}^{\mathrm{DL}} - 2 & \text{in slots } 0 \text{ and } 10 \quad \text{for frame structure type 1} \\ N_{\mathrm{symb}}^{\mathrm{DL}} - 1 & \text{in slots } 1 \text{ and } 11 \quad \text{for frame structure type 2} \end{cases}$$

$$n = -5, -4, \ldots, -1, 62, 63, \ldots 66$$

are reserved and not used for transmission of the secondary synchronization signal.

6.12 OFDM baseband signal generation

The time-continuous signal $s_l^{(p)}(t)$ on antenna port p in OFDM symbol l in a downlink slot is defined by

$$s_l^{(p)}(t) = \sum_{k=-\left\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}/2 \right\rfloor}^{-1} a_{k^{(-)},l}^{(p)} \cdot e^{j2\pi k \Delta f \left(t - N_{\mathrm{CP},l} T_{\mathrm{s}}\right)} + \sum_{k=1}^{\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}/2 \right\rceil} a_{k^{(+)},l}^{(p)} \cdot e^{j2\pi k \Delta f \left(t - N_{\mathrm{CP},l} T_{\mathrm{s}}\right)}$$

for $0 \le t < \left(N_{\mathrm{CP},l} + N\right) \times T_{\mathrm{s}}$ where $k^{(-)} = k + \left\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}} / 2 \right\rfloor$ and $k^{(+)} = k + \left\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}} / 2 \right\rfloor - 1$. The variable N equals 2048 for $\Delta f = 15\,\mathrm{kHz}$ subcarrier spacing and 4096 for $\Delta f = 7.5\,\mathrm{kHz}$ subcarrier spacing.

The OFDM symbols in a slot shall be transmitted in increasing order of l, starting with $l = 0$, where OFDM symbol $l > 0$ starts at time $\sum_{l'=0}^{l-1} (N_{\mathrm{CP},l'} + N) T_{\mathrm{s}}$ within the slot. In case the first OFDM symbol(s) in a slot use normal cyclic prefix and the remaining OFDM symbols use extended cyclic prefix, the starting position the OFDM symbols with extended cyclic prefix shall be identical to those in a slot where all OFDM symbols use extended cyclic prefix. Thus there will be a part of the time slot between the two cyclic prefix regions where the transmitted signal is not specified.

Table 6.12-1 lists the value of $N_{\mathrm{CP},l}$ that shall be used. Note that different OFDM symbols within a slot in some cases have different cyclic prefix lengths.

Table 6.12-1: OFDM parameters.

Configuration		Cyclic prefix length $N_{\mathrm{CP},l}$
Normal cyclic prefix	$\Delta f = 15\,\mathrm{kHz}$	160 for $l = 0$ 144 for $l = 1,2,\ldots,6$
Extended cyclic prefix	$\Delta f = 15\,\mathrm{kHz}$	512 for $l = 0,1,\ldots,5$
	$\Delta f = 7.5\,\mathrm{kHz}$	1024 for $l = 0,1,2$

6.13 Modulation and upconversion

Modulation and upconversion to the carrier frequency of the complex-valued OFDM baseband signal for each antenna port is shown in Figure 6.13-1. The filtering required prior to transmission is defined by the requirements in [6].

Petitioners' Exhibit 1003, p. 885
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

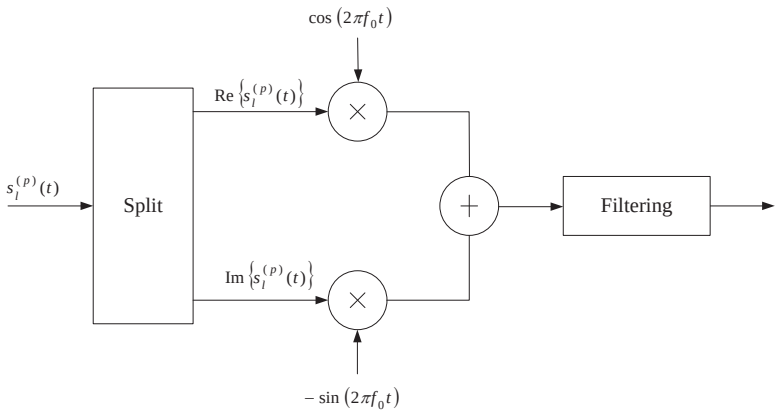


Figure 6.13-1: Downlink modulation.

7 Generic functions

7.1 Modulation mapper

The modulation mapper takes binary digits, 0 or 1, as input and produces complex-valued modulation symbols, $x=I+jQ$, as output.

7.1.1 BPSK

In case of BPSK modulation, a single bit, $b(i)$, is mapped to a complex-valued modulation symbol $x=I+\mathrm{j}Q$ according to Table 7.1.1-1.

Table 7.1.1-1: BPSK modulation mapping.

$b(i)$	*I*	*Q*
0	$1/\sqrt{2}$	$1/\sqrt{2}$
1	$-1/\sqrt{2}$	$-1/\sqrt{2}$

7.1.2 QPSK

In case of QPSK modulation, pairs of bits, $b(i),b(i+1)$, are mapped to complex-valued modulation symbols $x=I+\mathrm{j}Q$ according to Table 7.1.2-1.

Table 7.1.2-1: QPSK modulation mapping.

$b(i),b(i+1)$	*I*	*Q*
00	$1/\sqrt{2}$	$1/\sqrt{2}$
01	$1/\sqrt{2}$	$-1/\sqrt{2}$
10	$-1/\sqrt{2}$	$1/\sqrt{2}$
11	$-1/\sqrt{2}$	$-1/\sqrt{2}$

Petitioners' Exhibit 1003, p. 886
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.1.3 16QAM

In case of 16QAM modulation, quadruplets of bits, $b(i),b(i+1),b(i+2),b(i+3)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.3-1.

Table 7.1.3-1: 16QAM modulation mapping.

$b(i),b(i+1),b(i+2),b(i+3)$	*I*	*Q*
0000	$1/\sqrt{10}$	$1/\sqrt{10}$
0001	$1/\sqrt{10}$	$3/\sqrt{10}$
0010	$3/\sqrt{10}$	$1/\sqrt{10}$
0011	$3/\sqrt{10}$	$3/\sqrt{10}$
0100	$1/\sqrt{10}$	$-1/\sqrt{10}$
0101	$1/\sqrt{10}$	$-3/\sqrt{10}$
0110	$3/\sqrt{10}$	$-1/\sqrt{10}$
0111	$3/\sqrt{10}$	$-3/\sqrt{10}$
1000	$-1/\sqrt{10}$	$1/\sqrt{10}$
1001	$-1/\sqrt{10}$	$3/\sqrt{10}$
1010	$-3/\sqrt{10}$	$1/\sqrt{10}$
1011	$-3/\sqrt{10}$	$3/\sqrt{10}$
1100	$-1/\sqrt{10}$	$-1/\sqrt{10}$
1101	$-1/\sqrt{10}$	$-3/\sqrt{10}$
1110	$-3/\sqrt{10}$	$-1/\sqrt{10}$
1111	$-3/\sqrt{10}$	$-3/\sqrt{10}$

7.1.4 64QAM

In case of 64QAM modulation, hextuplets of bits, $b(i),b(i+1),b(i+2),b(i+3),b(i+4),b(i+5)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.4-1.

Petitioners' Exhibit 1003, p. 887
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 7.1.4-1: 64QAM modulation mapping.

$b(i),b(i+1),b(i+2),b(i+3),b(i+4),b(i+5)$	*I*	*Q*	$b(i),b(i+1),b(i+2),b(i+3),b(i+4),b(i+5)$	*I*	*Q*
000000	$3/\sqrt{42}$	$3/\sqrt{42}$	100000	$-3/\sqrt{42}$	$3/\sqrt{42}$
000001	$3/\sqrt{42}$	$1/\sqrt{42}$	100001	$-3/\sqrt{42}$	$1/\sqrt{42}$
000010	$1/\sqrt{42}$	$3/\sqrt{42}$	100010	$-1/\sqrt{42}$	$3/\sqrt{42}$
000011	$1/\sqrt{42}$	$1/\sqrt{42}$	100011	$-1/\sqrt{42}$	$1/\sqrt{42}$
000100	$3/\sqrt{42}$	$5/\sqrt{42}$	100100	$-3/\sqrt{42}$	$5/\sqrt{42}$
000101	$3/\sqrt{42}$	$7/\sqrt{42}$	100101	$-3/\sqrt{42}$	$7/\sqrt{42}$
000110	$1/\sqrt{42}$	$5/\sqrt{42}$	100110	$-1/\sqrt{42}$	$5/\sqrt{42}$
000111	$1/\sqrt{42}$	$7/\sqrt{42}$	100111	$-1/\sqrt{42}$	$7/\sqrt{42}$
001000	$5/\sqrt{42}$	$3/\sqrt{42}$	101000	$-5/\sqrt{42}$	$3/\sqrt{42}$
001001	$5/\sqrt{42}$	$1/\sqrt{42}$	101001	$-5/\sqrt{42}$	$1/\sqrt{42}$
001010	$7/\sqrt{42}$	$3/\sqrt{42}$	101010	$-7/\sqrt{42}$	$3/\sqrt{42}$
001011	$7/\sqrt{42}$	$1/\sqrt{42}$	101011	$-7/\sqrt{42}$	$1/\sqrt{42}$
001100	$5/\sqrt{42}$	$5/\sqrt{42}$	101100	$-5/\sqrt{42}$	$5/\sqrt{42}$
001101	$5/\sqrt{42}$	$7/\sqrt{42}$	101101	$-5/\sqrt{42}$	$7/\sqrt{42}$
001110	$7/\sqrt{42}$	$5/\sqrt{42}$	101110	$-7/\sqrt{42}$	$5/\sqrt{42}$
001111	$7/\sqrt{42}$	$7/\sqrt{42}$	101111	$-7/\sqrt{42}$	$7/\sqrt{42}$
010000	$3/\sqrt{42}$	$-3/\sqrt{42}$	110000	$-3/\sqrt{42}$	$-3/\sqrt{42}$
010001	$3/\sqrt{42}$	$-1/\sqrt{42}$	110001	$-3/\sqrt{42}$	$-1/\sqrt{42}$
010010	$1/\sqrt{42}$	$-3/\sqrt{42}$	110010	$-1/\sqrt{42}$	$-3/\sqrt{42}$
010011	$1/\sqrt{42}$	$-1/\sqrt{42}$	110011	$-1/\sqrt{42}$	$-1/\sqrt{42}$
010100	$3/\sqrt{42}$	$-5/\sqrt{42}$	110100	$-3/\sqrt{42}$	$-5/\sqrt{42}$
010101	$3/\sqrt{42}$	$-7/\sqrt{42}$	110101	$-3/\sqrt{42}$	$-7/\sqrt{42}$
010110	$1/\sqrt{42}$	$-5/\sqrt{42}$	110110	$-1/\sqrt{42}$	$-5/\sqrt{42}$
010111	$1/\sqrt{42}$	$-7/\sqrt{42}$	110111	$-1/\sqrt{42}$	$-7/\sqrt{42}$
011000	$5/\sqrt{42}$	$-3/\sqrt{42}$	111000	$-5/\sqrt{42}$	$-3/\sqrt{42}$
011001	$5/\sqrt{42}$	$-1/\sqrt{42}$	111001	$-5/\sqrt{42}$	$-1/\sqrt{42}$
011010	$7/\sqrt{42}$	$-3/\sqrt{42}$	111010	$-7/\sqrt{42}$	$-3/\sqrt{42}$
011011	$7/\sqrt{42}$	$-1/\sqrt{42}$	111011	$-7/\sqrt{42}$	$-1/\sqrt{42}$
011100	$5/\sqrt{42}$	$-5/\sqrt{42}$	111100	$-5/\sqrt{42}$	$-5/\sqrt{42}$
011101	$5/\sqrt{42}$	$-7/\sqrt{42}$	111101	$-5/\sqrt{42}$	$-7/\sqrt{42}$
011110	$7/\sqrt{42}$	$-5/\sqrt{42}$	111110	$-7/\sqrt{42}$	$-5/\sqrt{42}$
011111	$7/\sqrt{42}$	$-7/\sqrt{42}$	111111	$-7/\sqrt{42}$	$-7/\sqrt{42}$

7.2 Pseudo-random sequence generation

Pseudo-random sequences are defined by a length-31 Gold sequence. The output sequence $c(n)$ of length M_{PN}, where $n = 0,1,\ldots,M_{\mathrm{PN}}-1$, is defined by

Petitioners' Exhibit 1003, p. 888
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$c(n) = \left(x_1(n+N_C) + x_2(n+N_C)\right) \bmod 2$$
$$x_1(n+31) = \left(x_1(n+3) + x_1(n)\right) \bmod 2$$
$$x_2(n+31) = \left(x_2(n+3) + x_2(n+2) + x_2(n+1) + x_2(n)\right) \bmod 2$$

where $N_C = 1600$ and the first m-sequence shall be initialized with $x_1(0) = 1, x_1(n) = 0, n = 1,2,...,30$. The initialization of the second m-sequence is denoted by $c_{\text{init}} = \sum_{i=0}^{30} x_2(i) \cdot 2^i$ with the value depending on the application of the sequence.

8 Timing

8.1 Uplink-downlink frame timing

Transmission of the uplink radio frame number i from the UE shall start $(N_{\text{TA}} + N_{\text{TA offset}}) \times T_s$ seconds before the start of the corresponding downlink radio frame at the UE, where $0 \le N_{\text{TA}} \le 20512$, $N_{\text{TA offset}} = 0$ for frame structure type 1 and $N_{\text{TA offset}} = 624$ for frame structure type 2. Note that not all slots in a radio frame may be transmitted. One example hereof is TDD, where only a subset of the slots in a radio frame is transmitted.

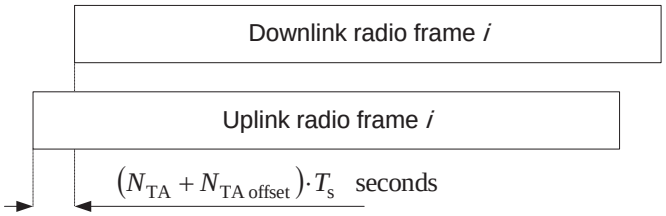


Figure 8.1-1: Uplink-downlink timing relation.

Petitioners' Exhibit 1003, p. 889
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Annex A (informative): Change history

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
2006-09-24	-	-	-		Draft version created	-	0.0.0
2006-10-09	-	-	-		Updated skeleton	0.0.0	0.0.1
2006-10-13	-	-	-		Endorsed by RAN1	0.0.1	0.1.0
2006-10-23	-	-	-		Inclusion of decision from RAN1#46bis	0.1.0	0.1.1
2006-11-06	-	-	-		Updated editor's version	0.1.1	0.1.2
2006-11-09	-	-	-		Updated editor's version	0.1.2	0.1.3
2006-11-10	-	-	-		Endorsed by RAN1#47	0.1.3	0.2.0
2006-11-27	-	-	-		Editor's version, including decisions from RAN1#47	0.2.0	0.2.1
2006-12-14	-	-	-		Updated editor's version	0.2.1	0.2.2
2007-01-15	-	-	-		Updated editor's version	0.2.2	0.2.3
2007-01-19	-	-	-		Endorsed by RAN1#47bis	0.2.3	0.3.0
2007-02-01	-	-	-		Editor's version, including decisions from RAN1#47bis	0.3.0	0.3.1
2007-02-12	-	-	-		Updated editor's version	0.3.1	0.3.2
2007-02-16	-	-	-		Endorsed by RAN1#48	0.3.2	0.4.0
2007-02-16	-	-	-		Editor's version, including decisions from RAN1#48	0.4.0	0.4.1
2007-02-21	-	-	-		Updated editor's version	0.4.1	0.4.2
2007-03-03	RAN#35	RP-070169			For information at RAN#35	0.4.2	1.0.0
2007-04-25	-	-	-		Editor's version, including decisions from RAN1#48bis and RAN1 TDD Ad Hoc	1.0.0	1.0.1
2007-05-03	-	-	-	-	Updated editor's version	1.0.1	1.0.2
2007-05-08	-	-	-	-	Updated editor's version	1.0.2	1.0.3
2007-05-11	-	-	-	-	Updated editor's version	1.0.3	1.0.4
2007-05-11	-	-	-	-	Endorsed by RAN1#49	1.0.4	1.1.0
2007-05-15	-	-	-	-	Editor's version, including decisions from RAN1#49	1.1.0	1.1.1
2007-06-05	-	-	-	-	Updated editor's version	1.1.1	1.1.2
2007-06-25	-	-	-	-	Endorsed by RAN1#49bis	1.1.2	1.2.0
2007-07-10	-	-	-	-	Editor's version, including decisions from RAN1#49bis	1.2.0	1.2.1
2007-08-10	-	-	-	-	Updated editor's version	1.2.1	1.2.2
2007-08-20	-	-	-	-	Updated editor's version	1.2.2	1.2.3
2007-08-24	-	-	-	-	Endorsed by RAN1#50	1.2.3	1.3.0
2007-08-27	-	-	-	-	Editor's version, including decisions from RAN1#50	1.3.0	1.3.1
2007-09-05	-	-	-	-	Updated editor's version	1.3.1	1.3.2
2007-09-08	RAN#37	RP-070729	-	-	For approval at RAN#37	1.3.2	2.0.0
12/09/07	RAN_37	RP-070729			Approved version	2.0.0	8.0.0
28/11/07	RAN_38	RP-070949	0001	-	Introduction of optimized FS2 for TDD	8.0.0	8.1.0
28/11/07	RAN_38	RP-070949	0002	-	Introduction of scrambling sequences, uplink reference signal sequences, secondary synchronization sequences and control channel processing	8.0.0	8.1.0
05/03/08	RAN_39	RP-080219	0003	1	Update of uplink reference-signal hopping, downlink reference signals, scrambling sequences, DwPTS/UpPTS lengths for TDD and control channel processing	8.1.0	8.2.0
28/05/08	RAN_40	RP-080432	0004	-	Correction of the number of subcarriers in PUSCH transform precoding	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0005	-	Correction of PHICH mapping	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0006	-	Correction of PUCCH resource index for PUCCH format 2	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0007	3	Correction of the predefined hopping pattern for PUSCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0008	-	Non-binary hashing functions	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0009	1	PUCCH format 1	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0010	1	CR on Uplink DM RS hopping	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0012	1	Correction to limitation of constellation size of ACK transmission in PUSCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0015	1	PHICH mapping for one and two antenna ports in extended CP	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0016	1	Correction of PUCCH in absent of mixed format	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0017	-	Specification of CCE size and PHICH resource indication	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0018	3	Correction of the description of frame structure type 2	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0019	-	On Delta^pucch_shift correction	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0021	-	Corrections to Secondary Synchronization Signal Mapping	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0022	-	Downlink VRB mapping to PRB for distributed transmission	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0023	-	Clarification of modulation symbols to REs mapping for DVRB	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0024	1	Consideration on the scrambling of PDSCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0025	-	Corrections to Initialization of DL RS Scrambling	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0026	1	CR on Downlink RS	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0027	-	CR on Uplink RS	8.2.0	8.3.0

Petitioners' Exhibit 1003, p. 890
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
28/05/08	RAN_40	RP-080432	0028	1	Fixed timing advance offset for LTE TDD and half-duplex FDD	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0029	1	Timing of random access preamble format 4	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0030	1	Uplink sounding RS bandwidth configuration	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0031	-	Use of common RS when UE-specific RS are configured	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0032	1	Uplink RS Updates	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0033	-	Orthogonal cover sequence for shortened PUCCH format 1a and 1b	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0034	-	Clarification of PDCCH mapping	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0035	-	TDD PRACH time/frequency mapping	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0036	-	Cell Specific Uplink Sounding RS Subframe Configuration	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0038	-	PDCCH length for carriers with mixed MBSFN and Unicast Traffic	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0040	-	Correction to the scrambling sequence generation for PUCCH, PCFICH, PHICH, MBSFN RS and UE specific RS	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0041	-	PDCCH coverage in narrow bandwidths	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0042	-	Closed-Loop and Open-Loop Spatial Multiplexing	8.2.0	8.3.0
28/05/08	RAN_40	RP-080432	0043	-	Removal of small-delay CDD	8.2.0	8.3.0
09/09/08	RAN_41	RP-080668	48	1	Frequency Shifting of UE-specific RS	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	49	1	Correction of PHICH to RE mapping in extended CP subframe	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	50	-	Corrections to for handling remaining Res	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	51	-	PRACH configuration for frame structure type 1	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	52	2	Correction of PUCCH index generation formula	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	53	-	Orthogonal cover sequence for shortened PUCCH format 1a and 1b	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	54	-	Correction of mapping of ACK/NAK to binary bit values	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	56	2	Remaining issues on SRS hopping	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	57	1	Correction of n_cs(n_s) and OC/CS remapping for PUCCH formats 1/1a/1b and 2/2a/2b	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	59	-	Corrections to Rank information scrambling in Uplink Shared Channel	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	60	-	Definition on the slot number for frame structure type 2	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	61	-	Correction of the Npucch sequence upper limit for the formats 1/1a/1b	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	62	1	Clarifications for DMRS parameters	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	63	-	Correction of n_prs	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	64	1	Introducing missing L1 parameters to 36.211	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	65	3	Clarification on reception of synchronization signals	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	66	-	Correction to the downlink/uplink timing	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	67	-	ACK/NACK Scrambling scheme on PUCCH	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	68	-	DCI format1C	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	69	-	Refinement for REG Definition for n = 4	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	71	-	Correcting Ncs value for PRACH preamble format 0-3	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	73	-	Correction of the half duplex timing advance offset value	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	74	-	Correction to Precoding for Transmit Diversity	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	75	-	Clarification on number of OFDM symbols used for PDCCH	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	77	-	Number of antenna ports for PDSCH	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	78	-	Correction to Type 2 PUSCH predetermined hopping for Nsb=1 operation	8.3.0	8.4.0
09/09/08	RAN_41	RP-080668	79	-	PRACH frequency location	8.3.0	8.4.0
03/12/08	RAN_42	RP-081074	70	1	Correction for the definition of UE-specific reference signals	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	72	2	Corrections to precoding for large delay CDD	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	80	-	Correction to the definition of nbar_oc for extended CP	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	81	1	Specification of reserved REs not used for RS	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	82	2	Clarification of the random access preamble transmission timing	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	83	1	Indexing of PRACH resources within the radio frame	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	84	6	Alignment of RAN1/RAN2 specification	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	86	-	Clarification on scrambling of ACK/NAK bits for PUCCH format 2a/2b	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	87	-	Correction of introduction of shortened SR	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	88	-	Corrections to 36.211	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	89	-	Clarification on PUSCH DM RS Cyclic Shift Hopping	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	92	1	Correction to the uplink DM RS assignment	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	93	-	Clarify the RNTI used in scrambling sequence initialization	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	94	1	On linkage Among UL Power Control Parameters	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	95	-	Clarification on PUSCH pre-determined hopping pattern	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	96	-	Clarification of SRS sequence-group and base sequence number	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	97	1	SRS subframe configuration	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	98	-	Remaining SRS details for TDD	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	99	-	Clarifying UL VRB Allocation	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	100	-	Clarification on PUCCH resource hopping	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	101	-	Correction for definition of Qm and a pseudo code syntax error in Scrambling.	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	105	1	Remaining Issues on SRS of TDD	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	106	-	Correction of reference to RAN4 specification of supported uplink	8.4.0	8.5.0

Petitioners' Exhibit 1003, p. 891
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
					bandwidth		
03/12/08	RAN_42	RP-081074	107	-	General corrections to SRS	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	109	2	Correction to PCFICH specification	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	110	1	Correction to Layer Mapping for Transmit Diversity with Four Antenna Ports	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	111	-	Correction of the mapping of cyclic shift filed in DCI format 0 to the dynamic cyclic shift offset	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	112	-	DRS collision handling	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	113	-	Clarification to enable reuse of non-active PUCCH CQI RBs for PUSCH	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	114	1	PUSCH Mirror Hopping operation	8.4.0	8.5.0
03/12/08	RAN_42	RP-081074	108	1	Extended and normal cyclic prefix in DL and UL for LTE TDD	8.4.0	8.5.0
04/03/09	RAN_43	RP-090234	115	1	Alignment of PRACH configuration index for FS type 1 and type 2	8.5.0	8.6.0
04/03/09	RAN_43	RP-090234	118	1	Clarification for DRS Collision handling	8.5.0	8.6.0
04/03/09	RAN_43	RP-090234	121	1	Removing inverse modulo operation	8.5.0	8.6.0
04/03/09	RAN_43	RP-090234	123	1	Clarification on the use of preamble format 4	8.5.0	8.6.0
04/03/09	RAN_43	RP-090234	124	-	Clarification of RNTI used in scrambling sequence	8.5.0	8.6.0
04/03/09	RAN_43	RP-090234	125	1	Clarifying PDCCH RE mapping	8.5.0	8.6.0
04/03/09	RAN_43	RP-090234	126	-	Correction of preamble format 4 timing	8.5.0	8.6.0
04/03/09	RAN_43	RP-090234	127	2	Corrections to SRS	8.5.0	8.6.0
04/03/09	RAN_43	RP-090234	128	2	Clarification of PDSCH Mapping to Resource Elements	8.5.0	8.6.0
04/03/09	RAN_43	RP-090234	129	1	Alignment with correct ASN1 parameter names	8.5.0	8.6.0
04/03/09	RAN_43	RP-090234	130	-	Correction to PUCCH format 1 mapping to physical resources	8.5.0	8.6.0
04/03/09	RAN_43	RP-090234	132	-	Correction to type-2 PUSCH hopping	8.5.0	8.6.0
04/03/09	RAN_43	RP-090234	134	-	Alignment of SRS configuration	8.5.0	8.6.0
27/05/09	RAN_44	RP-090527	135	-	Correction on UE behavior for PRACH 20ms periodicity	8.6.0	8.7.0
15/09/09	RAN_45	RP-090888	137	1	Clarification on DMRS sequence for PUSCH	8.7.0	8.8.0
15/09/09	RAN_45	RP-090888	138	1	Correction to PHICH resource mapping for TDD and to PHICH scrambling	8.7.0	8.8.0
01/12/09	RAN_46	RP-091168	142	-	Clarification of the transmit condition for UE specific reference signals	8.8.0	8.9.0
01/12/09	RAN_46	RP-091172	139	2	Introduction of LTE positioning	8.9.0	9.0.0
01/12/09	RAN_46	RP-091177	140	3	Editorial corrections to 36.211	8.9.0	9.0.0
01/12/09	RAN_46	RP-091257	141	1	Introduction of enhanced dual layer transmission	8.9.0	9.0.0
16/03/10	RAN_47	RP-100209	144	1	Removal of square brackets on positioning subframe periodicities	9.0.0	9.1.0
16/03/10	RAN_47	RP-100209	145	-	Clarification of the CP length of empty OFDM symbols in PRS subframes	9.0.0	9.1.0
16/03/10	RAN_47	RP-100210	146	-	Clarification of MBSFN subframe definition	9.0.0	9.1.0
07/12/10	RAN_50	RP-101320	148	-	Introduction of Rel-10 LTE-Advanced features in 36.211	9.1.0	10.0.0
15/03/11	RAN_51	RP-110254	149	1	Correction on UE behavior for PRACH preamble format 4	10.0.0	10.1.0
15/03/11	RAN_51	RP-110256	150	-	Corrections to Rel-10 LTE-Advanced features in 36.211	10.0.0	10.1.0
01/06/11	RAN_52	RP-110818	153	2	PUSCH interaction with periodic SRS	10.1.0	10.2.0
01/06/11	RAN_52	RP-110819	154	1	Correction on describing PUCCH format 3	10.1.0	10.2.0
01/06/11	RAN_52	RP-110821	155	3	Correction on codebooks for CSI-RS based feedback for up to 4 CSI-RS ports.	10.1.0	10.2.0
01/06/11	RAN_52	RP-110821	156	-	Correction on overlapping non-zero-power and zero-power CSI-RS configurations	10.1.0	10.2.0
01/06/11	RAN_52	RP-110821	157	-	Correction on CSI-RS configuration	10.1.0	10.2.0
01/06/11	RAN_52	RP-110821	158	-	PDSCH transmission in MBSFN subframes	10.1.0	10.2.0
01/06/11	RAN_52	RP-110823	159	-	Correction on implicit derivation of transmission comb per antenna port for SRS	10.1.0	10.2.0
01/06/11	RAN_52	RP-110823	160	-	Uplink DMRS sequence in RACH procedure	10.1.0	10.2.0
15/09/11	RAN_53	RP-111229	162	-	Corrections on DMRS for Extended CP	10.2.0	10.3.0
15/09/11	RAN_53	RP-111228	163	-	Clarification of applicability of precoding power scaling factors for PDSCH	10.2.0	10.3.0
15/09/11	RAN_53	RP-111228	164	-	Correction to modulation and upconversion on PRACH	10.2.0	10.3.0
15/09/11	RAN_53	RP-111229	165	-	Clarification on cyclic prefix of PDSCH in MBSFN subframes	10.2.0	10.3.0
15/09/11	RAN_53	RP-111229	166	3	Corrections on indication in scrambling identity field in DCI format 2B and 2C	10.2.0	10.3.0
05/12/11	RAN_54	RP-111668	167	-	A correction to PDSCH precoding for CQI calculation	10.3.0	10.4.0
05/12/11	RAN_54	RP-111668	168	-	Correction to figure of CSI-RS pattern in extended-CP subframe	10.3.0	10.4.0
13/06/12	RAN_56	RP-120736	169	-	Correction to resource mapping for PDSCH	10.4.0	10.5.0
13/06/12	RAN_56	RP-120739	171	-	Correction for DMRS group hopping and sequence hopping	10.4.0	10.5.0
13/06/12	RAN_56	RP-120738	172	-	Correction to assumed CSI-RS transmissions in subframes used for paging	10.4.0	10.5.0
04/12/12	RAN_58	RP-121839	174	-	Correction to assumed CSI-RS transmissions in secondary cells	10.5.0	10.6.0
26/02/13	RAN_59	RP-130254	177	-	Clarification of CSI RS mapping to resource elements	10.6.0	10.7.0
26/02/13	RAN_59	RP-130254	179	-	Correction to CSI Reference Signals	10.6.0	10.7.0

Petitioners' Exhibit 1003, p. 892
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

APPENDIX 4

3GPP TSG RAN WG1 Meeting #86bis **R1-1608562**
Lisbon, Portugal, 10th – 14th October 2016

Source: **MCC Support**

Title: **Final Report of 3GPP TSG RAN WG1 #86 v1.0.0 (Gothenburg, Sweden, 22nd – 26th August 2016)**

Document for: **Approval**



Petitioners' Exhibit 1003, p. 894
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table of contents

1 Opening of the meeting 6
1.1 Call for IPR 6
1.2 Competition law statement 6
1.3 Network usage conditions 6
2 Approval of Agenda 6
3 Approval of Minutes from previous meeting 7
4 Highlights from RAN Plenary 7
5 Incoming Liaison Statements 7
6 UTRA 13
6.1 Maintenance of UTRA Releases 4 – 13 13
6.1.1 FDD 13
6.1.2 TDD 14
6.2 DTX/DRX enhancements in CELL_FACH - WID in RP-160185 14
6.2.1 DRX improvements 14
6.2.2 DTX improvements 14
6.3 Multi-Carrier enhancements for UMTS - WID in RP-161259. 15
6.3.1 2ms+10ms and 10ms+10ms configurations for (DB)-DC-HSUPA 15
6.4 Other 15
7 E-UTRA 15
7.1 Maintenance of E-UTRA Releases 8 – 13 15
7.1.1 Maintenance of E-UTRA Release 8 – 12 16
7.1.2 Maintenance of Release 13 LTE carrier aggregation enhancement beyond 5 carriers 17
7.1.3 Maintenance of Release 13 licensed-assisted access to unlicensed spectrum 17
7.1.4 Maintenance of Release 13 elevation beamforming/full-dimension MIMO for LTE 17
7.1.5 Maintenance of Release 13 further LTE physical layer enhancements for MTC 18
7.1.6 Maintenance of Release 13 NB-IoT 21
7.2 LTE Release 14 24
7.2.1 Enhanced Licensed-Assisted Access to Unlicensed Spectrum *WID in RP-160881*. 24
7.2.1.1 PUSCH design 24
7.2.1.2 SRS design 27
7.2.1.3 Channel access framework 27
7.2.1.4 Other 30
7.2.2 Support for V2V services based on LTE sidelink - *WID in RP-161272* 30
7.2.2.1 Remaining details of physical layer structure 31
7.2.2.2 Remaining details of UE autonomous resource selection mode 32
7.2.2.2.1 Details of transmission resource (re)selection based on SA decoding and power/energy measurement 32
7.2.2.2.2 Details of timing of PSCCH/PSSCH transmission and the indication of the intention to reuse the frequency resource for another TB 34
7.2.2.2.3 Details of the measurement metric to reflect the congestion level 35
7.2.2.2.4 Other 35
7.2.2.3 Remaining details of resource pool design 35
7.2.2.4 Remaining details of scheduling for sidelink resource in eNB scheduling mode 37
7.2.2.4.1 Details of DCI format for SPS and dynamic scheduling 37
7.2.2.5 Remaining details of SCI contents 38
7.2.2.6 Remaining details of coexistence of PC5-based V2V operation and legacy Uu operation 38
7.2.2.7 Remaining details of sidelink synchronization procedure 39
7.2.2.8 Other 39
7.2.3 LTE-based V2X Services - *WID in RP-161298* 40
7.2.3.1 Enhancement to UL SPS 40
7.2.3.2 Resource selection for pedestrian UEs 40
7.2.3.3 Other 41
7.2.4 Enhancements on Full-Dimension (FD) MIMO for LTE - *WID in RP-160623* 41
7.2.4.1 Reference signals 41
7.2.4.1.1 Non-precoded CSI-RS 41
7.2.4.1.2 Beamformed CSI-RS 43
7.2.4.1.3 Uplink DM-RS 45
7.2.4.2 CSI reporting 46
7.2.4.2.1 Non-precoded CSI-RS codebooks 46
7.2.4.2.2 CSI reporting for hybrid CSI-RS 47
7.2.4.2.3 Advanced CSI reporting and interference measurement 48
7.2.4.3 DMRS-based open-loop and semi-open-loop transmission 50

Petitioners' Exhibit 1003, p. 895
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.2.5 Downlink Multiuser Superposition Transmission for LTE - *WID in RP-161019* 51
7.2.5.1 Superposition transmissions 51
7.2.5.2 Mechanisms for efficient operation 52
7.2.5.3 Evaluation for MUST using up to 8Tx 53
7.2.5.4 Other 53
7.2.6 eMBMS enhancements for LTE - *WID in RP-161297* 54
7.2.6.1 Longer cyclic prefix for MBSFN subframe 54
7.2.6.2 Increased number of MBSFN subframes per radio frame 55
7.2.6.3 MBSFN subframes without a unicast control region and cell-specific reference signals 55
7.2.6.4 Other 55
7.2.7 SRS Carrier Based Switching for LTE - *WID in RP-160935* 55
7.2.7.1 SRS Transmission on TDD CCs without PUSCH 55
7.2.7.2 Details of periodic and/or aperiodic SRS 56
7.2.7.3 Details of collision handling 56
7.2.7.4 Other 56
7.2.8 Further Indoor Positioning enhancements for UTRA and LTE -*WID in RP-160538* 57
7.2.8.1 Remaining issues for OTDOA enhancements 57
7.2.8.2 PRS-based beacons 57
7.2.8.3 E-CID enhancements 58
7.2.8.4 Other 58
7.2.9 Uplink Capacity Enhancements for LTE - *WID in RP-160664* 58
7.2.10 Further Enhanced MTC for LTE - *SID in RP-161321* 59
7.2.10.1 Higher data rates 60
7.2.10.2 Multicast 61
7.2.10.3 Other 61
7.2.11 Enhancements of NB-IoT - *WID in RP-161324.* 61
7.2.11.1 Positioning 61
7.2.11.1.1 Requirements 62
7.2.11.1.2 Uplink-based narrowband positioning 62
7.2.11.1.3 Downlink-based narrowband positioning 62
7.2.11.1.4 Comparison of uplink- and downlink-based methods 63
7.2.11.2 Multicast support 63
7.2.11.3 Non-anchor PRB enhancements 64
7.2.11.4 Other 64
7.2.12 Shortened TTI and processing time for LTE - *WID in RP-161299.* 64
7.2.12.1 Shortened processing time for 1ms TTI 65
7.2.12.2 Shortened TTI length together with shortened processing time 66
7.2.12.2.1 Design of sTTI for DL and UL 66
7.2.12.2.2 Processing time 68
7.2.12.3 Other 68
7.2.13 Performance enhancements for high speed scenario - *WID in RP-160172* 68
7.2.14 Study on Further enhancements to Coordinated Multi-Point Operation - *SID in RP-160954* 69
7.2.14.1 Remaining details of the deployment scenarios and system-level evaluation assumptions 69
7.2.14.2 Potential enhancements for non-coherent joint transmission 70
7.2.14.3 Potential enhancements for coordinated scheduling/beamforming with FD-MIMO 70
7.2.15 Study on Enhancement of VoLTE - *SID in RP-160902* 70
7.2.15.1 VoLTE/video quality improvements 70
8 NR 71
8.1 Study on New Radio Access Technology - SID in RP-161214 71
8.1.1 Forward compatibility for new radio interface 71
8.1.2 Waveform and multiple access schemes for new radio interface 74
8.1.2.1 Waveform 74
8.1.2.2 Multiple access scheme 77
8.1.3 Numerology and frame structure for new radio interface 81
8.1.3.1 Numerology 81
8.1.3.2 Frame structure 83
8.1.4 Channel coding and modulation for new radi'o interface 95
8.1.4.1 Channel coding 95
8.1.4.2 Modulation 99
8.1.5 Multi-antenna scheme for new radio interface 100
8.1.6 Aspects related to initial access and mobility 114
8.1.7 Remaining details on evaluation and scenarios for new radio interface 121
8.1.8 Other 125
8.2 Other 127

Petitioners' Exhibit 1003, p. 896
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

9 Closing of the meeting....130
Annex A: List of Tdocs at RAN1 #86....131
Annex B: List of CRs agreed at RAN1 #86....132
Annex C-1: List of Outgoing LSs from RAN1 #86....138
Annex C-2: List of Incoming LSs from RAN1 #86....140
Annex D: List of Approved updated WIDs....143
Annex E: List of draft TSs/TRs agreed at RAN1 #86....144
Annex F: List of actions....145
Annex G: List of participants at RAN1 #86....153
Annex H: TSG RAN WG1 meetings in 2016 – 2017....154

Petitioners' Exhibit 1003, p. 897
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Main facts summary

3GPP TSG WG RAN1 #86 meeting, hosted by the European Friends of 3GPP, was held at the Gothia Towers Hotel, Gothenburg, Sweden.
The meeting started at 9:00 on Monday 22nd August and finished at 17:00 on Friday 26th August 2016.
The number of attending delegates, having confirmed their participation through the electronic check-in application, was **422.**
Note that the number of registered was a kind of record and reached 599.

The list of action points that required RAN1 close follow-up is listed in Annex F (end of document).

The number of contribution documents for this meeting was 2432, and those documents were categorized as followed.

Agenda Item	Input Document	Treated Document
All	2432	1075

Note: The amount of documents includes those discussed during the email discussion session post meeting.

Petitioners' Exhibit 1003, p. 898
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

1 Opening of the meeting

Mr Satoshi Nagata (RAN1 Chairman) welcomed the participants of the RAN WG1 86 meeting and opened the meeting at 09:00. Mr Johan Bergman from Ericsson welcomed the delegates on behalf of the European Friends of 3GPP, Alcatel-Lucent, Apple, BlackBerry, Deutsche Telekom, Ericsson, Huawei, Intel, KPN, Motorola, Nokia, Orange, Qualcomm, SIMAlliance, Sony, TeliaSonera, Telefonica, TIM, Telenor, Vodafone and detailed the domestic arrangements for the full week.

1.1 Call for IPR

The attention of the members of this Technical Specification Group was drawn to the fact ***that 3GPP Individual Members have the obligation*** *under the IPR Policies of their respective Organizational Partners to* ***inform their respective*** *Organizational Partners* ***of Essential IPRs they become aware of****.*
The members take note that they are hereby invited:

- *to investigate whether their organization or any other organization owns IPRs which were, or were likely to become Essential in respect of the work of 3GPP.*
- *to notify their respective Organizational Partners of all potential IPRs, e.g., for ETSI, by means of the IPR Information Statement and the Licensing declaration forms (e.g. see the ETSI IPR forms http://webapp.etsi.org/Ipr/).*

1.2 Competition law statement

The Chairman also drew Member's attention to the fact that 3GPP activities are subject to antitrust and competition laws and that compliance with said laws is therefore required of any participant of this WG meeting including the Chairman and Vice Chairmen. In case of question, please contact your legal counsel.
The present meeting will be conducted with strict impartiality and in the interests of 3GPP.
Furthermore, the Chairman reminded Members that timely submission of work items/contributions in advance of WG meetings is important to allow for full and fair consideration of such matters.

1.3 Network usage conditions

The PCG has laid down the following network usage conditions:

Users shall not use the network to engage in illegal activities. This includes activities such as copyright violation, hacking, espionage or any other activity that may be prohibited by local laws.

Users shall not engage in non-work related activities that consume excessive bandwidth or cause significant degradation of the performance of the network.
Since the **network is a shared resource**, users should exercise some basic etiquette when using the 3GPP network at a meeting. It is understood that high bandwidth applications such as downloading large files or video streaming might be required for business purposes, but delegates should be strongly discouraged in performing these activities for personal use. Downloading a movie or doing something in an interactive environment for personal use essentially wastes bandwidth that others need to make the meeting effective. The meeting chairman should remind end users that the network is a shared resource; the more one user grabs, the less there is for another. Email and its attachments already take up significant bandwidth (certain email programs are not very bandwidth efficient). In case of need the chair can ask the delegates to restrict IT usage to things that are essential for the meeting itself.

1. DON'T place your WiFi device in ad-hoc mode
2. DON'T set up a personal hotspot in the meeting room
3. DO try 802.11a if your WiFi device supports it
4. DON'T manually allocate an IP address
5. DON'T be a bandwidth hog by streaming video, playing online games, or downloading huge files
6. DON'T use packet probing software which clogs the local network (e.g., packet sniffers or port scanners)

2 Approval of Agenda

R1-166055 **Draft Agenda of RAN1#86 meeting** **RAN1 Chair**
Satoshi Nagata (Chairman) proposed the agenda for the meeting, as well the schedule of the week.
Discussion: No comment.
Decision: The agenda is approved.

Petitioners' Exhibit 1003, p. 899
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

3 Approval of Minutes from previous meeting

R1-166056 Final Report of 3GPP TSG RAN1 #85 v1.0.0 ETSI
The document was presented by Patrick Mérias (ETSI Mobile Competence Center) and provides the outcomes of last meeting in China.
Discussion: MCC→ due to the inflation of contributions (>1800 at meeting start), RAN1 will shortly burst the 9999 tdocs per year barrier (4 digits upper limit) – RAN1 was warned that 5 digits numbering might be introduced at the next meeting.
MCC→ rapporteurs of WI/SI chairing sessions during the week are requested to highlight and use the bold type to clearly show the treated contributions in their notes and help MCC recording correct statuses in 3GU.
Decision: The document is approved.

4 Highlights from RAN Plenary

R1-166057 Selected highlights from RAN#72 of relevance to RAN1 RAN1 Chair
The document was presented by RAN1 Chair and feedbacks the decisions made by RAN#72, relevant to RAN1.
Discussion: Chair → regarding the additional ad-hoc meetings for NR, current view is as follows:

- January 2017 – 5days meeting – likely in the US (exact location still to be defined)
- June 2017 – 4days meeting – likely in Asia (Japan, India)

Decision: The document is noted.

5 Incoming Liaison Statements

R1-166073 LS to RAN1 on clarification on MIMO capability RAN2, Huawei
The document was presented by Xia Yuan from Huawei and raises an IOT issue if UE and network have different understanding in the case where, for instance the UE supports following two combinations simultaneously:
Combination 1: Band A 4*4 layers; Band B 2*2 layers
Combination 2: Band A 2*2 layers; Band B 4*4 layers;
How can the UE to determine the maximum number of layers for RI bit and Kc? 4*4 layers for band A or 2*2 layers for band A?
Decision: The document is noted.
R1-167906 Reply LS for clarification on MIMO capability Huawei
Discussion: .Qualcomm confirmed solution 2 is the preferred one. Potential UE capability discussion may be needed in RAN2.
Decision: The document is noted and final LS is agreed in R1-167914.

R1-166086 LS on 256QAM support for UE Category 9/10 from Rel-12 RAN, Intel
The document was presented by Seunghee Han from Intel and asks to create the CRs reflecting that:

- For a Rel-12 UE supporting all UE radio access capability parameters for both Cat.9/10 and Cat.13,
  - The UE can report both Cat.9/10 and Cat.13
    - The eNB may understand that the UE supports all UE radio access capability parameters of both Cat.9/10 and Cat.13
      - Therefore either category can be applied individually (but not a combination of parameters of different categories)

Decision: The document is noted.

R1-166192 Discussion on UE reporting both category 9/10 and 13 Huawei, HiSilicon
The document was presented by Xia Yuan from Huawei.

- Proposal: DL UE category 13 could indicate category 9 or 10 if supported

Decision: The document is noted.

R1-166500 Discussion on simultaneous signaling of categories 9/10 and 13 Intel Corporation
The document was presented by Alexei from Davydov and proposes the following principles for deriving rate matching parameters and storing the received soft channel bits for such UEs are as follows:

- No specification change is required for the rate matching procedure in TS 36.212 to support UE simultaneously indicating support of category 9/10 and 13
- To support UE simultaneously indicating support of category 9/10 and 13 the Nsoft for sorting the received soft channel bits in TS 36.213 should be based on UE category 9/10 rather than DL category 13.

Discussion: Qualcomm → not aligned with RAN's agreement
Decision: The document is noted.
R1-167191 Introduction of simultaneous signalling of categories 9/10 and 13 Intel Corporation
R1-167192 Introduction of simultaneous signalling of categories 9/10 and 13 Intel Corporation

Agreements:

Petitioners' Exhibit 1003, p. 900
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- No specification change is required for the rate matching procedure in TS 36.212 to support UE simultaneously indicating support of category 9/10 and 13
- For TS 36.213, N'_{soft} is the maximum "Total number of soft channel bits" [12] among all the indicated UE categories [11] of this UE.

R1-167398 Correction on storing soft channel bits for different UE categories Huawei, HiSilicon, NTT DOCOMO, SoftBank

- Change the soft channel bits assumption to be suitable for all the UE categories in TS36.213 so that the total number of soft channel bits is based on the maximum "Total number of soft channel bits" of all the UE categories supported by this UE.

Decision: The document is noted and CR0704 to 36.213 is not pursued.

Following LS was received during RAN1#86:

R1-168520 LS on Support of CAT 9/10 and CAT 13 RAN2

RAN2 agrees to use existing IEs i.e the UE indicates both ue-Category-v1170 (= Category 9/10) and ue-CategoryDL-r12 (= Category 13) when it supports both Category 9/10 and Category 13. RAN2 confirms that there is no backward compatibility issue when the UE sends both UE category IEs. Furthermore, the corresponding Rel-12/13 CRs for TS36.306 have been agreed in R2-165855 and R2-165856.

Decision: The document is noted.

LAA

R1-166066 Long Term Evolution in Operation in Unlicensed Spectrum Must Not Interfere with Wi-Fi City of Madison (Office of the Mayor of)

The document was presented by RAN1 Chair.

Decision: The document is noted.

R1-166083 Response to Wi-Fi Alliance comments on "Way forward on coexistence tests for LAA" RAN4, Qualcomm, Ericsson

The document was presented by RAN1 Chair.

Decision: The document is noted.

R1-167928 LS on CSI measurement ambiguity in LAA RAN4, LGE

The document (Incoming LS received in RAN1#86) was presented by Joon Kui Ahn from LGE and asked RAN1 to clarify whether following sentence could be applied in LAA CSI reporting case or not.

"*For a non-BL/CE UE, if there is no valid downlink or no valid special subframe for the CSI reference resource in a serving cell, CSI reporting is omitted for the serving cell in uplink subframe n.*" (in RAN1 specification TS 36.213 for CSI reporting)

Decision: The document is noted.

R1-166812 Discussion on RAN4 LS on CSI measurement ambiguity in LAA LG Electronics

Decision: The document is noted. Continue offline discussion until Friday – (LGE)

Friday: No progress – continue discussion until the next meeting.

R1-167880 Reply LS on Rel-13 LAA specifications RAN, Qualcomm, NTT DOCOMO

The document was presented by Srinivas Yerramalli from Qualcomm

Decision: The document is noted.

R1-167881 "Response to Liaison Statement on coexistence simulation results for DL only LAA" Wi-Fi Alliance

The document is a response to the liaison statement questions asked in R1-161396, summarizes changes made to the ns-3 simulator, and how such changes affect the results presented in R1-156621.

Decision: The document is noted. Continue offline discussion until Friday, if needed –(Qualcomm)

R1-167118 Draft response LS to WFA regarding LAA Qualcomm Incorporated

Friday Decision: Qualcomm withdrew R1-167118 as there did not seem to be a need identified (in this meeting at least) to respond to the LS.

R1-167908 Review of 3GPP LAA Specification Rel. 13 IEEE 802 LMSC

The document states that some of the comments in IEEE 802's Liaison Statement to 3GPP RAN1 dated 18 March 2016 (802.19-16-0037-09) have been resolved satisfactorily and represents a great success for the consensus process that started with the 3GPP LAA Workshop back in August 2015. However, there are a number of important outstanding issues, for which IEEE requests RAN1 to continue to look for satisfactory compromises with IEEE 802 and other interested stakeholders..

Decision: The document is noted. Continue offline discussion until Friday – (Qualcomm)

Friday Decision:

R1-166666 Draft response LS to 802dot11 regarding LAA Qualcomm Incorporated

Petitioners' Exhibit 1003, p. 901
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The document is noted.

eMTC

R1-166069 LS on HARQ process selection for UL asynchronous HARQ RAN2, Huawei

The document was presented by Matthew Webb from Huawei.

- In asynchronous HARQ operation, HARQ process is associated with TTI based on the received UL grant except for UL grant in RAR. Each asynchronous HARQ process is associated with a HARQ process identifier. For UL transmission with UL grant in RAR, HARQ process identifier "0" is used.

Discussion: No action to RAN1 – no impact to spec
Decision: The document is noted.

R1-166081 LS on continuous uplink transmission in eMTC RAN4, Intel

The document was presented by Debdeep Chatterjee from Intel and asks RAN1 to specify UL compensation gaps, including related UE behaviour.
Discussion: No action to RAN1.
Decision: The document is noted.

NB-IoT

R1-166061 Reply LS on questions on NB-IOT CT1, Nokia

The document was presented by Rapeepat Ratasuk from Nokia.
Discussion: No action to RAN1.
Decision: The document is noted.

R1-166070 LS to RAN1 on WLAN RSSI RAN2, Nokia

The document was presented by Klaus Hugl from Nokia and asks RAN1 to correct the definition of WLAN RSSI.
Decision: The document is noted.

R1-167547 Correction to the Beacon RSSI definition Nokia, Intel, Alcatel-Lucent Shanghai Bell, Qualcomm Incorporated, Ericsson
Decision: The document is noted and CR0034 to 36.214 (Rel-12) is agreed.
R1-167549 Correction to the WLAN RSSI definition Nokia, Intel, Alcatel-Lucent Shanghai Bell, Qualcomm Incorporated, Ericsson
Decision: The document is noted and CR0035 to 36.214 (Rel-13) is agreed.

Latency reduction

R1-166071 LS to RAN1 on RAN2 agreements on skipping Uplink transmission RAN2, Nokia

The document was presented byTimo Lunttila from Nokia and asks RAN1

- to confirm the RAN2 assumption that non-adaptive retransmissions on SPS resource are done based on RV 0 and to provide feedback if any concern,
- to align RAN1 specifications if needed regarding the assumption that the UCI should be sent on PUCCH even if there is a valid PUSCH allocation on that subframe

Decision: The document is noted.

R1-167507 Addition of LTE_LATRED_L2-Core Ericsson LM

Add that PUSCH is not transmitted if not high layers generates a MAC entity for the corresponding HARQ process
Decision: The document is noted and CR0709 of 36.213 is for email approval until Sept 12th (Spec editor – Motorola Mobility)

R1-167023 On skipping uplink transmission Nokia, Alcatel-Lucent Shanghai Bell

The document was presented byTimo Lunttila from Nokia.

- Proposal #1: The RAN2 working assumption on using RV0 with non-adaptive retransmissions on SPS resources can be confirmed.
- Proposal #2: In the case of UL skipping, UCI consisting of HARQ-ACK, periodic CSI and/or scheduling request indicator is transmitted on PUCCH following the legacy rules for the case when there is no PUSCH transmission.
- Proposal #3: An UL grant triggering Aperiodic CSI transmission is considered as a regular dynamic UL grant. UL skipping does not apply in this case.

Decision: The document is noted.

R1-167506 Discussion on skipping Uplink transmission Ericsson

The document was presented by Daniel Larsson from Ericsson and proposes to:

- Agree to the LS to RAN2 in R1-167505
- Agree to the CR in R1-167507

Decision: The document is noted.

Petitioners' Exhibit 1003, p. 902
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-167505 [DRAFT] LS on RAN2 agreements on skipping Uplink transmission Ericsson

R1-166665 Discussion of LS from RAN2 on skipping uplink transmission Qualcomm Incorporated
Decision: The document is noted.

Agreements:

- In the case of UL skipping, UCI consisting of HARQ-ACK, periodic CSI and/or scheduling request indicator is transmitted on PUCCH following the legacy rules for the case when there is no PUSCH transmission.
- An UL grant triggering Aperiodic CSI transmission is considered as a regular dynamic UL grant. UL skipping does not apply in this case

Continue discussion until Friday – (Nokia)
Friday:
R1-168527 [DRAFT] Reply LS on RAN2 Agreements on Skipping Uplink Transmission Nokia
Decision: The document is noted and final LS is agreed in R1-168528.

R1-166084 Reply LS on SRS carrier switching interruption time RAN4, Huawei
The document was presented by Weimin Xiao from Huawei.
Decision: The document is noted and acknowledged by RAN1.

V2X
R1-166060 LS to RAN1 on RAN2 agreements related to V2X RAN2, LGE
The document was presented by Hanbyul Seo from LGE and provides RAN2 TP (R2-163650) capturing agreements of RAN2#93bis – already included in the TR 36.885.
Decision: The document is noted.

R1-166062 LS to RAN1 on SPS RAN2, LGE
The document was presented by Hanbyul Seo from LGE and informs RAN1 that for UL SPS, the majority of companies agree that from a RAN2 point of view, it is not necessary to send an indication to the eNB that an SPS grant will not be used. Therefore, the working assumption on "the UE can indicate to the eNB that it does not intend to transmit data before a transmission associated to an SPS configuration" is not needed.
Decision: The document is noted.

R1-166068 Reply LS on EPC procedures for providing eNB with V2X authorization information RAN2, LGE
The document was presented by Hanbyul Seo from LGE and provides answers to SA2.
Discussion: No action to RAN1.
Decision: The document is noted.

R1-166072 LS to RAN1 on agreed TPs RAN2, LGE
The document was presented by Hanbyul Seo from LGE and provides RAN2 TPs (R2-164495, R2-164497, R2-164553) capturing agreements of RAN2#94 – already included in the TR 36.885.
Decision: The document is noted.

V2V
R1-166063 LS on V2V transmission path selection RAN2, Huawei
The document was presented by Philippe Sartori from Huawei and provides the follwing RAN2's agrrements:

- The following configurations are allowed by eNB for transmission of V2V: 1) Uu only, 2) PC5 only and 3) both Uu and PC5 for V2V transmissions in different carriers.
- If both Uu and PC5 are configured for V2V transmissions, it is left up to UE upper layers which path is selected. FFS whether any additional AS information is provide to upper layers.
- The eNB can configure the V2V transmission configuration in SIB and/or dedicated signalling.

Decision: The document is noted.

R1-166082 Reply LS on V2V multicarrier configuration RAN4, LGE, Ericsson
The document was presented by Stefano Sorrentino from Ericsson and shows RAN4 conclusion to scenarios supporting multiple component carrier (MCC) operation for V2V services based on LTE sidelink functionality:

- Analysis and specification of transmission and reception requirements for single component carrier (CC) operation will be completed as a first priority (e.g. for both licensed LTE bands and ITS spectrum at 5.9GHz).
    - The analysis and specification of transmission and reception requirements for MCC V2V operation will be completed in RAN4 as second priority as part of the V2V WI.

Petitioners' Exhibit 1003, p. 903
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

  - If the MCC operation for V2V service can't be completed within V2V WI time line, RAN4 suggests to further study in Rel-14 pending agreement in the RAN plenary. Therefore MCC operation for V2V operation will be supported in Rel-14.
- Note that MCC V2V operation will depend on the V2V UE RF architecture and RAN4 needs further time to study support of MCC V2V operation and LTE operation with intra UE capabilities.

Decision: The document is noted.

R1-167878 **LS on V2V Authorization RAN3, Huawei**
RAN3 believes that the V2V authorization information needs to be provided to the eNB from a trusted node (i.e. the MME or another eNB), and to be extensible in the future (i.e. further considering the possible outcome of the RAN V2X SI). RAN3 has technically endorsed the attached CRs which introduce a *Vehicular Services Authorized* IE.
Discussion: No action to RAN1.
Decision: The document is noted.

Network Assistance for Network Synchronization in LTE
R1-166085 **LS on Network Assistance for Network Synchronization in LTE RAN, Huawei**
The document was presented by Elean Fan from Huawei and asks RAN1 clarifying the feasibility on standardization of the time-stamps T1 and T2 for received RACH preamble in case of Solution 1 (network based solution reusing the existing signaling during handover).
Decision: The document is noted.

R1-167177 **Feasibility on standardization of the time-stamps for received RACH preamble Huawei**
- UE transmitting RACH upon handover is an existing procedure in LTE
- To get the time stamps T1 and T2 upon receiving the RACH preamble, no UE changes are required
- To get the time stamps T1 and T2 upon receiving the RACH preamble, no additional physical layer signalling is required

Decision: The document is noted.
R1-166198 Reply LS on Network Assistance for Network Synchronization in LTE Huawei

Agreements:
- UE transmitting RACH upon handover is an existing procedure in LTE
- RAN1 does not need to specify eNB measurements to support this feature (if specified)

R1-167916 **Reply LS on Network Assistance for Network Synchronization in LTE RAN1**
Decision: The document is agreed.

Mobility enhancements
R1-166074 **LS on the evaluation of simultaneous transmission and reception RAN2, ZTE**
Decision: The document is noted.
R1-166078 **Response LS on the feasibility of mobility enhancement solutions RAN3, ZTE**
There is no information exchanged, today, related to timing offset, between source and target eNBs in asynchronous case over any RAN3 interfaces.
Decision: The document is noted.
R1-166080 **Reply LS on the feasibility of mobility enhancement solutions RAN4, ZTE**
Decision: The document is noted.
R1-167810 **Summary of email discussion on replying LS for mobility enhancement solutions ZTE Corporation**
Decision: The document is noted.

VoLTE
R1-166075 **LS on VoLTE and video quality related enhancements RAN2, Ericsson**
The document was presented by Johan Bergman from Ericsson and asks RAN1 to investigate the trade-off between packet delay budget and achievable coverage to assess the benefits of VoLTE/video quality related enhancements, and provide feedback.
Decision: The document is noted.

R1-168136 **[DRAFT] Reply LS on VoLTE and video quality related enhancements CMCC**
Decision: The document is noted and final LS is agreed in R1-168256

HSPA (see AI6.3)
R1-166067 LS on RAN2 aspects on MC enhancements RAN2, Huawei
R1-166076 LS on Multi-carrier enhancements RAN3, Huawei

NR

Petitioners' Exhibit 1003, p. 904
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166058 Updated characteristics of terrestrial IMT systems for frequency sharing / interference analysis in the frequency range between 24.25 GHz and 86 GHz ITU-R WP5D
The document was presented by RAN1 Chair en behalf of ITU-R and the following updates from the previous version:
1. Three parameters (access technique, modulation parameters and channel spacing) were removed.
2. Two new parameters (Duplex Method and SINR operating range) were added. However, the relevance of Duplex Method parameter for sharing studies is still being considered.

Decision: The document is noted.

R1-167375 [Draft] LS on Parameters for WP5D sharing and compatibility studies NTT DOCOMO, INC.
The document was presented by Kazuaki Takeda from NTT DOCOMO.
Discussion: Qualcomm → 1024QAM should be mentioned – to be considered at the same level as the others
Samsung → concern of introducing 1024QAM (no proposal yet available)
Decision: The document is noted and agreed with updated Note 2 in R1-167917 as follows:
Note 2: There is no agreement in RAN1, but the use of QPSK, 16QAM, 64QAM, 256QAM, and possibly 1024QAM constellations are at least considered, while details, e.g., mapping of bits to constellation points, are under study. Accordingly, SINR operating range includes at least the SINR values for which QPSK, 16QAM, 64QAM, 256QAM, and possibly 1024QAM can be used.

R1-166059 MODELLING AND SIMULATION OF IMT NETWORKS FOR USE IN SHARING AND COMPATIBILITY STUDIES ITU-R WP5D
The document was presented by RAN1 Chair en behalf of ITU-R and describes detailed IMT system parameters needed for modelling, their implementation in the simulations, and the methodology to calculate the aggregate effect of potential interference generated by an IMT system.
Decision: The document is noted.

R1-167882 Proposal for Improved RMa model and upgraded open source channel simulator NYU Wireless
The document shares the results of recent modelling and measurements that will correct errors in the existing 3GPP RMa model as it appears in TR 38.900, and offers recently published results that may help in system and link-level simulations, as well as highlighting the use of these results in an improved version of an open source simulator discussed in a July 2016 IEEE T-MTT paper and in the upcoming October 2016 "All Things Cellular" paper.
Decision: The document is noted.

R1-166064 INCREASING LEVELS OF RF NOISE IN THE ENVIRONMENT AND CONSEQUENT INTERFERENCE TO RADIOCOMMUNICATION SERVICES ITU-R WP 1A
The document was presented by RAN1 Chair en behalf of ITU-R and deals with increasing levels of RF noise radiated or superimposed along the electrical mains supply and the consequent increase in instances of EMI.
Decision: The document is noted.

R1-166077 Reply LS on Formation of IEEE 1914 Next Generation Fronthaul Interface Working Group RAN3, Intel
The document was presented by … from Intel and informs IEEE 1914 that in the context of the NR SI, RAN architecture and functional splits are being studied by RAN3.
Discussion: No action to RAN1.
Decision: The document is noted.

R1-166079 LS on Characteristics of terrestrial IMT systems for frequency sharing/interference analysis in the frequency range between 24.25 GHz and 86 GHz RAN4, Nokia
The document was presented by Tuomo Säynäjäkangas from Nokia.
Discussion: No action to RAN1.
Decision: The document is noted.

R1-167879 Reply LS to ITU-R WP5D/TEMP/39(Rev.2) = RP-160508 on Characteristics of terrestrial IMT systems for frequency sharing/interference analysis in the frequency range between 24.25 GHz and 86 GHz RAN, Nokia
The document was presented by Tuomo Säynäjäkangas from Nokia and confirms the following schedule agreed RAN:
RAN#72 (June 2016): RAN send LS to ITU-R WP5D including time plan and expected future LSs from 3GPP to WP5D
RAN#73 (Sep 2016): RAN send LS to ITU-R WP5D on initial system characteristics based on RAN1&RAN4 input
RAN#74 (Dec 2016): RAN send LS to ITU-R WP5D on final system characteristics based on RAN1&RAN4 input
Note: Dependent on the ITU-R WP5D deadline (which is not yet published in RP-160508), RAN may approve the output by correspondence after the Dec. 2016 meeting.
Decision: The document is noted.

R1-166087 LS on 5G NR study – mMTC use case RAN, MediaTek
The document was presented by … from MediaTek and informs RAN1 that within the scope of the NR Study, NB-IoT and eMTC should be used as the reference benchmark for assessing the performance of new proposals according to mMTC use case.
Decision: The document is noted.

Petitioners' Exhibit 1003, p. 905
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-167534 **Discussion on benchmark mMTC with NB-IoT/eMTC MediaTek Inc.**

- Proposal #1: The new techniques for mMTC should provide significant gain compared with NB-IoT/eMTC.
- Proposal #2: Building penetration loss is added in channel model in system level evaluation for mMTC.
- Proposal #3: Performance in coverage extension (i.e., 154dB, 164dB) should be evaluated and benchmarked with NB-IoT/eMTC. Data rate v.s. MCL curve can be used as a metric.
- Proposal #4: Spectral efficiency in both normal coverage and extended coverage level should both be evaluated and benchmarked with NB-IoT/eMTC. Sum throughput v.s. MCL can be used as a metric.
- Proposal # 5: PAPR and CM of NR for mMTC should not be higher than NB-IoT, especially in extended coverage.
- Proposal #6: The BOM cost of low-end mMTC device in NR needs to be benchmarked with NB-IoT/eMTC.
- Proposal #7: Single solution is strived for all the scenarios (e.g., normal coverage and extended coverage) and operation modes (e.g., standalone and inband deployed with eMBB/ URLLC).

Decision: The document is noted.

R1-166065 **LS on 5G millimeter wave channel simulator NYU WIRELESS**
The document was presented by RAN1 Chair en behalf of NYW and shares the results of the recent July 2016 IEEE T-MTT paper, and provides information about a new public resources useful for 5G air interface and system design work.
Decision: The document is noted.

6 UTRA

R1-168038 **Chairpersons' summary of the UMTS sessions UMTS Session Chairpersons (Huawei, Ericsson)**
The document was presented by Carmela Cozzo from Huawei and Gerardo Medina from Ericsson.
Decision: The document is endorsed and incorporated as follows.

Incoming Liaison Statements related to AI 6.3.
R1-166067 **LS on RAN2 aspects on MC enhancements RAN2, Huawei**
Decision: The document (RAN2 agreed TP) is noted.
R1-166076 **LS on Multi-carrier enhancements RAN3, Huawei**
Decision: The document (RAN3 agreed TP) is noted.
Both TPs have already been included in TR25.707.

6.1 Maintenance of UTRA Releases 4 – 13

6.1.1 FDD

R1-166495 **Clarifications on UL Discontinuous Transmission with DCH enhancements Qualcomm Europe Inc.(France)**
Decision: CR0749 to 25.214 (Rel-12, F) is agreed.
R1-166496 **Clarifications on UL Discontinuous Transmission with DCH enhancements (Rel. 13) Qualcomm Europe Inc.(France)**
Decision: CR0750 to 25.214 (Rel-12, A) is agreed.

R1-167681 **Discussion on power scaling for R13 DC HSUPA with CS Huawei, HiSilicon**
R1-167711 **25.214 CR (Rel-13, F) Correction of Dual Carrier HSUPA enhancements for UTRAN CS Huawei, HiSilicon**
Decision: The document is revised and CR0753r1 to 25.214 (Rel-13, F) is agreed in R1-168031

R1-167709 **25.214 CR (Rel-13, F) Correction of DCH enhancements Huawei, HiSilicon**
Discussion: CR category should be A
Decision: The document is noted, revised and CR0751r1 to 25.214 (Rel-13, A) is agreed in R1-168032
R1-167710 **25.214 CR (Rel-12, A) Correction of DCH enhancements Huawei, HiSilicon**
Discussion: CR category should be F
Decision: The document is noted, revised and CR0752r1 to 25.214 (Rel-12, F) is agreed in R1-168033

R1-167758 **On incorporating the definition of "UL DPCH 20ms Mode" in TS 25.212 Ericsson**
Decision: The documment is noted and CR is not pursued.
R1-167759 **On incorporating the definition of "UL DPCH 20ms Mode" in TS 25.212 Ericsson**
Decision: The documment is noted and CR is not pursued.
R1-167760 **Editorial clarification on the definitions of "UL DPCH 10ms Mode" and "UL DPCH 20ms Mode" of DCH enhancements for UMTS Ericsson**
Decision: CR0754 to 25.214 (Rel-12, D) is agreed.

Petitioners' Exhibit 1003, p. 906
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-167761 **Editorial clarification on the definitions of "UL DPCH 10ms Mode" and "UL DPCH 20ms Mode" of DCH enhancements for UMTS Ericsson**
Decision: CR0755 to 25.214 (Rel-13, A) is agreed.

R1-167762 **On incorporating the definition of "UL DPCH 20ms Mode" and adding the TS 25.321 in the list of references of TS 25.211 Ericsson**
Decision: The document is noted, revised and CR0323r1 to 25.211 (Rel-12, D) is agreed in R1-168035 (without the change: addition of the definition)

R1-167763 **On incorporating the definition of "UL DPCH 20ms Mode" and adding the TS 25.321 in the list of references of TS 25.211 Ericsson**
Decision: The document is noted, revised and CR0324r1 to 25.211 (Rel-13, F) is agreed in R1-168036 (without the change: addition of the definition)

6.1.2 TDD

None.

6.2 DTX/DRX enhancements in CELL_FACH - WID in RP-160185

6.2.1 DRX improvements

R1-167682 **Considerations on DRX in CELL_FACH Huawei, HiSilicon**

R1-167764 **On incorporating the DL scheduling notification based on regular HS-SCCH control information to the new power saving mechanism in CELL_FACH Ericsson**

R1-167765 **DL scheduling notification based on regular HS-SCCH control information as part of the new power saving mechanism in CELL_FACH Ericsson**

R1-167813 **Discussions on HS-SCCH DRX in CELL_FACH design Qualcomm Europe Inc.(France)**
R1-167814 **Introduction of HS-SCCH Order for HS-SCCH DRx feature in enhanced Cell Fach Qualcomm Europe Inc.(France)**
R1-167815 **UE Procedures for HS-SCCH DRx feature in enhanced Cell Fach Qualcomm Europe Inc.(France)**

Conclusions for 6.2.1:
RAN1 recommends a Rx Burst duration of 1 subframe or 2 subframes in the HS-DSCH receiving formula specified in TS 25.331 (LS to be sent to RAN2)
R1-168030 **LS on Updates on HS-SCCH DRx Feature in Cell Fach RAN1, Qualcomm**
Decision: The document is noted and LS is agreed.

HS-SCCH order is to be used to signal a UE wake-up trigger.
Email discussion until next plenary submission deadline (Sept 9th on Qualcomm CRs.

6.2.2 DTX improvements

R1-167683 **Considerations and evaluation of DTX in CELL_FACH Huawei, HiSilicon**
R1-167684 **DTX solution in CELL_FACH Huawei, HiSilicon**
R1-167766 **A complementary assessment on the potential gains associated to the introduction of DTX in CELL_FACH Ericsson**
R1-167767 **Technical findings on introducing DTX in CELL_FACH Ericsson**

Conclusions:
Based on R1-167766 findings, the average gains from DTX in cell FACH range from 0.02 to 0.10 (10 resources) and from 0.07 to 0.34dB for the case of 25 common E-DCH resources configured in the cell. The following table summarizes the gains from DTX in CELL_FACH

Summary of the potential gains that can be obtained by fully applying DTX on the stand alone UL DPCCH in CELL_FACH without severely impacting the cell's capacity

	Back-off timer configurations	10 Common E-DCH resources configured in the Cell		25 Common E-DCH resources configured in the Cell	

Petitioners' Exhibit 1003, p. 907
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Average Blocking Target 5%		Range of the Percentile Gain (90-99% Percentile)	Range of the Average Gain	Range of the Percentile Gain (90-99% Percentile)	Range of the Average Gain
	4TTIs – 24TTIs (8ms-48ms)	0.11508dB – 0.2333 dB	0.0206dB – 0.1028 dB	0.2333dB – 0.6085 dB	0.0745dB – 0.3419dB

6.3 Multi-Carrier enhancements for UMTS - WID in RP-161259.

R1-168089 **LS on Multi-Carrier enhancements**
W.r.t configuring Multi-Carrier enhancements in combination with legacy features, RAN2 would like to understand, in case that primary and secondary uplink frequency is configured with different TTIs, whether it is feasible to configure uplink DTX on either primary frequency or secondary frequency or both.
Decision: The document is noted.

6.3.1 2ms+10ms and 10ms+10ms configurations for (DB)-DC-HSUPA

R1-167685 **Overview of multicarrier enhancements** **Huawei, HiSilicon**
R1-167686 **Initial considerations on power scaling** **Huawei, HiSilicon**

Agreement: The legacy power scaling can be reused for DB-DC/DC 10ms+10ms TTI configurations.

R1-167687 **Initial considerations on TTI switching** **Huawei, HiSilicon**
R1-167768 **TTI Switching for Multicarrier Enhancements in UMTS** **Ericsson**

Agreement: It is RAN1 opinion that the TTI switching mechanism should be introduced in Multicarrier Enhancements for HSUPA.

R1-168037 **Ls to RAN2/3 on RAN1 progress on MC Enhancements, Huawei**
Decision: The document is noted and the LS is agreed.

6.4 Other

R1-167755 **PRACH optimization for latency reduction during uplink signalling traffic** **Nokia, Alcatel-Lucent Shanghai Bell**

7 E-UTRA

7.1 Maintenance of E-UTRA Releases 8 – 13

Only essential corrections.
Note that individual companies can submit draft CRs to this agenda item for Rel-13 items.

R1-166190 **Introduction of 1.2Gbps and 1.6Gbps UE categories in Rel-13** **Huawei, HiSilicon, SoftBank**
Proposal 1: Introduce DL UE categories 18 and 19 to support DL peak data rate of 1.2Gbps and 1.6Gbps respectively
Proposal 2: Reuse UL cat 3, 5, 7 and 13 for DL cat 18 and 19 as corresponding UL categories
The specification impacts on TS36.212 can be found in a companion contribution [R1-167401].
Decision: The document is noted.
R1-167401 **Introduction of 1.2Gbps and 1.6Gbps UE categories in Rel-13** **Huawei, HiSilicon, NTT DOCOMO, SoftBank**
The document was presented by Xia Yuan from Huawei.
Assuming 1.2Gbps and 1.6Gbps UE categories in Rel-13 also support 8*8 MIMO deployment, the CR defines the soft buffer assumption for 8-layer encoding for 1.2Gbps and 1.6Gbps UE categories in Rel-13.
Discussion: . CR not needed if 8*8 MIMO is not supported in the two new UE categories.
If 8*8 MIMO is supported, CR is needed and RAN1 should let RAN knows about it
Decision: The document is noted and revised as a draft CR in
R1-168311 **Introduction of 1.2Gbps and 1.6Gbps UE categories in Rel-13** **Huawei, HiSilicon, NTT DOCOMO, SoftBank**
Decision: The document is noted and the draft CR is technically endorsed by RAN1.

R1-168312 **[Draft] LS on introducing 1.2Gbps and 1.6Gbps UE categories in Rel-13** **Huawei**
Decision: The document is noted and final LS is agreed in R1-168377

Petitioners' Exhibit 1003, p. 908
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-167398 Correction on storing soft channel bits for different UE categories in Rel-11 Huawei, HiSilicon, NTT DOCOMO, SoftBank
Decision: The document is noted, revised and CR0704r1 (Rel-11, F) is agreed in R1-168313. Also supported by Intel.
R1-167399 Correction on storing soft channel bits for different UE categories in Rel-12 Huawei, HiSilicon, NTT DOCOMO, SoftBank
Decision: The document is revised and CR0705r1 (Rel-12, A) is agreed in R1-168314. Also supported by Intel.
R1-167400 Correction on storing soft channel bits for different UE categories in Rel-13 Huawei, HiSilicon, NTT DOCOMO, SoftBank
Decision: The document is revised and CR0706r1 (Rel-13, A) is agreed in R1-168315. Also supported by Intel.

R1-167902 Introductions of new UE categories Qualcomm Incorporated
R1-168356 Way Forward on introduction of new UL categories Qualcomm
- Choose Alternative 2
  - Send an LS to RAN2 recommending developing the necessary CRs and sending them to RAN #73
- Note: This doesn't mean approving any of these categories – that would be decided at the Plenary

Decision: The document is noted.
R1-168357 [Draft] LS on introduction of new UL categories Qualcomm
R1-168431 Way Forward on introduction of new UL categories Qualcomm
- Choose Alternative 1
- Send two separate LSs to RAN2 recommending developing the necessary CRs and sending them to RAN#73
  - Introducing UL Category 19-20 with *TEI13*

UE UL Category	Maximum number of UL-SCH transport block bits transmitted within a TTI	Maximum number of bits of an UL-SCH transport block transmitted within a TTI	Support for 64QAM in UL	Support for 256QAM in UL
UL Category 19 – Rel-13	226128	75376	Yes	No
UL Category 20 – Rel-13	301504	75376	Yes	No

  - Introducing UL Category 21-22 with *LTE_UL_CAP_enh-Core*

UE UL Category	Maximum number of UL-SCH transport block bits transmitted within a TTI	Maximum number of bits of an UL-SCH transport block transmitted within a TTI	Support for 64QAM in UL	Support for 256QAM in UL
UL Category 21 – Rel-14	316584	105528	Yes	Yes
UL Category 22 – Rel-14	422112	105528	Yes	Yes

- Note: This doesn't mean approving any of these categories – that would be decided at the Plenary

Decision: The document is noted and the WF is agreed. Qualcomm requested to take a note that their preference remains Alt. 2.

R1-168432 [Draft] LS on introduction of new UL categories in Rel-13 Qualcomm
Decision: The document is noted and final LS is agreed in R1-168459.
R1-168433 [Draft] LS on introduction of new UL categories in Rel-14 Qualcomm
Decision: The document is noted and final LS is agreed in R1-168460.

7.1.1 Maintenance of E-UTRA Release 8 – 12

R1-166194 Discussion on the understanding of maximum code rate Huawei, HiSilicon
The document was presented by Xia Yuan from Huawei.
For Rel-12 DL UE categories and onwards, they shall NOT skip decoding a transport block in an initial transmission if the effective channel code rate is lower than or equal to 0.931, no matter whether they have 256QAM capability or not.
Decision: The document is noted.

R1-166229 Clarification on HARQ feedback under TDD-FDD CA in Rel-12 Qualcomm Incorporated
The document was presented by Wanshi Chen from Qualcomm and deals with one particular issue in TDD/FDD CA, where an FDD CC is configured as Pcell and with one of the DL MIMO transmission modes, while one or two TDD CCs are configured as Scell. In a subframe when a Pcell PUCCH or a PUSCH is transmitted and when the corresponding subframe in the TDD Scell(s) is an UL subframe, the following intended behavior is recommended to be confirmed by RAN1:
- If only one single codeword is detected on the FDD Pcell,
  - If PUCCH is transmitted, PUCCH format 1a is used;
  - If PUSCH is transmitted, 2-bit HARQ is assumed.

Discussion: Intel→ format 1b should be feedback
Decision: The document is noted. Continue offline discussion until Friday (Qualcomm)
Friday
R1-168501 Offline summary on Clarification on HARQ feedback under TDD-FDD CA in Rel-12 (R1-166229) Qualcomm
- The conclusion for the issue discussed in R1-166229 is aligned with RAN1 understanding, with the clarification that "PUCCH format 1a is *effectively* used" for the case of PUCCH format 1b with channel selection, due to the codepoints (ACK, ACK) or (NAK, NAK) for PUCCH format 1b when only one TB is detected for the MIMO Pcell

Petitioners' Exhibit 1003, p. 909
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- No CR is necessary

R1-167432 **draft CR on the correction from SC-FDFMA to SC-FDMAPanasonic Corporation**
The document was presented by Alex Golitschek from Panasonic.
Decision: The document is noted and agreed as CR0279 to 36.211 in R1-167933.

7.1.2 Maintenance of Release 13 LTE carrier aggregation enhancement beyond 5 carriers

R1-166600 **Draft 36.213 CR Clarification on HARQ-ACK transmission CATT**
The document was presented by Fang Chen Cheng from CATT.
Decision: The document is noted and agreed as CR0719 to 36.213 in R1-167936.

7.1.3 Maintenance of Release 13 licensed-assisted access to unlicensed spectrum

R1-166138 **Correction on "special subframe" for frame structure type 3 in 36.213 for Rel-13 LAA Huawei, HiSilicon**
The document was presented by Xia Yuan from Huawei.
Decision: The document is noted and agreed as CR0718 to 36.213 in R1-167934.

R1-166813 **Correction on CSI reference resource definition in LAA LG Electronics**
The document was presented by Joon Kui Ahn from LGE.
Decision: The document is noted. Continue offline discussion until Friday.
Friday: Not pursued.

R1-167180 **Correction for energy detection threshold for multi-carrier LBT operation in 36.213 for Rel-13 LAA Huawei, HiSilicon**
Decision: The document is not pursued.

R1-167181 **Correction for PHICH resource reservation on the LAA cell in 36.211 for Rel-13 LAA Huawei, HiSilicon**
The document was presented by Xia Yuan from Huawei.
Decision: The document is noted and agreed as CR0280 to 36.211 in R1-167935.

R1-167402 **Correction on the determination of EPDCCH starting position ITRI**
The document was presented by Chien-min Lee from ITRI.
Decision: The document is noted. Continue offline discussion until Friday.
Friday: CR0264 to 36.211 is agreed.

R1-167785 **Draft CR on LAA post transmission backoff BROADCOM LIMITED**
The document was presented by Sindhu Verma from Broadcom.
Decision: The document is noted. Continue offline discussion until Friday.
Friday:
R1-168546 **CR on LAA post transmission backoff BROADCOM LIMITED**
Decision: The document is noted. Typo in CR number. CR is revised and agreed as CR0741r1 in R1-168555.
MCC: post meeting to correct wrong revision number.

7.1.4 Maintenance of Release 13 elevation beamforming/full-dimension MIMO for LTE

R1-166230 **Draft CR on FD-MIMO codebooks Qualcomm Incorporated**
Decision: The document is noted. Continue offline discussion until Friday – Chao (Qualcomm)
Friday: revised in R1-167937 and agreed as CR0740 to 36.213 in R1-168544.
MCC: post meeting to add the missing WI code LTE_EBF_FDMIMO_Core and correct wrong revision number.

R1-166337 **Correction on FD-MIMO Codebooks in 36.213 Nokia, Alcatel-Lucent Shanghai Bell, Samsung**
The document was presented by Min Zhang from Nokia.
Decision: The document is noted and CR0693 to 36.213 is agreed.
MCC: post meeting to add the missing WI code LTE_EBF_FDMIMO_Core.
R1-166502 Correction on class B codebook Intel Corporation
Decision: The document is not pursued.

R1-166338 **Correction on RRC Parameters for SRS Enhancement in 36.213 Nokia, Alcatel-Lucent Shanghai Bell**
The document was presented by Min Zhang from Nokia.
Decision: The document is noted and CR0694 to 36.213 is agreed.
MCC: post meeting to add the missing WI code LTE_EBF_FDMIMO_Core.

Petitioners' Exhibit 1003, p. 910
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166501 **Quasi co-location assumptions for DM-RS antenna ports in MU-MIMO** **Intel Corporation**
The document was presented by Alexei Davidov from Intel.
Discussion: .
Decision: The document is noted. Continue offline discussion until Friday.
Friday
R1-168365 Quasi co-location assumptions for DM-RS antenna ports in MU-MIMOIntel Corporation
Decision: The document is not pursued.

R1-166503 **Correction on bitwidth of class A codebook** **Intel Corporation**
Decision: The document is noted and CR0213 to 36.212 is agreed in R1-167938.
MCC: Post meeting CR revision shall be corrected (rev 1 to be replaced by rev -) and WI code is LTE_EBF_FDMIMO-Core.

R1-167168 **Corrections on CRI bit width in 36.212** **Huawei, HiSilicon**
Decision: The document is noted and CR0214 to 36.212 is agreed in R1-167939.
MCC: Post meeting CR revision shall be corrected (rev 1 to be replaced by rev -).

R1-167678 Corrections on Codebooks in 36.213 Huawei, HiSilicon
Decision: The document is noted and CR0710 to 36.213 is agreed.
MCC: Post meeting CR WI code shall be corrected to LTE_EBF_FDMIMO-Core.

R1-167404 Correction on the citation of table indexs for mapping of ICRI to MCRI ITRI
Decision: The document is noted and CR0708 to 36.213 is agreed.

7.1.5 Maintenance of Release 13 further LTE physical layer enhancements for MTC

R1-168400 **Chairman's notes of AI 7.1.5 on Maintenance of Release 13 further LTE physical layer enhancements for MTC** **Ad-Hoc chair (Qualcomm)**
The document was presented by Wanshi Chen from Qualcomm.
Decision: The document is endorsed and content is incorporated as follows.

UL compensation gaps
R1-166655 **Considerations on UL compensation gaps Sony**

Valid subframes
R1-166237 **On valid MBSFN subframes and SIB2 decoding for eMTC Qualcomm Incorporated**
R1-166238 **Draft LS for valid MBSFN subframes for eMTC** **Qualcomm Incorporated**
Conclusion: Continue offline discussion coming up a suggested text for changing 36.331 (Qualcomm), as part of the LS.
Friday:
R1-167959 **Draft LS to RAN2 regarding valid MBSFN subframes for eMTC** **Qualcomm**
Decision: The document is noted. The LS in R1-167959 is endorsed with "MBSFN subframes are given by (2)" changed to "MBSFN subframes are given by (1)". LS is revised and final version is agreed in R1-168425.

R1-167945 **Draft CR for MBSFN subframes and SIB2 decoding** **Qualcomm Incorporated**
Decision: The document is noted. The CR is R1-167945 is endorsed, and final CR is agreed as CR0721r2 to 36.213 (Rel-13, F) in R1-168437.

R1-167433 **Clarification of valid subframe in eMTC** **Panasonic Corporation**
Decision: The document is noted. The CR in R1-167433 is endorsed with the update non-BL/CE, and final CR is agreed as CR0283 to 36.211 (Rel-13, F) in R1-168234.

R1-167434 **Clarification of valid subframe in eMTC** **Panasonic Corporation**
Decision: The document is noted. The CR in R1-167434 is endorsed with potential parameter name update (for offline discussion), and final CR to be prepared in R1-168235
Note: this CR is also to be included part of the offline discussion for the LS to RAN2 to be drafted by Alberto (Qualcomm)
Friday:
R1-168235 **Clarification of valid subframe in eMTC** **Panasonic Corporation**
Decision: The document is not presented (different content). Email discussion/approval based on R1-167434 until Sept 1st (Panasonic)

R1-167854 MBSFN subframes are invalid DL BL/CE subframes for BL/CE UE Ericsson
Not pursued.

DCI

Petitioners' Exhibit 1003, p. 911
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166236 **CR for SRS bit in DCI Qualcomm Incorporated**
R1-166622 **Presence of SRS bit in DCI 6-0A and 6-1ASequans Communications**
R1-166624 eMTC corrections for RAN1 specifications Sequans Communications (Section 6)
Decision: The CR in R1-166236 is endorsed, and agreed as CR0738 to 36.213 (Rel-13, F) in R1-168535.

R1-167155 **On the mapping of TPC command field to power correction values in TS 36.213 Huawei, HiSilicon**
Decision: The CR in R1-167155 is endorsed with the following update "0/3/4/6-0A", and agreed as CR0723 to 36.213 (Rel-13, F) in R1-168156.

R1-167737 **Draft CR for clarification of DCI sizes for format 6-1A (TM6 and TM9) in TS 36.212 Virtuosys Limited**
Decision: Discuss further offline
Friday:
R1-168161 **Draft CR for clarification of DCI sizes for format 6-1A (TM6 and TM9) in TS 36.212 Virtuosys Limited**
Decision: The CR in R1-168161 is agreed in principle, and final CR is agreed in R1-168452.
Post meeting: MCC noticed that wrong CR number was provided and revised R1-168452 in R1-168212 (CR0216r1 to 36.212)

MPDCCH
R1-167941 **Draft CR for clarification on MPDCCH monitoring on SFN rollover and search space overlap Qualcomm Incorporated**
Decision: Continue offline discussion, including R1-167862
R1-167862 **Overlapping MPDCCH search spaces for BL/CE UE Ericsson**
Friday:
R1-168509 **Clarification on MPDCCH monitoring on SFN rollover and search space overlap Qualcomm Incorporated**
Decision: CR0736 to 36.213 (Rel-13, F) is agreed.

R1-166621 MPDCCH search-space with Temporary C-RNTI Sequans Communications
Decision: CR0259 to 36.211 (Rel-13, F) is agreed.
R1-166624 eMTC corrections for RAN1 specifications Sequans Communications (Section 3)

R1-167154 **Correction on MPDCCH in the special subframe for CEModeB in TS 36.211 Huawei, HiSilicon**
Decision: The CR in R1-167154 is endorsed in principle (further check offline about 36.213 text). Final CR is agreed as CR0281 to 36.211 in R1-168155.

R1-167184 **Correction on the reference of narrowband definition in TS 36.213 Huawei, HiSilicon**
Decision: CR0698 to 36.213 (Rel-13, F) is agreed.

R1-167187 **Correction on the MPDCCH scheduling Paging in special subframe in TS 36.213 Huawei, HiSilicon**
Decision: The CR in R1-167187 is endorsed with the following update (final CR to be prepared in R1-168158)
- For TDD, in special subframes, ~~and~~for MPDCCH in Type-1 -common search space

R1-167403 Correction on the determination of DL narrowbands for MPDCCH candidates ITRI
R1-167679 Correction on Type0-common search space monitoring in TS 36.213 Huawei, HiSilicon
R1-167680 Correction on indentation in TS 36.211 Huawei, HiSilicon
Continue discussion offline.
Friday
R1-168158 **Correction on the MPDCCH scheduling Paging in special subframe in TS 36.213 Huawei, HiSilicon**
Decision: CR0724 to 36.213 (Rel-13, F) is agreed.

PDSCH
R1-166234 **CR for PDSCH scrambling for SIQualcomm Incorporated**
R1-167186 **Correction on the scrambling initialization for SIB1-BR/SI for eMTC in TS 36.213 Huawei, HiSilicon**
Decision: The CR in R1-167186 is endorsed in principle (further discuss offline about the wording), and final CR is agreed as CR0700 to 36.213 (Rel-13, F) in R1-168157.

R1-166235 **Draft CR for P-RNTI PDSCH hopping Qualcomm Incorporated**
R1-167849 **Frequency hopping for PDSCH for SI and paging messages for BL/CE UE Ericsson**
Decision: The CR in R1-167849 is agreed, along with the CR in R1-166235. Revised CR (using R1-167849) to be revisited in R1-167953
Decision: CR0272 to 36.211 (Rel-13, F) is agreed in R1-167953.

R1-166428 Remaining issues on eMTC CATT (Proposal 1)

Petitioners' Exhibit 1003, p. 912
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-167185 Correction on the relationship between IMCS and ITBS for DCI format 6-1A in TS 36.213 Huawei, HiSilicon
Decision: CR0699 to 36.213 (Rel-13, F) is agreed.

R1-167714 RV version for PDSCH carrying paging Nokia, Alcatel-Lucent Shanghai Bell
Decision: Continue offline discussion
Friday:
R1-168359 RV version for PDSCH carrying paging Nokia, Alcatel-Lucent Shanghai Bell
Decision: The CR in R1-168359 is endorsed. Provide a revision with the change tracking on the cover sheet removed in R1-168399 agreed as CR0729r1 to 36.213 (Rel-13, F).

R1-167856 PDSCH start subframe in TDD for BL/CE UE Ericsson
Decision: The CR in R1-167856 is endorsed by adding a space in between "DL" and "subframe". Final CR is agreed as CR0714r1 to 36.213 (Rel-13, F) in R1-168462.

DL reference signals
R1-167153 Correction on scrambling sequence initialization for reference signals associated with PDSCH and MPDCCH in TS 36.211 Huawei, HiSilicon
R1-167852 Scrambling of DL DMRS for BL/CE UE Ericsson
Decision: CR0275 to 36.211 (Rel-13, F) is agreed.
R1-167861 Enable cross-subframe channel estimation for BL/CE UE Ericsson
Decision: CR0276 to 36.211 (Rel-13, F) is agreed.

CSI
R1-166240 Draft CR for subband CQI report without hopping Qualcomm Incorporated
Decision: Continue offline discussion
Friday: No progress – continue discussion at next meeting.

R1-166241 Draft CR for subband CQI report and TM6 Qualcomm Incorporated
Decision: The CR in R1-166241 is endorsed, and final CR is agreed as CR0215 to 36.212 (Rel-13, F) in 1-168287.
R1-167857 Repetition with aperiodic CSI for BL/CE UE Ericsson
Decision: Continue offline discussion especially regarding whether or not UCI is transmitted in the same set of subframes for PUSCH transmission. Finally CR0715 to 36.213 (Rel-13, F) is agreed.
MCC: Post meeting CR number 0714 shall be replaced by 0715.

PUSCH
R1-166683 Draft CR on RV Cycling for PUSCH Samsung
Decision: Further discussion offline, including PDSCH aspects
The CR in R1-168161 is endorsed with the superscript PUSCH corrected to PDSCH, and final CR is agreed as CR0732 to 36.213 (Rel-13, F) in R1-168450 (NOTE: MCC will take care of removing "DRAFT" on the cover page)

R1-167311 Draft CR for PUSCH rate matching and SRS dropping Qualcomm Incorporated
Decision: Further discussion offline
Conclusion:
- The principle in R1-167311 is aligned with RAN1 understanding. No CR is necessary.

PUCCH
R1-166242 Draft CR for PUCCH transmission and invalid subframes Qualcomm Incorporated
Decision: Further discussion offline. Finally CR is agreed as CR0737 to 36.213 (Rel-13, F) in R1-168521.
R1-166243 Draft CR for aperiodic CSI with repetitions Qualcomm Incorporated
R1-166244 Draft CR for PUCCH resource allocation Qualcomm Incorporated
Decision: The CR in R1-166244 is endorsed, and final CR is agreed as CR0728 to 36.213 (Rel-13, F) in R1-168519.
R1-167858 PUCCH resource start offset in RRC_CONNECTED for BL/CE UE Ericsson
R1-166428 Remaining issues on eMTC CATT (Proposal 2)
R1-167677 Correction on the PUCCH transmission in TS 36.211 Huawei, HiSilicon
R1-167864 Default UL frequency hopping interval for PUCCH for BL/CE UE Ericsson
Decision: Further discussion offline

UL frequency retuning
R1-166498 On timeline issues with shortened PUCCH format Qualcomm Incorporated
R1-166630 Simulation results for PUCCH frequency retuning NEC
R1-166684 PUCCH Structure for Frequency Retuning Samsung
R1-167848 PUCCH frequency retuning for BL/CE UE Ericsson
Further discussion offline

Petitioners' Exhibit 1003, p. 913
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Further in the week:
R1-168461 WF on PUCCH retuning for BL/CE UE Ericsson
R1-168465 Operation Alternatives for PUCCH Retuning Samsung
R1-168514 WF on PUCCH retuning for BL/CE UE Ericsson, Samsung, NEC, Qualcomm, Virtuosys, Sony, Sierra Wireless, NTT DoCoMo, AT&T, Intel
Also supported by Verizon

Agreements:
- PUCCH retuning gap for BL/CE UEs is created through puncturing
- RAN1 would discuss the possibility to have 1-bit signalling for PUCCH puncturing vs. PUCCH rate matching for PUCCH retuning in Rel-14

The corresponding CR to be drafted for email approval until 9/2 – (Ericsson)

Random access
R1-166232 Draft CR for clarification on PRACH system frame number Qualcomm Incorporated
Decision: Further discussion offline. Finally CR is agreed as CR0285 to 36.211 (Rel-13, F) in R1-168508.
R1-166233 Draft CR for overriding of valid-invalid mask for msg3 Qualcomm Incorporated
R1-166623 Transport block size determination for Msg2 Sequans Communications
Decision: CR0695 to 36.213 (Rel-13, F) is agreed.
R1-167855 Msg2 TBS determination for BL/CE UE Ericsson
R1-166624 eMTC corrections for RAN1 specifications Sequans Communications (Sections 5 and 7)
R1-167157 Correction on the determining PRACH starting subframe in TS 36.211 Huawei, HiSilicon
Decision: Further discussion offline
R1-167718 Overriding of invalid subframe for msg3 PUSCH when R=1 Nokia, Alcatel-Lucent Shanghai Bell
Decision: CR in R1-167718 is endorsed with the following update (final CR to be prepared in R1-168424).
- When ~~value of is~~ the number of Msg3 PUSCH repetitions

Decision: CR0722r1 to 36.213 (Rel-13, F) is agreed in R1-168424.

R1-167853 Default max number of PUSCH repetitions for Msg3 for BL/CE UE Ericsson
Decision: Further discussion offline. Finally CR0711 to 36.213 (Rel-13, F) is agreed.

R1-167940 Correction for UL grant size in RAR Sequans Communications
Late submission
Decision: Further discussion offline.
The CR in R1-167940 is agreed in principle but should be based on 36.213 V13.2.0. Revised and agreed R1-168513 (CR0720r1 to 36.213).

R1-167909 Frequency hopping interval for MPDCCH during random access for BL/CE UE Ericsson
Late submission
Decision: Further discussion offline. Finally CR0278 to 36.211 (Rel-13, F) is agreed.

Collisions
R1-166619 MPDCCH collision with PSS/SSS Sequans Communications
Conclusion:
- The principle in R1-166619 is aligned with RAN1 understanding. No CR is necessary

R1-166620 MPDCCH mapping over reserved CRS tones in PBCH subframes Sequans Communications
Decision: Further discussion offline.
Conclusion:
- The principle in R1-166620 is aligned with RAN1 understanding. No CR is necessary.

R1-166624 eMTC corrections for RAN1 specifications Sequans Communications (Sections 2 and 4)
R1-166659 Simultaneous transmission & reception in HD-FDD Sony
Conclusion:
- Proposal 1 in R1-166659 is aligned with RAN1 understanding. No CR is necessary.

R1-167156 Clarification on collision between SR and PDSCH with repetitions in TS 36.213 Huawei, HiSilicon
Decision: Further discussion offline.

7.1.6 Maintenance of Release 13 NB-IoT

R1-168401 Chairman's notes of AI 7.1.6 on Maintenance of Release 13 NB-IoT Ad-Hoc chair (Qualcomm)
The document was presented by Wanshi Chen from Qualcomm.

Petitioners' Exhibit 1003, p. 914
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Decision: The document is endorsed and content is incorporated as follows.

DL Common Channels
R1-166247 Draft CR for N_SF value for SI Qualcomm Incorporated
R1-166197 Corrections on NPDSCH related procedure in TS 36.213 Huawei, HiSilicon
Decision: The CR in R1-166197 is endorsed in principle. Refined text for the last change. Revised and agreed as CR0692r1 to 36.213 (Rel-13, F) in R1-167990.
R1-166642 Missing definition of higher layer parameter eutra-CRS-SequenceInfo NEC
R1-167783 Corrections on Narrowband reference signal (NRS) in TS 36.211 Ericsson
Decision: Agree in principle to capture eutra-CRS-SequenceInfo related information in 36.213. Further discussion offline on the details. To be revisited in final CR in R1-168319 (NEC)
Friday:
R1-168319 Missing definition of higher layer parameter eutra-CRS-SequenceInfo NEC
Decision: Final CR is agreed as CR0730 to 36.213 (Rel-13, F) in R1-168374.

R1-167178 Corrections on the presence of NRS for standalone and guard band operation mode in TS 36.211 Huawei, HiSilicon
Also supported by Qualcomm, Intel
R1-167437 Clarification of NRS assumption Panasonic Corporation
Also supported by ZTE, Ericsson, DCM, Nokia, ASB, Samsung, LGE
Decision: Continue discussion offline
R1-168444 Corrections on the presence of NRS for standalone and guard band operation mode in TS 36.211 Huawei, HiSilicon
Decision: CR0263 to 36.211 (Rel-13, F) is agreed.
R1-168238 Clarification of valid NB-IoT DL subframe configuration Samsung , Panasonic
R1-168516 Clarification of NB-IoT DL subframe configuration Huawei, HiSilicon
Decision: The CR in R1-168516 is endorsed, revised in:
R1-168539 Clarification of NB-IoT DL subframe configuration Huawei, HiSilicon
Decision: CR0739 to 36.213 (Rel-13, F) is agreed.

R1-167166 Correction on NPBCH in TS 36.211 Huawei, HiSilicon
Decision: CR0260 to 36.211 (Rel-13, F) is agreed.
R1-167183 Correction on BCH rate matching in TS 36.212 Huawei, HiSilicon
Decision: CR0211 to 36.212 (Rel-13, F) is agreed.
R1-167174 Correction on NPSS mapping in TS 36.211 Huawei, HiSilicon, Rohde & Schwarz
Decision: Continue discussion offline
Friday:
R1-168293 Correction on NPSS mapping in TS 36.211 Huawei, HiSilicon, Rohde & Schwarz
Decision: CR0262r1 to 36.211 (Rel-13, F) is agreed.

LS received during RAN1#86
R1-168340 LS on applicability of NRSRQ measurement RAN4, Huawei
R1-168296 Correction on NRSRQ applicability Huawei, HiSilicon
Decision: CR0037 to 36.214 (Rel-13, F) is agreed.

Antenna Ports
R1-167435 Correction of NB-IoT antenna port mapping Panasonic, Huawei, HiSilicon, NEC, MediaTek
Decision: The CR in R1-167435 is endorsed in principle. Further re-wording offline. Final CR is agreed as CR0284 to 36.211 (Rel-13, F) in R1-168236.
R1-167436 Quasi-colocation of NB-IoT antenna portsPanasonic, Huawei, HiSilicon
Decision: The CR in R1-167436 is endorsed with change from section 16.6 to 16.7. Further re-wording offline. Final CR is agreed as CR0726 to 36.213 (Rel-13, F) in R1-168237

Further discussion offline whether antenna port in 36.214 needs to be clarified or not (Panasonic)
Friday:
R1-168199 Correction on NRS port number mappingHuawei, HiSilicon, Panasonic, Samsung
Decision: CR0036 to 36.214 (Rel-13, F) is agreed.

NPDCCH
R1-166184 Correction on NPDCCH related procedure on TS 36.213 Huawei, HiSilicon
Decision: CR0690 to 36.213 (Rel-13, F) is agreed.
- Note: the gap includes the one under the sentence "If NPUSCH UL Gap is inserted at the end of NPUSCH transmission"

Petitioners' Exhibit 1003, p. 915
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166499 **Draft CR on parameters for NPDCCH order** **Qualcomm Incorporated**
Decision: Further discussion offline, including the change from N0 to N1, whether or not N-PDCCH order is used or not, whether or not a mapping table is used, and "repetition level" to "repetition #", whether or not the necessity of last sentence
Decision: No CR is necessary.

R1-167312 Draft CR about Correction on PDCCH order related description ZTE
R1-167176 **On NPDCCH scrambling** **Huawei, HiSilicon**
R1-167179 Corrections on NPDCCH scrambling in TS 36.211 Huawei, HiSilicon
Withdrawn

R1-167419 **Corrections on NPDCCH scrambling in TS 36.211 Huawei, HiSilicon, Intel, Neul, Qualcomm**
Also supported by MTK
Decision: CR0265 to 36.211 (Rel-13, F) is agreed.
R1-167188 **Corrections on NPDCCH search space for random access in connected mode in TS 36.213 Huawei, HiSilicon**
Decision: CR0701 to 36.213 (Rel-13, F) is agreed.

NPDSCH
R1-167313 Draft CR on clarification of scheduling delay ZTE
Decision: The CR of the first change of 16.3.3 in R1-167313 is endorsed. Final CR is agreed as CR0734 to 36.213 (Rel-13, F) in R1-168496.
R1-167782 Corrections on DL Gap on NPDSCH TS 36.211 Ericsson
Decision: Further discussion offline
R1-167438 Clarification of valid NB-IoT DL subframe configuration Panasonic Corporation
Decision: Further discussion offline

PUSCH
R1-166180 **Correction on DMRS for NB-IoT in TS 36.211** **Huawei, HiSilicon**
R1-167314 **Draft CR on clarification of DM RS** **ZTE**
Decision: Further discussion offline on R1-166180 and R1-167314.
CR0253 to 36.211 (Rel-13, F) is agreed in R1-166180.

R1-166182 **Correction on SC-FDMA signal generation for NB-IoT in TS 36.211** **Huawei, HiSilicon**
Decision: CR0255 to 36.211 (Rel-13, F) is agreed.
R1-166641 Correction to SC-FDMA baseband signal generation for NB-IoT NEC
R1-166245 **Draft CR for PUSCH timing delay for NB-IoT** **Qualcomm Incorporated**
Decision: Further discussion offline.
The CR in R1-166245 is endorsed. Final CR is agreed as CR0731 to 36.213 (Rel-13, F) in R1-168375.

R1-167172 **Correction on NPUSCH related procedure on TS 36.213** **Huawei, HiSilicon**
Decision: CR0696 to 36.213 (Rel-13, F) is agreed.
R1-167316 **Remaining issue on collision of NPUSCH and NPRACH** **ZTE**
R1-167173 **Correction on UL collisions in TS 36.211** **Huawei, HiSilicon**
Decision: The CR in R1-167173 is endorsed in principle. Offline discussion on refined wording (including whether possible LS to RAN2 and RAN4). Revised and agreed as CR0261r1 to 36.211 (Rel-13, F) in R1-167991.

NPRACH
R1-166181 **Correction on NPRACH in TS 36.211** **Huawei, HiSilicon**
Decision: Revised and agreed as CR0254r1 to 36.211 (Rel-13, F) in R1-168364.
R1-166248 **Draft CR for NPRACH generation** **Qualcomm Incorporated**
R1-167315 **Draft CR on clarification of random access signal generation** **ZTE**
R1-167838 **Corrections on NPRACH generation TS 36.211** **Ericsson**
Decision: Offline discussion for the above 4 CRs. To have a single final CR to be revisited in R1-168364.

R1-166183 **Correction on random access procedure for NB-IoT on TS 36.213** **Huawei, HiSilicon**
Decision: The CR in R1-166183 regarding section 16.3.2 is endorsed. Final CR is agreed as CR0689r1 to 36.213 (Rel-13, F) in R1-167989.

R1-168172 **Introduction of a reserved range of NPRACH sub-carriers for contention based access, Ericsson, ZTE, Qualcomm**
Decision: The CR in R1-168172 is endorsed in principle, conditional on RAN2 approval of 36331CR2334. Remove the comment, and showing change tracking for deletion and insertion of equation. Final CR is agreed as CR0282r1 to 36.211 (Rel-13, F) in R1-168495.

Petitioners' Exhibit 1003, p. 916
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Other UL
R1-166246 Capability for NB-IoT uplink gaps Qualcomm Incorporated
Decision: Further discussion offline
R1-167317 Remaining power control issue on multiple NB-IoT carriers operation ZTE
Decision: Further discussion offline

R1-168284 WF on signaling of nrs-Power of non-anchor carrier ZTE, Qualcomm,Panasonic
Agreement:
- nrs-Power offset of non-anchor PRB relative to nrs-Power of anchor PRB should be included in RRC signaling.
- Send LS to RAN2 – R1-168474
  - {-12, -10, -8, -6, -4,-2, ~~-1~~, 0, 3}

R1-168474 LS on nrs-Power signaling for NB-IoT non-anchor carrier ZTE
Decision: The document is noted and final LS is agreed in R1-168497 including the above update.

RRC Parameters
R1-166195 Corrections to RRC parameter names for NB-IoT in TS 36.211 Huawei, HiSilicon
Decision: CR0256 to 36.211 (Rel-13, F) is agreed.
R1-166196 Corrections to RRC parameter names for NB-IoT in TS 36.213 Huawei, HiSilicon
Decision: CR0691 to 36.213 (Rel-13, F) is agreed.

R1-167911 Phase difference between NRS and CRS Qualcomm Incorporated
Late submission
Decision: Further discussion offline
R1-168358 Phase difference between NRS and CRS Qualcomm Incorporated
Decision: The draft CR in R1-168358 is endorsed in principle, adding a note about overlap with LTE baseband signal generation sections. Final CR is agreed as CR0735 to 36.213 (Rel-13, F) in R1-168507.
Note: this CR is not intended to change legacy LTE signal generation.
Post meeting: MCC noticed that wrong CR number was provided and revised R1-168507 in R1-168219 (CR0287r1 to 36.211).

7.2 LTE Release 14

7.2.1 Enhanced Licensed-Assisted Access to Unlicensed Spectrum WID in RP-160881.

R1-168402 Chairman's notes of AI 7.2.1 on Enhanced Licensed-Assisted Access to Unlicensed Spectrum Ad-Hoc chair (Nokia, Ericsson)
The document was presented by Matthew Baker from Nokia.
Decision: The document is endorsed and incorporated as follows.

Draft CRs
R1-166224 Introduction of eLAA into 36.212 HuaWei Technologies Co., Ltd
R1-167898 Introduction of eLAA (PHY layer aspects) in 36.213 Motorola Mobility
R1-167899 Introduction of eLAA (UL Channel Access Procedure) in 36.213 Motorola Mobility

Friday
Rapporteur will provide a list of agreements and WA until August 29th.
Editors shall provide updated draft CRs until Sept 6th , for email approval by Sept 12th.

7.2.1.1 PUSCH design

Remaining details including PUSCH structure, resource allocation and scheduling aspects

Agreement: For enabling the start times within the first DFTS-OFDM symbol, a longer cyclic prefix for the next DFTS-OFDM symbol to occupy part of the first DFTS-OFDM symbol is used

Agreement:
- RA field in DCI 0A/4A/0B/4B is 6 bits
- The 64 code points indicated by the 6 bits include the legacy RIV for contiguous interlace allocation except the code points for the allocation of 7 contiguous interlaces (70 PRBs)
  - This set of code points has 51 values
- Additional code points are defined for allocation of interlaces as follows:
  - 0,1,5,6
  - 2,3,4,7,8,9
  - 0, 5

Petitioners' Exhibit 1003, p. 917
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- 1, 6
- 2, 7
- 3, 8
- 4, 9
- 1, 2, 3, 4, 6, 7, 8, 9
- Remaining code points are reserved

Agreement: One of four starting symbol positions can be signaled for the first subframe in DCI formats 0A/4A/0B/4B

Agreement: LBT type is not explicitly signaled to the UE for SRS without PUSCH.

Agreement:
- MCS 0-28 indicated to the UE in DCI formats 0A/4A/0B/4B are interpreted according to the uplink MCS table for modulation and TBS
- RV is explicitly signaled for all MCSs.

Agreement:
- TB disabling is indicated if MCS 29 is indicated for the corresponding TB in DCI formats 4A/4B.
  - The disabling applies for all scheduled subframes for DCI format 4B

Agreement:
- An aperiodic CSI report without UL-SCH is triggered when the UE receives DCI formats 0A/0B with MCS 29 and an aperiodic CSI trigger
- An aperiodic CSI report without UL-SCH is triggered when the UE receives DCI formats 4A/4B with MCS 29 for both TBs and an aperiodic CSI trigger
- UE is not expected to receive an aperiodic CSI only request if more than one subframe is scheduled with DCI formats 0B/4B

Agreement:
- 4 bits for timing offset are included in DCI format 0A/4A
  - Note: This is already agreed for DCI format 0B/4B
- DCI format 0A/4A includes 4 bits indicating HARQ process ID
  - Note: This is already agreed for DCI format 0B/4B
- DCI format 0A includes 2 bits RV indicating RV=0, 1, 2, or 3
- DCI format 4A includes 2 bits RV indicating RV=0, 1, 2 or 3 which is common to both TBs

Agreement:
- For each DCI format 0B, 4A and 4B the following BD adjustment is applied
  - (0, 33, 66, 100)% for 1st and 2nd AL and (0, 50, 100, 150)% for 3rd to 5th AL

Agreement: If not otherwise indicated by the RRC parameter supportedBlindDecoding-r13, the eNB can assume the total number of supported blind decodes to be #CCs_supported*32+#CCs_UL_TM2_supported*16 USS BDs

- SRS triggering offset in format 0B/4B (Klaus)

R1-168028 WF on SRS triggering with DCI Format 4B Nokia, ASB

Agreement:
- For SRS triggered with DCI format 4B, the SRS subframe location is determined relative/as an offset n to the first subframe of the multi-subframe scheduling burst according to

  $n = mod\ (x, N)$

  where x is the value of the SRS subframe indication in the SRS parameter set configuration ($x \in \{0,1,2,3\}$) and N is the number of scheduled UL subframes.

Discussion on: TPC code point for max power (Qualcomm)
Proposal:
- One of the code points for TPC in DCI Format 0A/0B/4A/4B indicates the UE to transmit at the highest allowed power on that serving cell
  - In the accumulated mode, the TPC command indicates {-1,0,1,[full power or large step]}
  - In the absolute mode, the TPC command indicates
    - Option 1: {-4,0,4,[full power or large step]}
    - Option 2: {-4,-1,1,4} (no change from current proposal)

Petitioners' Exhibit 1003, p. 918
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Agreement:

- Precoder indicator field in DCI format 4B applies to all the subframes in the DCI
  - Mapping to number of layers and TPMI is the same as DCI format 4
- A single DMRS and OCC field is signaled for all subframes indicated in DCI formats 0B/4B
  - The parameter n^(2)_DMRS,Lambda applies to all indicated subframes

Agreement: The UE is not expected to start a new transmission subject to LBT earlier than 1 DFTS-OFDM symbol after the end of the previous transmission by the UE

Friday

Agreements:

- C-PDCCH indicates a pair of values (UL burst duration, offset)
  - UL burst duration is the number of consecutive UL subframes belonging to the same channel occupancy, with the DL subframes in the same channel occupancy signaling the UL burst duration.
  - Offset is the number of subframes to the start of indicated UL burst from the start of the subframe carrying the C-PDCCH.
  - The LBT procedure for any UL subframe from the subframe in which C-PDCCH was received upto and including all subframes until the end of the signaled UL burst duration, for which the eNB had already indicated to perform Category 4 LBT, can be switched to an LBT based on 25 us CCA.
    - The UE shall not switch to 25 us CCA if only part of a set of contiguously scheduled subframes without gap appears in the UL burst indication
  - The UE is not required to receive any DL signals/channels in a subframe indicated to be a UL subframe on the carrier
  - 5 bits to indicate combinations of offset and burst duration.
    - The code points include {offset, duration} combinations as follows
      - All combinations of {{1, 2, 3, 4, 6}, {1, 2, 3, 4, 5, 6}}
      - Reserved
      - No signaling of burst and offset

Agreements:

- DCI 0A/4A/0B/4B includes a single bit to indicate whether the UL grant is a triggered grant or not.
- If it is a triggered grant, the UE may transmit after receiving a 1 bit trigger in the PDCCH DCI scrambled with CC-RNTI in a subframe received after the subframe carrying the UL grant
- The timing between the 2nd trigger transmitted in subframe N and the earliest UL transmission is a UE capability, if the earliest UL transmission is before subframe N+4 (UE capability signaling between transmission in subframe N+1 and N+2 and N+3)
- The 4 bit field ‘SF timing’ in DCI format 0A/4A/0B/4B for the triggered grant is reused as follows:
  - When the UE may transmit after reception of the trigger is signaled to the UE 2 bits are reused to indicate X:
    - Having received a trigger in subframe N, the UE is allowed to start transmission in subframe N+X+Y
      - X={0,1,2,3} indicated reusing two bits in the DCI
      - Y is given by the UL burst offset in the C-PDCCH DCI scrambled by CC-RNTI in the same subframe where the trigger is transmitted
  - The UE receives signaling in the first DCI 0A/4A/0B/4B grant indicating the number of subframes after which the grant becomes invalid reusing 2bits. The initial grant becomes invalid if M ms after the initial grant, no valid trigger has been received.
    - 2 bit: M={8,12,16,20}
- UE follows the LBT type indicated by the UL grant

Agreements:

- When CSI report is triggered using DCI 0A/4A/0B/4B, the reference subframe is the last valid subframe with reference to the subframe in which the CSI report is transmitted
- Note: This may not need any specification change

Agreement: DCI formats 0A and 1A which are transmitted in the same serving cell and that schedule the same serving cell shall have the same sizes. Bit padding is used to achieve this.

R1-166123	PUSCH resource allocation	Huawei, HiSilicon
R1-166124	Enabling transmissions within the first SC-FDMA symbol in a subframe	Huawei, HiSilicon
R1-166137	Two-stage scheduling for eLAA	Huawei, HiSilicon
R1-166249	Remaining details of PUSCH waveform	Qualcomm Incorporated

Petitioners' Exhibit 1003, p. 919
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166250 TBS selection for PUSCH for multi-TTI grants Qualcomm Incorporated
R1-166251 PUSCH and eLAA procedures Qualcomm Incorporated
R1-166252 Control details for UL scheduling Qualcomm Incorporated
R1-166253 Remaining details of DCI and UL search space design Qualcomm Incorporated
R1-166504 PUSCH resource allocation method Intel Corporation
R1-166505 Indication of the starting PUSCH DFT-S-OFDM symbols Intel Corporation
R1-166506 Remaining issues with PUSCH structure Intel Corporation
R1-166631 Remaining issues on PUSCH resource allocation NEC
R1-166667 eLAA PUSCH transmission Fujitsu
R1-166685 Remaining issues on PUSCH design for eLAA Samsung
R1-166686 PUSCH Scheduling and Resource Allocation Samsung
R1-166814 Remaining issues on PUSCH transmission in LAA LG Electronics
R1-166815 Remaining issues on DCI formats for UL scheduling in LAA LG Electronics
R1-166987 Remaining details of PUSCH design for eLAA ZTE
R1-167024 PUSCH resource allocation details Nokia, Alcatel-Lucent Shanghai Bell
R1-167026 Remaining Issues on LAA SCell PUSCH Transmit Power Nokia, Alcatel-Lucent Shanghai Bell
R1-167073 On remaining scheduling aspects for eLAA Nokia, Alcatel-Lucent Shanghai Bell
R1-167074 On Two-Stage UL scheduling for eLAA Nokia, Alcatel-Lucent Shanghai Bell
R1-167075 On eLAA UE blind decoding capabilities Nokia, Alcatel-Lucent Shanghai Bell
R1-167133 Special handling of MCS/TBS for normal PUSCH and the PUSCH containing UCI/SRS/blanking symbol(s) Huawei, HiSilicon
R1-167182 Remaining issues on scheduling design for eLAA Huawei, HiSilicon
R1-167190 Discussion on synchronous and asynchronous HARQ method for eLAA Huawei, HiSilicon
R1-167343 Remaining details on PUSCH resource allocation and scheduling design for eLAA NTT DOCOMO, INC.
R1-167344 Discussion on power headroom report and buffer status report enhancement for eLAA NTT DOCOMO, INC.
R1-167420 MCS, TBS and TPMI Determination in Single and Multi-Subframe Grants Panasonic
R1-167421 Codeword Disabling for eLAA Uplink MIMO Panasonic
R1-167605 Remaining details on DCI design for multiple-subframe scheduling for LAA UL SHARP Corporation, MTI
R1-167606 Remaining details on PUSCH structure for LAA UL SHARP Corporation
R1-167719 On PUSCH Structure for Transmission within First DFTS-OFDM Symbol Ericsson
R1-167720 On Resource Allocation Aspects for eLAA Ericsson
R1-167721 On Remaining details of Scheduling Aspects for eLAA Ericsson
R1-167734 Indication of starting symbol for multi-subframe scheduling ETRI
R1-167776 Resource Allocation with Minimal Predefined Patterns for eLAA PUSCH KT Corp.
R1-168093 WF on eLAA PUSCH retransmission with synchronous HARQ Huawei, HiSilicon
R1-168182 WF on simultaneous transmission of periodic and aperiodic CSI in eLAA Qualcomm

7.2.1.2 SRS design

Remaining details including whether SRS is transmitted for small gaps between SRS and following PUSCH

Agreement (Update of previous agreements: (RAN1#85 Email discussion [85-05-04]))

- If the triggering for SRS without PUSCH is received in a DL assignment in subframe n, the UE should send SRS without PUSCH in subframe n+k (not considering the LBT failure).
  - The SRS transmission is not limited to DL ending partial subframe
- k is indicated by 3 bits in DL grant. "000" represents no triggering for SRS without PUSCH; "001"~"111" represents SRS without PUSCH is transmitted in subframe n+4~n+10 respectively.

R1-166136 Remaining issues on LBT for SRS for eLAA Huawei, HiSilicon
R1-166254 SRS procedures for eLAA Qualcomm Incorporated
R1-166663 LBT parameters for SRS in eLAA Sony
R1-166687 Remaining issues of SRS transmission followed by PUSCH Samsung
R1-166816 Consideration on SRS and following PUSCH LG Electronics
R1-166988 Remaining details of SRS design for eLAA ZTE
R1-167625 On the Subframe Indication in SRS Triggering in eLAA Nokia, Alcatel-Lucent Shanghai Bell
R1-167722 On the Minimum Gap between SRS and PUSCH Transmissions Ericsson

7.2.1.3 Channel access framework

Remaining details including LBT options for SRS not immediately followed by PUSCH, contention window size adjustment for UL Category 4 LBT, continuing transmission of continuously scheduled subframes, energy detection threshold, LBT related signaling aspects and revised and 2-stage grants.

R1-168078 WF on multi-carrier UL LBT operation Huawei, HiSilicon

Petitioners' Exhibit 1003, p. 920
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Agreement:

- A UE that has received UL grants on a set of carriers scheduled with Cat. 4 LBT with the same starting point in the subframe on all carriers can switch to a 25 us LBT immediately before transmission on a carrier in the set if Cat. 4 LBT has successfully completed on a designated carrier in the set.
  - The UE must select one carrier uniformly randomly among the carriers which were scheduled with Cat. 4 LBT as the designated carrier prior to starting the Cat. 4 LBT procedure on any of the carriers in the set.
- Note: if operating in the 5GHz band, refer to the ETSI regulations w.r.t. choosing the set of carriers.

Proposal:

- An eNB starting the DL transmission based on Type B multi-carrier LBT acquiring a given MCOT, can share its channel occupancy with its UEs on all the carriers completing Type B LBT.
  - The channel occupancy is started with a DL transmission after the carrier performing Cat.4 LBT completes Cat.4 LBT

Friday

Agreement:

- An eNB starting the DL transmission based on Type B multi-carrier LBT acquiring a given MCOT, can share its channel occupancy with its UEs on each of the carriers completing 25us LBT in the DL, if the UL transmission follows the previous subframes (DL transmission or UL transmission from other UEs on the same carrier) with a gap of not more than 25us and a successful 25us UL LBT is performed by the UE within the gap

---

Agreements:

- When the UE is scheduled two sets of UL subframes with Cat. 4 LBT, with two different UL grants and the Cat. 4 LBT does not complete for transmission of any of the subframes in the first set of UL subframes, then the Category 4 LBT for the second set of UL subframes is performed as follows
  - If the LBT priority class of the second set of UL subframes is the same as the first set of UL subframes, the UE may continue the Cat. 4 LBT for the first set of subframes for transmission of the second set of UL subframes
  - If the LBT priority class of the second set of UL subframes is different from the first set of UL subframes
    - If the LBT priority class of the second set of UL subframes(e.g. Class 1) is higher than the priority class of the first set of UL subframes (e.g., Class 3), the UE may terminate the previous Cat. 4 LBT and start a new Cat. 4 LBT
    - If the LBT priority class of the second set of UL subframes (e.g., Class 3) is lower than the priority class of the first set of UL subframes (e.g., Class 1), the UE shall terminate the previous Cat. 4 LBT and start a new Cat. 4 LBT
  - Note: If the UE continues Cat. 4 LBT, it shall use all the Cat. 4 LBT parameters that were used for the first set of subframes

R1-168165 WF on UE PSD restriction in eLAA LG Electronics, Nokia, ASB

R1-168181 WF on supporting triggering based UL grants in eLAA Qualcomm, Nokia, ASB, Intel, ZTE, Fujitsu, Huawei, HiSilicon

Agreement:

- For LBT for SRS not transmitted contiguously with PUSCH, a Cat. 4 LBT with priority class 1 is used.
- SRS transmissions do not contribute to the contention window update.

Agreement (Update of previous agreement)

- ~~FFS:~~ For a set of consecutive scheduled subframes without any gaps that are subject to LBT, after the first successful LBT in that set, the UE continues transmission for all the remaining subframes in the set.
  - FFS: Early termination of the channel occupancy

Agreement: For category 4 LBT for PUSCH transmission on LAA SCell, the CWS is adjusted per UE and at UE based on the following procedures at UE and eNB:

- If the UE fails to transmit all of the scheduled contiguous subframes with a category 4 LBT, UE may keep the contention window size unchanged for all the LBT priority classes.
- The first subframe with UL-SCH that was transmitted at least 4 ms prior to the UL grant reception in the most recent transmitted burst of contiguous subframes that is transmitted after performing a category 4 LBT procedure is defined as the reference subframe. The HARQ ID of the reference subframe is HARQ_ID_ref.
- Based on the UL grant content

Petitioners' Exhibit 1003, p. 921
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

  - if the NDI bit for at least one of the active HARQ processes (i.e. TB not disabled) of HARQ_ID_ref in the reference subframe is toggled, the contention window size at the UE is reset for all the priority classes.
  - Otherwise (i.e. HARQ_ID_ref not scheduled or NDI of the active HARQ process(es) of HARQ_ID_ref not toggled) the contention window size of all priority classes at the UE is increased to the next higher value.
- The CWS is reset to the minimum value if the maximum CWS is used for K consecutive LBT attempts for transmission only for the priority class for which maximum CWS is used for K consecutive LBT attempts.
  - K is selected by UE implementation from the set of values from (1, …,8).

Agreement:
- The maximum energy detection threshold requirement for a UE is aligned with the requirement for an eNB as specified in Rel-13
- The eNB can signal a RRC parameter to the UE so that the UE can derive a maximum energy detection threshold value.
  - If no RRC signalling is received, the UE uses a default maximum energy detection threshold value, X_Thresh_Max, as defined in Rel-13, using Pc_max_H,c for P_TX in the calculation of X_Thresh_Max

Agreement:
- RRC signaling has the ability to indicate to a UE either an absolute maximum energy detection threshold value or an offset to the default maximum energy detection threshold value
- Absolute maximum energy detection threshold values are indicated in the range of -85 dBm to -52 dBm in steps of 1 dB.
- Offset to the default maximum energy detection threshold value are indicated in the range of -13 dB to +20 dB in steps of 1 dB.
- Note: Ability to signal a certain maximum energy detection threshold does not indicate feasibility of operating at that threshold value.

R1-168345 Draft LS on further RRC Parameters for Enhanced LAA for LTE Huawei
Decision: The document is noted and final LS is agreed in R1-168346

Agreement: The UE is not required to consider LBT success or failure on the set of carriers on which transmission is attempted in order to apply power scaling rules for that set of carriers

Agreement: If the UE starts a contiguous transmission spanning a set of subframes on an LAA SCell, and the UE suspends transmission prior to the last scheduled subframe in the transmission, then the UE may resume transmission on the remaining subframes in the transmission immediately after performing an LBT of duration 25 microseconds if the channel was observed to be continuously idle since the transmission was suspended. If the channel was not observed to be continuously idle, then the UE may resume transmission after performing a successful Cat. 4 LBT with LBT parameters according to the indicated LBT priority class in the UL grant that scheduled the subframe in the transmission.

Agreement: The UE may expect an LBT priority class field in a UL grant regardless of the LBT type indicated to the UE in the UL grant. If 25 us LBT is indicated as the LBT type, then the LBT priority class is the one used by the eNB to obtain access to the channel. If Cat. 4 LBT is indicated as the LBT type, then the LBT priority is the one that is to be used by the UE to perform its Cat. 4 LBT.

Agreement: If the eNB schedules UL transport blocks with 25 us LBT in a shared channel occupancy without scheduling any DL transport blocks and if less than 10% of the scheduled UL transport blocks have been received successfully, the eNB increases its contention window size, otherwise the eNB resets its contention window.

R1-166134 Signaling for UL LBT parameters for eLAA Huawei, HiSilicon
R1-166135 Contention window size adjustment for UL category 4 LBT for eLAA Huawei, HiSilicon
R1-166255 Remaining details of UL LBT Qualcomm Incorporated
R1-166507 Remaining details of the UL channel access mechanism Intel Corporation
R1-166508 Necessary modifications to existing Logical Channel Prioritization mechansim Intel Corporation
R1-166688 Remaining issues on CWS adjustment for Cat 4 LBT Samsung
R1-166689 Remaining issues of LBT for SRS Samsung
R1-166690 Remaining issues of LBT signalling Samsung
R1-166691 Discussion on two-step UL grant scheduling Samsung
R1-166817 CWS adjustment for LAA LG Electronics
R1-166818 LBT parameter signalling in LAA LG Electronics
R1-166819 Remaining details on UL LBT for LAA LG Electronics
R1-166989 Remaining details of LBT Design for eLAA ZTE
R1-167132 Discussion on UL multi-carrier LBT for eLAA Huawei, HiSilicon
R1-167196 Channel acess scheme for UE multiplexing Kyocera Corporation
R1-167345 Remaining details on channel access framework for eLAA NTT DOCOMO, INC.

Petitioners' Exhibit 1003, p. 922
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-167509 Remaining issues of LBT mechanism for LAA uplink Lenovo (Beijing) Ltd
R1-167607 Remaining details on channel access framework for LAA UL SHARP Corporation
R1-167626 Remaining Issues on Channel Access for LAA UL Nokia, Alcatel-Lucent Shanghai Bell
R1-167627 Multi-Carrier Channel Access for LAA UL Nokia, Alcatel-Lucent Shanghai Bell
R1-167692 Common PDCCH design Intel Corporation
R1-167723 On Contention Window Adjustment for Category 4 UL LBT Ericsson
R1-167724 Additional Evaluations for eLAA Ericsson
R1-167725 Energy Detection Threshold for eLAA Ericsson
R1-167726 On Reported RSSI from Wi-Fi Devices Ericsson
R1-167727 On Continuous Transmission for Consecutive Scheduled UL Subframes Ericsson
R1-167728 On LBT Related Signaling for eLAA Ericsson
R1-167729 On Remaining LBT details for Transmission of SRS without PUSCH Ericsson
R1-167731 Discussion on overlapping of LBT procedures HTC Corporation
R1-167735 CWS adjustment mechanism for CAT 4 UL LBT in eLAA ETRI
R1-167736 Remaining details of SRS LBT for eLAA ETRI
R1-167769 Considerations for the Cat 4 CW size adjustment Sequans Communications
R1-167780 Contention Window adaptation procedure for Uplink CAT 4 LBT in eLAA BROADCOM LIMITED
R1-167781 Details of Cat 4 LBT procedure for eLAA Uplink BROADCOM LIMITED
R1-167786 Discussion on Modifying UL LBT Type WILUS Inc.
R1-167787 Indication of Reference Subframe for CW adjustment WILUS Inc.
R1-167788 UL Multi-carrier Transmission for eLAA WILUS Inc.
R1-167793 Discussion on LBT for aperiodic SRS transmissions not multiplexed with PUSCH BROADCOM LIMITED
R1-167800 Handling of transmission errors in case of consecutively scheduled Uplink subframes in eLAA BROADCOM LIMITED
R1-168077 WF on UL transmission for consecutive subframes Huawei, HiSilicon
R1-168242 WF on CWS adjustment for category 4 UL LBT in eLAA LG Electronics
R1-168361 Way forward on the UL burst duration indication Intel

7.2.1.4 Other

R1-166820 UCI transmission for LAA LG Electronics

7.2.2 Support for V2V services based on LTE sidelink - *WID in RP-161272*

R1-168403 Chairman's notes of AI 72.2 on Support for V2V services based on LTE sidelink Ad-Hoc chair (Nokia, LGE)
The document was presented by Matthew Baker from Nokia.
Decision: The document is endorsed and incorporated as follows.

Friday
Rapporteur will provide a list of agreements and WA until August 29th.
Editors shall provide updated draft CRs until Sept 6th , for email approval by Sept 12th.

Draft CRs
R1-166223 Introduction of V2V into TS36.212 HuaWei Technologies Co., Ltd
R1-167900 Introduction of V2V into TS36.213 Motorola Mobility

R1-168458 36.201CR0016 Introduction of V2V into 36.201 Nokia
Modify section 4.2.1 as follows:
Sidelink transmissions are defined for ProSe Direct Discovery and ProSe Direct Communication between UEs. The sidelink transmissions use the same frame structure as uplink and downlink when the UEs are in network coverage; however, the sidelink transmissions are restricted to a sub-set of the uplink resources. V2X communication between UEs is supported via sidelink transmissions or via the eNB.
Revised and agreed in R1-168201.

R1-168100 Summary of Monday V2V offline discussions LG Electronics
R1-168247 Summary of Wednesday V2V offline discussions LG Electronics
R1-168451 Summary of Thursday V2V offline discussions LG Electronics

Agreements:
- Only normal CP is supported in Rel-14 V2V WI.
- For PSCCH DM RS, the proposal in R1-168439 with u = 8

The following LS was received during the week:

Petitioners' Exhibit 1003, p. 923
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-168126 **Response LS to Priority for V2V RAN WG2**
R1-168245 **Draft LS on RAN1 agreements in sidelink-based V2V LG Electronics [RAN WG1]**
Updated in R1-168249. Approved in R1-168251 with the following change:

- At least when SA and data are transmitted in the same subframe, SA resource should be reselected only when the associated data resource is reselected

R1-168246 **Draft LS on L1 parameters for sidelink-based V2V LG Electronics, [RAN WG1]**
Revised and approved in R1-168252 with the following change:

- Add the probability p used in Step 3 with the value range [0, 0.2, 0.4, 0.6, 0.8].
- Capture the following in the comments of "Minimum of PSSCH MCS" and "Maximum of PSSCH MCS":
  - Note that the current RAN1 specification does not support 64 QAM in sidelink.
- **Overall Description:**

RAN1 agreed on L1 parameters for LTE_SL_V2V-Core. RAN1 would like to inform RAN2 that the list of agreed L1 parameters is in the attached spreadsheet. Changes to the content of R1-165968 are marked in yellow. RAN1 would like to observe that congestion control and synchronization will be discussed and the outcome may have RRC impact.

7.2.2.1 Remaining details of physical layer structure

Including RS sequence of PSCCH/PSSCH/PSBCH

R1-168117 **WF on PSSCH DMRS LG Electronics, Huawei, HiSilicon, Nokia**
Agreement:

- Destination ID is not signaled via SA.
- 16 CRC bits from SA are used in generating PSSCH DMRS sequence and data scrambling sequence.

R1-168440 **WF on PSSCH sequence on V2V LG Electronics, KT, Intel**
Agreement:

Parameter		PSSCH
Group hopping		enabled
	$n_{\mathrm{ID}}^{\mathrm{RS}}$	n_{X}
	n_s	$2n_{ss}^{\mathrm{PSSCH}}+k,\ k=0,1$
	f_{ss}	$\lfloor n_{\mathrm{X}}/16 \rfloor \bmod 30$
Sequence hopping		disabled
Cyclic shift	$n_{\mathrm{CS},\lambda}$	$\lfloor n_{\mathrm{X}}/2 \rfloor \bmod 8$
Orthogonal sequence	$[w^{\lambda}(0)\ \ w^{\lambda}(1)\ \ w^{\lambda}(2)\ \ w^{\lambda}(3)]$	$[+1\ \ +1\ \ +1\ \ +1]$ if $n_{\mathrm{X}} \bmod 2=0$ $[+1\ \ -1\ \ +1\ \ -1]$ if $n_{\mathrm{X}} \bmod 2=1$
Reference signal length	$M_{\mathrm{sc}}^{\mathrm{RS}}$	$M_{\mathrm{sc}}^{\mathrm{PSSCH}}$
Number of layers	υ	1
Number of antenna ports	P	1

where $r_{\mathrm{PSSCH}}^{(\lambda)}\left(m\cdot M_{\mathrm{sc}}^{\mathrm{RS}}+n\right)=w^{(\lambda)}(m)r_{u,v}^{(\alpha_\lambda)}(n),\ m=0,1,2,3$

n_{X} is X bits in SA to be used in generating PSSCH DMRS sequence.

Formula for n_s for group hopping to be confirmed on Friday.
Friday: Formula for n_s for group hopping is confirmed.

R1-166164 Details of PSCCH DMRS design Huawei, HiSilicon
R1-166256 Link Level Enhancements for V2V Qualcomm Incorporated
R1-166509 Remaining details of PSCCH and PSSCH physical layer structure for V2V communication Intel Corporation
R1-166510 Remaining details of PSBCH physical layer structure for V2V communication Intel Corporation
R1-166575 Considerations on DMRS Sequence Selection Beijing Xinwei Telecom Techn.
R1-166713 Remaining details on DMRS Samsung

Petitioners' Exhibit 1003, p. 924
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166821	Remaining details on DMRS for PSCCH and PSSCH	LG Electronics
R1-166822	Remaining details on DMRS for PSBCH	LG Electronics
R1-166823	Remaining issues on physical layer structure for PC5-based V2V	LG Electronics
R1-166951	Outstanding Physical Layer Structure Details and Receiver Behavior for Sidelink V2V	Ericsson
R1-166959	DMRS design details for PSCCH, PSSCH and PSBCH	Ericsson
R1-166976	RS sequence of PSCCH/PSSCH	ZTE
R1-167151	Discussion of transmission parameters range of PSSCH	Huawei, HiSilicon
R1-167750	DM-RS sequence for PSCCH/PSSCH/PSBCH in V2V	Innovative Technology Lab Co.
R1-168381	WF on PSBCH demodulation for V2V communication	Intel Corporation
R1-168439	WF on PSCCH sequence on V2V	LG Electronics
R1-168472	WF on V2V Cyclic Prefix	Qualcomm, CATT

7.2.2.2 Remaining details of UE autonomous resource selection mode

R1-168475	WF on Resource definition	Ericsson

7.2.2.2.1 Details of transmission resource (re)selection based on SA decoding and power/energy measurement

Including down-selection of the options for sensing and transmission resource selection, considering the working assumption "Priority information in a decoded SCI is used in resource (re)selection"

Agreements:

- Step 2: UE excludes resources at least based on SA decoding and additional conditions.
- When SA and its associated data are transmitted in same subframe, option 2-1 (measure on DMRS of PSSCH) is supported
  - Option 2-1: A resource is excluded if it is indicated or reserved by a decoded SA and PSSCH RSRP in the associated data resource is above a threshold.
    - PSSCH Reference Signal Received Power (PSSCH-RSRP) is defined as the linear average over the power contributions (in [W]) of the resource elements that carry demodulation reference signals associated with PSSCH, within PRBs indicated by the associated PSCCH.
    - The reference point for the PSSCH-RSRP shall be the antenna connector of the UE.
    - If receiver diversity is in use by the UE, the reported value shall not be lower than the corresponding PSSCH-RSRP of any of the individual diversity branches.
- The threshold is a (pre)configurable function of the priority information.
  - SA contains the 3-bit PPPP field.
  - The threshold is in a range between [-128 dBm] and [0 dBm] with the granularity of [2] dB including minus infinity and plus infinity.
    - Email discussion until Sept. 2nd on the numbers in the brackets – (Huawei)
  - The threshold is dependent of both the priority information of the TB to be transmitted and the priority information of the decoded SA.
    - 64 thresholds are (pre)configured in total.
- In Step 2, a UE that decodes an SA in TTI m + c within the sensing period assumes that the same frequency resource is reserved by the SA transmitter UE at TTI m + d +P*i.
  - P is a parameter fixed to 100 in Rel-14. Possible configurability of this parameter in future releases should be considered in the CR.
  - i is selected in the range [0, 1, …, 10] which will be restricted by carrier-specific network configuration or preconfiguration. i=0 means "no intention to reserve the frequency resource."
    - RAN1 assumes the full flexibility in signaling this restriction, e.g., 10-bit bitmap is signaled in this (pre)configuration to indicate each of [1, …, 10] is allowed or not.
    - Selection of i is up to UE implementation. RAN1 assumes that UE performs no transmission or no resource reservation if it has no data. FFS in RAN2 how to ensure this RAN1 assumption.
  - i is signalled in the SA using a 4-bit field.
- In Step 2, if an instance of a candidate semi-persistent resource X with the period of P*I collides with a next instance of the resource Y, which is reserved by another UE's SA and meets the condition of exclusion in the agreed threshold-test, then the UE shall exclude resource X.
  - I is the value to be signaled for i in its SA.
- If the number of remaining resource after Step 2 is smaller than [20]% of the total resources within the selection window, the UE repeats Step 2 using all the thresholds increased by [3] dB until the number of remaining resource after Step 2 is larger than [20]% of the total resources.
  - Each resource in this counting corresponds to the desired resource allocation.
  - Other mechanisms related to the congestion control will be discussed in the V2X WI if time is not allowed in the V2V WI.
  - Companies are encouraged to check what the proper number above is. The number can be revisited during the CR phase.
- In Step 3,

Petitioners' Exhibit 1003, p. 925
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- The measurement periodicity of PSSCH resource is P in this step.
  - The measurement is restricted to the resources remaining after Step 2.

Consideration of the following are moved to the V2X work item:

- Case of SA and its associated data being transmitted in different subframes

Agreement: "The total resources within the selection window" above means the total resources in the interval determined in Step 1 to identify the resources the UE must take into account as possible candidates resources.

Agreement:

- In Step 3,
  - Step 3-0: When the counter reaches zero,
    - With probability p, the UE keeps the current resource and the counter is reset.
    - With probability 1-p, resource is reselected by Step 3-1 and 3-2.
    - Carrier-specific parameter p is (pre)configured in the range [0, 0.2, 0.4, 0.6, 0.8].
  - Step 3-1: UE measures and ranks the remaining PSSCH resources based on total received energy and selects a subset
    - The subset is the set of candidate resources with the lowest total received energy. The size of the subset is [20]% of the total resources within the selection window.
      - Note that the size of this subset is equal to the minimum possible size of the outcome of Step 2.
  - Step 3-2: UE randomly selects one resource from the subset
- When a TB is transmitted in one subframe, when a UE tries to select M sub-channels in one subframe in Step 3, a resource can be any M contiguous sub-channels not excluded in Step 2.
- Energy measurement of each resource is the average of the energy measured in each constituent sub-channel.

Email discussion until September 2nd on the definition of the energy measurement in each sub-channel - (LGE).
[20%] value to be checked until RAN1#86bis.

Agreement:

- When a TB is transmitted in two subframes, at least the following resource selection is supported:
  - One resource is selected using the mechanism defined for the case where a TB is transmitted in one subframe.
  - Selection of another resource is random under the condition that
    - The selected resource shall be in the remaining subset of the outcome of step 3, and
    - The selected resource shall not be in the same subframe as the first resource, and
    - The SCI shall be able to indicate the time gap between the two selected resources.
  - If no resource can meet the condition for the second resource selection, a TB is transmitted only using the first resource.

Any other resource selection methods can be considered in the V2X work item, taking into account progress in ETSI, e.g. the following:
The resource allocation follows the resource allocation when a TB is transmitted in a single subframe, but the resource is defined as a set of subchannels in two consecutive subframes.

SA resource selection
R1-166826 **Resource selection details for UE autonomous resource selection mode in PC5-based V2V LG Electronics**
Decision: The document (Section 2.2) is noted.
R1-167834 **V2V SA Resource selection PANASONIC R&D Center Germany**
R1-167923 **WF on SA and data association Huawei, HiSilicon, LGE, Ericsson, Qualcomm**
Also supported by Panasonic.

Agreement: A UE cannot transmit TB without SA, i.e., SA is transmitted with each (re)transmission of a TB.

Agreement: At least when a pool is (pre)configured such that a UE always transmits SA and data in the same subframe, UE is not expected to combine PSCCH transmitted in different subframes.

Agreement:

- When a pool is (pre)configured such that a UE always transmits SA and data in adjacent RBs in the same subframe,
  - The sub-channel with the lowest index among those selected for data transmission is used for SA transmission.
- When a pool is (pre)configured such that a UE can transmit SA and data in non-adjacent RBs in the same subframe,
  - The number of SA candidate resources in a SA pool is the same as the number of sub-channels in the associated data pool.
    - Sequential one-to-one association is made between an SA candidate resource and a sub-channel in the

Petitioners' Exhibit 1003, p. 926
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

associated data pool.
    - The SA resource associated with the lowest index among those selected for data transmission is used for SA transmission.
- PSCCH DM RS CS is blindly detected.
    - Transmitter UE randomly selects one CS out of 4 candidates (details FFS) for every PSCCH transmission.
    - At each SA resource candidate, a UE is not required to decode more than one PSCCH.
        - It is RAN1 understanding that a UE will select the CS with the highest reception power. The related UE requirement is up to RAN4 decision.
- At least when SA and data are transmitted in the same subframe, SA resource should be reselected only when the associated data resource is reselected.

R1-168264 WF on resource selection for SA CATT

R1-166169 Details of sensing procedure and resource (re)selection triggering mechanisms Huawei, HiSilicon
R1-166204 Discussion on the remaining issues for priority handling Huawei, HiSilicon
R1-166257 Details of sensing using autonomous resource selection for V2V Qualcomm Incorporated
R1-166429 Discussion on UE autonomous resource selection mechanism in V2V CATT
R1-166511 Sidelink measurements for V2V sensing and resource re-selection procedures Intel Corporation
R1-166512 Transmitter behavior for sidelink resource re-selection Intel Corporation
R1-166714 Details on sensing based resource (re)selection Samsung
R1-166825 Sensing details for UE autonomous resource selection mode in PC5-based V2V LG Electronics
R1-166977 SA and data resource (re)selection ZTE
R1-167008 Resource reselection triggers Ericsson
R1-167009 Resource reselection Ericsson
R1-167013 Subchannelization and measurements for sensing for V2V over PC5 Ericsson
R1-167076 Discussion on triggering resource reselection based on collision detection Sony
R1-167355 Further details of UE autonomous resource (re)selection for V2V NTT DOCOMO, Inc.
R1-167409 Explicit/implicit resource (re)selection based on SA decoding/energy measurement ITRI
R1-167586 Resource selection using SA decoding and energy measurements INTERDIGITAL COMMUNICATIONS
R1-167587 Priority handling for V2V over PC5INTERDIGITAL COMMUNICATIONS
R1-167693 Design options to support priority for V2V communication Intel Corporation
R1-167694 Discussion on resource selection aspects to support V2V communication with different transmission periodicity Intel Corporation
R1-167835 Discussion on resource selection and indication in V2V based on sensing PANASONIC R&D Center Germany
R1-168380 WF on V2V priority specific thresholds Intel Corporation
R1-168383 WF on step #3 of V2V resource reselection procedureIntel Corporation
R1-168384 WF on UE-specific transmission windows for V2V communication Intel Corporation
R1-168454 WF on resource selection for multiple transmissions CATT, Qualcomm Incorporated, LG Electronics

7.2.2.2.2 Details of timing of PSCCH/PSSCH transmission and the indication of the intention to reuse the frequency resource for another TB

Including the discussion points identified in [85-09]

Agreement:
- UE makes resource selection/reselection decision at TTI m (>=n).
    - TTI m when the UE makes resource selection/reselection decision is the arrival time of the corresponding TB.
- For resource reselection, the UE must take into account as possible candidates resources in the interval [m+T1,m+T2] in Step 1.
    - T1 <= [4] where T1 is up to UE implementation.
    - 20 <= T2 <=100 where T2 is up to UE implementation.
        - Selection of T2 shall fulfill the latency requirement.
- Sensing window is changed to [m-a, m-b), where a=b+1000 and b=1.
- Note: If there is any inconsistency between the above proposal and the existing agreement, the above proposal overrides.
- If a problem is found, e.g., in designing the time resource indication in SCI, this agreement may be revisited.

R1-166258 Details of semi-persistent transmission for V2V Qualcomm Incorporated
R1-166435 Discussion on details of resource reselection and reservation CATT
R1-166513 On timing relationship between sensing window, packet arrival, resource reselection trigger, PSCCH and PSSCH transmissions Intel Corporation

Petitioners' Exhibit 1003, p. 927
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166643 Contents of Schedule Assignment for SPS NEC
R1-166715 Timeline of PSCCH/PSSCH transmission and resource reservation Samsung
R1-166827 Remaining details of the indication of resource reservation LG Electronics
R1-166978 Considerations for UE SPS resource selection and indication ZTE
R1-167077 Discussion on the remaining issues of transmission UE behaviour Sony
R1-167356 Further details of sensing based semi-persistent resource selection for V2V NTT DOCOMO, Inc.
R1-167588 Forward reservation of resources on PSCCH INTERDIGITAL COMMUNICATIONS
R1-167751 Details on PSCCH/PSSCH transmission timing in UE autonomous resource selection mode Innovative Technology Lab Co.
R1-167926 Details of sensing timeline design Huawei, HiSilicon
R1-168139 WF on the timeline of sensing and PHY channel transmissions LGE
R1-168145 WF on reservation indication LGE
R1-168382 WF on timing relationship for V2V sensing and resource selection Intel Corporation

7.2.2.2.3 Details of the measurement metric to reflect the congestion level

R1-168348 WF on CBR measurement Ericsson
Decision: For email discussion until September 2nd (Ericsson)

R1-168080 WF on V2V congestion control Ericsson
Decision: For email discussion until September 2nd (Ericsson)

R1-166166 Congestion control for V2V Huawei, HiSilicon
R1-166259 Measurement metric for congestion control Qualcomm Incorporated
R1-166431 Measurement metric for the congestion level in V2X CATT
R1-166514 Metric and sidelink measurements for V2V congestion control Intel Corporation
R1-166616 UE measurement based congestion control Guangdong OPPO Mobile Telecom.
R1-166716 Discussion on congestion control Samsung
R1-166828 Details of congestion level measurement LG Electronics
R1-166953 Radio measurements for congestion control for V2X Ericsson
R1-166955 Congestion Control Framework for V2V Ericsson
R1-166969 Discussion on channel busy ratio measurement in V2V Panasonic
R1-166979 Discussion on congestion control of PC5 carrier ZTE
R1-167410 Considering measurement metric and report for zone based resource management in V2V service ITRI
R1-167422 Adaptation of MCS, RB allocation, and number of retransmissions Ericsson
R1-167621 Discussion on details of UE measurement for resource reselection Potevio
R1-167745 Congestion management for V2V in 5.9GHz ITS VODAFONE Group Plc
R1-167802 On congestion control for V2V communication Nokia, Alcatel-Lucent Shanghai Bell
R1-168079 WF on CBR Measurement Ericsson
R1-168349 Harmonized WF on Pools Configuration Ericsson, Huawei, HiSilicon
R1-168506 Harmonized WF on Pools Configuration Ericsson

7.2.2.2.4 Other

R1-166644 On the needs of collision detection and resolution in V2X NEC

7.2.2.3 Remaining details of resource pool design

Including how to configure SA and data resources and how a data pool is associated with an SA pool

R1-168101 WF on resource pool configuration LG Electronics

Agreement:

- Case 1: When a pool is (pre)configured such that a UE always transmits SA and data in adjacent RBs in the same subframe,
  - The resource pool consists of one or multiple sub-channels in frequency domain.
    - A sub-channel consists of a group of contiguous RBs in a same subframe.
    - The sub-channel size in a resource pool can be configured by eNB or preconfigured.
      - Candidate size of a sub-channel is {5, 6, 10, 15, 20, 25, 50, 75, 100}
    - Each sub-channel includes one SA resource candidate at the low end of the sub-channel from system perspective.
    - The SA resource candidate can be used for data transmissions.
    - Resource pool configuration includes the number of sub-channels in the pool.
    - Different sub-channels have disjoint group of adjacent RBs.

Petitioners' Exhibit 1003, p. 928
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Case 2: When a pool is (pre)configured such that a UE transmits SA and data potentially in non-adjacent RBs in the same subframe,
  - The PSSCH resource pool consists of one or multiple sub-channels in frequency domain.
    - A sub-channel consists of a group of contiguous RBs in a same subframe.
    - The sub-channel size in a resource pool can be configured by eNB or preconfigured.
    - Candidate size is for email discussion until September 2nd (LGE).
      - Note that only the RB sizes supported for UE transmission in Rel-13 will be supported in Rel-14 V2V.
      - The maximum number of sub-channels possible in a subframe is 20.
      - The minimum candidate size is not less than 4.
    - PSSCH resource pool configuration includes the number of sub-channels in the pool.
    - Different sub-channels have disjoint group of adjacent RBs.
    - A resource pool consists of N contiguous PRBs in frequency domain.
    - N = The sub-channel size * the number of sub-channels.
  - The PSCCH resource pool consists of a set of contiguous PRBs.
    - The size of a PSCCH resource pool is configurable.
    - Candidates of PSCCH resource are disjoint.
- Energy sensing granularity of PSSCH in Step 3 is the size of sub-channel.
- The UE always (re)selects an integer number of adjacent subchannels for transmission.
- A UE is not expected to try to decode more than [100] RBs in a subframe.
- A UE is not expected to try to decode more than [10] PSCCHs in a subframe.
- SA pool and the associated data pool can overlap. An SA pool and a non- associated data pool can overlap.
  - This overrides the existing agreement including "An RB of an SA pool in a TTI cannot be included an un-associated data pool (if exists)" made in RAN1#84bis.

Agreement:
- When a pool is (pre)configured such that a UE always transmits SA and data in adjacent RBs in the same subframe,
  - A resource pool consists of N contiguous PRBs in frequency domain.
    - N = The sub-channel size * the number of sub-channels.
    - A UE transmits PSSCH on the largest subset of PRBs in the selected sub-channel(s) subject to the DFT size restriction and the adjacency to the associated SA resource.
- When a pool is (pre)configured such that a UE can transmit SA and data in non-adjacent RBs in the same subframe,
  - The UE always transmits on an integer number of adjacent subchannels.

R1-168082 WF on pools for V2X Ericsson

Agreement:
- V2V pool is defined by a repeating bitmap mapped to all subframes except for at least SLSS subframes which are skipped
  - The bitmap length is 16, 20, or 100.
  - FFS if/how to handle the case where the bitmap does not repeat an integer number of times within the DFN period
- The bitmap defines which subframes are allowed for V2V SA/data transmission and/or reception for a pool.

Association of SA and data

R1-166162 Multiplexing of SA and its associated data Huawei, HiSilicon
R1-167925 WF on time resources indication Huawei, HiSilicon, LGE, Ericsson

Agreement:
- Once resource reselection is triggered, UE reselects resources for all the transmissions corresponding to a TB.
- SA only schedules transmission(s) corresponding to one TB.
- UE is not required to perform PSSCH-RSRP measurement in a TTI that occurs before the reception of a successfully decoded associated SA.
  - UE applies the PSSCH-RSRP measured in a TTI that occurs at or after the reception of a successfully decoded associated SA to a TTI that is indicated by the SA but occurs before the reception of the SA.
- Number of transmissions of a TB is 1 or 2.
- Each SA indicates the time/frequency resources of all the data transmissions corresponding to the same TB.

R1-166161 Resource pool design Huawei, HiSilicon
R1-166163 Indication of time and frequency resources Huawei, HiSilicon

Petitioners' Exhibit 1003, p. 929
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166260 Details of Resource Pool Design Qualcomm Incorporated
R1-166436 Resource pool enhancement in PC5-based V2V CATT
R1-166515 Details of resource pool design for sidelink V2V communication Intel Corporation
R1-166576 Consideration on V2V sub-channelisation Beijing Xinwei Telecom Techn.
R1-166645 Resource pool design for V2X NEC
R1-166717 Details on resource pool design Samsung
R1-166829 Remaining issues for resource pool configuration LG Electronics
R1-166963 On the orthogonality of SA and data pools Ericsson
R1-166974 Pool design for V2V Ericsson
R1-166975 On Pools Overlap for Mode 1 and Mode 2 Ericsson
R1-166980 Discussion on resource pools for V2V ZTE
R1-167357 Discussion on resource pool for PC5 based V2V Communications NTT DOCOMO, Inc.
R1-167619 V2V resource pool allocation Potevio
R1-167695 On PSCCH and PSSCH retransmission and combining options Intel Corporation
R1-167922 WF on floating period Huawei, HiSilicon, CATT
R1-167924 WF on SA resource allocation Huawei, HiSilicon
R1-168060 WF on resource pool signalling LG Electronics, Huawei, ITRI

7.2.2.4 Remaining details of scheduling for sidelink resource in eNB scheduling mode

R1-166956 Cross carrier and multi-operator scheduling for V2V over PC5 Ericsson
R1-168471 WF on DCI for PC5-based V2V with mode-1 CMCC

7.2.2.4.1 Details of DCI format for SPS and dynamic scheduling

Including how to trigger/release different SPS configurations

R1-166126 Enhancements to support cross-carrier scheduling for V2V Huawei, HiSilicon
R1-166167 SPS enhancement for V2V Huawei, HiSilicon
R1-166203 DCI design for V2V Huawei, HiSilicon
R1-166261 Details of DCI and SPS configuration Qualcomm Incorporated
R1-166430 Discussion on eNB signaling in V2V mode 1 CATT
R1-166718 Sidelink SPS operation for eNB scheduling mode Samsung
R1-166830 Remaining details of (E)PDCCH design of scheduling for sidelink resource LG Electronics
R1-166957 Contents of Downlink Control Information for V2V over PC5 Ericsson
R1-166970 Discussion on DCI design in V2V Panasonic
R1-166981 Scheduling of V2V SPS resources ZTE
R1-167091 Details of DCI in eNB scheduling mode CMCC
R1-167358 (E)PDCCH for sidelink SPS configuration switching NTT DOCOMO, Inc.
R1-167589 DCI contents for SPS and resource allocation in Mode 1 INTERDIGITAL COMMUNICATIONS
R1-167839 Details on PC5 SPS enhancement PANASONIC R&D Center Germany

R1-168301 WF on DCI used for multiple SPS configuartions NTT DOCOMO, Huawei, HiSilicon, Panasonic, CMCC, ITRI

Agreement:

- DCI for dynamic scheduling:
  - At least the following fields are included in the DCI
    - CIF (3 bits)
      - Interpretation of CIF is (pre)configured. This (pre)configuration can be different from CIF for UL/DL.
    - Lowest index of the sub-channel allocated to the initial transmission
    - SA content
      - Time gap between initial transmission and retransmission: [4] bits
      - Frequency resource location of the initial transmission and retransmission: 8 bits
    - FFS
      - TPC
  - The DCI length is the same as DCI format 0 configured for UL of the UE.
    - An RNTI different from C-RNTI/SPS-RNTI is used.
  - Time location of the initial transmission is the first subframe included in the resource pool on the V2V carrier that occurs after 4 ms from the DCI transmission subframe.
- Email discussion until September 2nd to finalise the above square-bracketed figure and FFS (Qualcomm)

Petitioners' Exhibit 1003, p. 930
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

SPS scheduling is postponed to V2X work item, e.g.:

- For SPS, the following are included in the DCI in addition to the content of the DCI for dynamic scheduling:
  - SPS configuration indicator
    - FFS whether this can indicate more than 1 SPS configuration
  - SPS activation / release indicator

7.2.2.5 Remaining details of SCI contents

R1-166202 Scheduling assignment design for V2V Huawei, HiSilicon
R1-166262 Details of SCI Qualcomm Incorporated
R1-166434 Discussion on contents of scheduling assignment CATT
R1-166516 Scheduling assignment for sidelink V2V communication Intel Corporation
R1-166719 SCI size and SCI contents Samsung
R1-166831 Remaining issues on SCI contents LG Electronics
R1-166971 Repetition and relationship between SA and associated data Panasonic
R1-166982 Discussion on SA content ZTE
R1-167011 Contents of PSCCH for V2V over PC5 Ericsson
R1-167359 Discussion on enahancement of scheduling assignement in V2V communications NTT DOCOMO, Inc.
R1-167510 SA contents for V2V Lenovo (Beijing) Ltd
R1-167590 SCI contents for R14 V2V INTERDIGITAL COMMUNICATIONS

R1-168379 WF on V2V priority signaling Intel Corporation

Agreement:

- SCI contents (48 bits in total):
  - Priority: 3 bits
  - Resource reservation: 4 bits
  - MCS: 5 bits
  - CRC: 16 bits
  - Retransmission index: 1 bit
  - Time gap between initial transmission and retransmission: [4] bits
    - This fields indicates a value in [0, [15]]. Value 0 means no retransmission of the associated TB.
  - Frequency resource location of the initial transmission and retransmission: Working assumption: 8 bits
    - Frequency location of the other transmission and the number subchannels are jointly encoded.
  - Reserved bits: [7] bits
    - A UE transmitting SCI defined in Rel-14 V2V WI shall set all these bits to 0.
    - A UE shall not use this field as virtual CRC.
- RV 0 and 2 are used for the initial transmission and retransmissions, respectively.

Email discussion until September 2nd to confirm the above working assumption and square-bracketed figures, and the details of joint encoding of frequency location of the other transmission and number of subchannels - (Huawei)

7.2.2.6 Remaining details of coexistence of PC5-based V2V operation and legacy Uu operation

Including prioritizing sidelink transmissions over UL transmissions

R1-166125 Coexistence of cellular and V2V services on the same carrier Huawei, HiSilicon
R1-166263 Coexistence of PC5 and Uu for V2V Qualcomm Incorporated
R1-166720 Coexistence of Uu and PC5 based V2V Samsung
R1-166832 Remaining issues on coexistence of PC5-based V2V and legacy Uu LG Electronics
R1-166961 On the Need for V2V Gaps Ericsson
R1-166983 Co-existence of PC5-based V2V operation and legancy Uu operation ZTE
R1-167175 Coexistence of cellular and V2V services in partial network coverage Huawei, HiSilicon
R1-167360 Details of prioritizing sidelink transmissions over UL transmissions NTT DOCOMO, Inc.
R1-167591 Coexistence of PC5-based V2V and legacy Uu operation INTERDIGITAL COMMUNICATIONS
R1-167803 On Prioritization of V2V Sidelink TX over WAN UL TX Nokia, Alcatel-Lucent Shanghai Bell
R1-168302 WF on prioritizing of LS V2V communication NTT DOCOMO

Power control
R1-166206 Power control for SA and data Huawei, HiSilicon
R1-168146 WF on power control LG Electronics, Huawei, HiSilicon, Qualcomm

Agreement:

- When PSCCH and the associated PSSCH are transmitted in the same subframe,
  - Power control parameters are (pre)configured only for PSSCH.

Petitioners' Exhibit 1003, p. 931
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- PSD offset to that of PSSCH is used to determine the transmission power of PSCCH.
  - The PSD offset is fixed to X(FFS in [0, 3]) dB in specifications.
  - **Friday**: Email approval on FFS until September 1st – (LGE)
- For all cases, the PSD difference between PSCCH and PSSCH shall be the same as the PSD offset value.

7.2.2.7 Remaining details of sidelink synchronization procedure

Including priority order of synchronization sources for remaining cases. Low priority is given to enhancements to Rel-12/13 SLSS-based synchronization.

R1-168283 WF on GNSS Priority for Synchronization Huawei, HiSilicon

Agreement:

- GNSS is at the highest priority of synchronization source for time and frequency when the following conditions are met:
  - The UE is out of coverage on the V2X carrier (as defined by RAN2)
  - The UE does not receive any eNB synchronization configuration
  - The UE directly receives GNSS with sufficient reliability (as defined by RAN4)
  - The UE does not receive any SLSS_net signal with in-coverage indicator 1
- The existing agreements apply when at least one of the above conditions is not met.
  - FFS UE behaviour when the UE is out-of-coverage and receives SLSS_net.
- RAN1 observed the potential benefit of (pre)configuring an offset to shift the DFN #0 w.r.t the reference timing derived from GNSS. RAN1 assumes that RAN2 will decide whether this feature will be included in the outcome of V2V WI.
  - The offset is in range [0, 1 ms] with the granularity of 1 us.
- LS to RAN2 to inform this (Stefano – Ericsson) in R1-168244. Approved in R1-168250 with adding RAN4 to CC.

Agreement: SLSS period is 160 ms. Note that this changes the existing working assumption.

R1-166168 Timing alignment of different synchronization sources for V2V Huawei, HiSilicon
R1-166200 OOC sync priority and SLSS ID set definition Huawei, HiSilicon
R1-166201 PSBCH contents and SLSS transmission procedure Huawei, HiSilicon
R1-166207 Sidelink synchronization enhancement in V2V communication Huawei, HiSilicon
R1-166264 Synchronization Procedure for V2V Qualcomm Incorporated
R1-166432 Synchronization enhancements in PC5-based V2V CATT
R1-166433 Timing alignment for V2V CATT
R1-166517 Sidelink synchronization procedure for V2V communication Intel Corporation
R1-166617 Discussion on the GNSS based synchronization Guangdong OPPO Mobile Telecom.
R1-166618 Discussion on the V2V synchronization source priority Guangdong OPPO Mobile Telecom.
R1-166721 Remaining issues on sidelink synchronization Samsung
R1-166833 Remaining details of sidelink synchronization LG Electronics
R1-166960 Distributed Synchronization Procedure for V2X over PC5 Ericsson
R1-166964 Receiver Timing Assumptions for V2V SL Operation Ericsson
R1-166984 The remaining details of sidelink synchronization procedure ZTE
R1-167007 PSBCH Contents for V2V Ericsson
R1-167012 V2V Signals Transmission Dropping for SLSS Reception Ericsson
R1-167014 SLSS/PSBCH and Transmitter Behavior under Congestion Control Restrictions Ericsson
R1-167361 SLSS enhancements for GNSS based synchronization NTT DOCOMO, Inc.
R1-167411 Discussion priority order and multiple synchronization references on sidelink synchronization procedure for V2V communication ITRI
R1-167412 Coordination among multiple synchronization sources on sidelink synchronization procedure for V2V communications ITRI
R1-167592 Priority order of synchronization sources INTERDIGITAL COMMUNICATIONS
R1-167608 Further Discussions on V2V Synchronization Design SHARP Corporation, MTI
R1-167804 Final details of V2V synchronization procedure Nokia, Alcatel-Lucent Shanghai Bell
R1-167837 V2V synchronization remaining issues PANASONIC R&D Center Germany
R1-168081 WF on SLSS periodicity Ericsson, Qualcomm, ZTE
R1-168455 WF on SLSS ID CATT, LG Electronics

7.2.2.8 Other

R1-166834 Open issues for V2V work item completion LG Electronics
R1-166835 on supporting 64 QAM for PC5-based V2V LG Electronics
R1-167152 Discussion on inband emission suppression for V2V communications Huawei, HiSilicon

Petitioners' Exhibit 1003, p. 932
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Rapporteur will capture in the status report all remaining essential issues of V2V that are to be transferred to the V2X WI.
LS to RAN2:
R1-168202 LS on L1 parameters for sidelink-based V2V RAN1, LGE
Decision: LS is agreed.

7.2.3 LTE-based V2X Services - *WID in RP-161298*

R1-168404 Chairman's notes of AI 7.2.3 on LTE-based V2X Services Ad-Hoc chair (Nokia)
The document was presented by Matthew Baker from Nokia.
Decision: The document is endorsed and incorporated as follows.

R1-166836 Work plan for LTE-based V2X Services LG Electronics

7.2.3.1 Enhancement to UL SPS

Including support for multiple SPS configurations

R1-166170 SPS enhancement on Uu for V2X Huawei, HiSilicon
R1-166265 Uplink SPS enhancements for V2X Qualcomm Incorporated
R1-166437 Discussion on enhancement of UL SPS in V2X CATT
R1-167015 UL-SPS for LTE-based V2X services Ericsson

Agreements:

- A SPS RNTI for V2X over Uu is necessary.
  - FFS whether this SPS RNTI is specific to V2X or can be the same as the legacy SPS C-RNTI
- A DCI format 0 for V2X scrambled by the SPS RNTI for V2X is used to activate or update the SPS.
- Both explicit release and an implicit release mechanism for SPS over Uu are supported (details FFS).
- Explicit signaling from the UE to the eNB (ask RAN2 if they can design the appropriate signalling, e.g. using a MAC CE) can be used to indicate to the eNB when activation/update/release is desired.
  - For activation, a "desirable time offset" (e.g. relative to SFN0) is included
- When the period is to be changed, the UE notifies the eNB with the new period
- Multiple SPS configurations can be active at the same time.
  - An indicator(s) in DCI format 0 (e.g. SPS index or an indicator mapped to SPS index) is used to differentiate SPS configurations.
    - FFS whether existing field(s) (e.g. TPC for PUSCH) is reused or a new field is added
  - FFS whether each SPS configuration is always activated/released by a separate DCI or whether multiple SPS configurations can be activated or released by a single DCI.
- In the event of a resource conflict between SPS configurations, only one transmission can occur
  - RAN1 leaves it up to RAN2 to determine any possible mechanism for resolving resource conflicts between SPS configurations

R1-166837 Discussion on details of (E)PDCCH design for uplink SPS LG Electronics

7.2.3.2 Resource selection for pedestrian UEs

Including random resource selection for P-UEs potentially on the PC5 resource pool shared with V-UE transmissions, with additional study on sensing operation during a limited time for P-UEs

R1-166838 Discussion on P-UE sidelink transmissions LG Electronics
R1-166266 PC5 for V2P Qualcomm Incorporated
R1-167805 On resource selection for V2P communication Nokia, Alcatel-Lucent Shanghai Bell
R1-166723 Resource selection for pedestrian UE Samsung
R1-166205 Discussion on the P-UE resource selection Huawei, HiSilicon
R1-166986 Considerations for resource selection for P-UEs ZTE
R1-166965 Discussion on P2x Ericsson
R1-167362 Evaluation and discussion on resource selection for pedestrian UEs NTT DOCOMO, Inc.
Revised in R1-167886
R1-167869 Discussion on sensing operation for P-UE Sequans Communications

R1-166438 Discussion on resource selection for P-UE CATT
R1-166993 Discussion on resource sensing and selection for pedestrian UEs Spreadtrum Communications
R1-167512 Discussion on resource selection for pedestrian UEs Lenovo (Beijing) Ltd
R1-167609 Power Efficient Sensing for V2X Pedestrian UEs SHARP Corporation
R1-168083 WF on new P2x transmission mode Ericsson

Petitioners' Exhibit 1003, p. 933
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-168385 **WF on pedestrian UE resource selection** **NTT Docomo, Huawei, HiSilicon**
Proposal:
- If shared Tx resource pool is used by pedestrian UEs and vehicle UEs
  - Pedestrian UE can sense in a subset of subframes and skip sensing in other subframes for energy saving
    - FFS details on how/when UE skip sensing
    - Vehicle UE resource selection is reused as the baseline for pedestrian UE resource selection
      - FFS details
  - FFS whether pedestrian UE can skip sensing in all the subframes and use random resource selection

Agreement:
- The specification supports the possibility for a P-UE to use random selection, including at least all P-UEs which do not have sidelink Rx capability
  - If a P-UE uses random selection, it shall only pools in which random selection by P-UEs is permitted
  - It is up to network configuration whether a pool in which random selection by P-UEs is permitted overlaps with other pools
  - The specification supports the possibility to configure pools in which random selection by P-UEs is not permitted
- The specification supports the possibility for a P-UE to use partial sensing in a subset of subframes
  - Details of P-UE partial sensing are FFS
    - V2V sensing-based resource selection is the baseline; strive to define P-UE partial sensing-based resource selection to be as similar as possible to V2V sensing-based resource selection
  - FFS whether support of partial sensing is mandatory for P-UEs with sidelink Rx capability
  - FFS under what conditions a P-UE that supports partial sensing uses partial sensing
  - If a P-UE uses partial sensing,
    - details of resource pool FFS

Pedestrian Authorization

R1-167817	Discussion on Pedestrian Authorization	Ericsson
R1-167828	[DRAFT] LS on Pedestrian Authorization	Ericsson
R1-168084	WF on authorization for pedestrian UEs	Ericsson

7.2.3.3 Other

Including support of inter-PLMN for Uu and PC5

R1-166208	Discussion on inter-PLMN supporting	Huawei, HiSilicon
R1-166209	Design for multi-carrier operation	Huawei, HiSilicon
R1-166267	Inter-PLMN support for PC5 and Uu	Qualcomm Incorporated
R1-166268	Co-channel coexistence for DSRC and LTE-V2V	Qualcomm Incorporated
R1-166839	Considerations on the co-channel coexistence of LTE PC5 V2V and IEEE 802.11p	LG Electronics
R1-166962	Discussion on inter-PLMN V2x PC5 and Uu operation	Ericsson
R1-166985	Uu transport enhancement for V2X ZTE	

R1-168025 **Draft LS on RAN1 agreements for LTE-based V2X** **LGE**
Decision: The LS to RAN2, RAN3 and SA2 is approved in R1-168026.

7.2.4 Enhancements on Full-Dimension (FD) MIMO for LTE - WID in RP-160623

R1-168405 **Chairman's notes of AI 7.2.4 on Enhancements on Full-Dimension (FD) MIMO for LTE** **Ad-Hoc chair (Samsung, Nokia)**
The document was presented by Matthew Baker from Nokia.
Decision: The document is endorsed and incorporated as follows.

R1-166724 **Rapporteur Workplan on eFD-MIMO** **Samsung, Nokia, CATT**

R1-168542 Friday's notes of FD-MIMO offline Nokia

7.2.4.1 Reference signals

7.2.4.1.1 Non-precoded CSI-RS

At least decide on:

- *Mk value(s)*

Petitioners' Exhibit 1003, p. 934
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- *High level mechanism for CSI-RS overhead reduction*

CSI-RS aggregation details

R1-166725 Discussions on CSI-RS enhancements for Class A CSI reporting Samsung
R1-167955 Further discussion on non-precoded CSI-RS design for eFD-MIMO ZTE Corporation, ZTE Microelectronics
Revision of R1-166329
R1-166269 Non-precoded CSI-RS design for up to 32 ports Qualcomm Incorporated
Section 2
R1-167137 CSI-RS pattern design for up to 32 ports Huawei, HiSilicon
R1-166339 Nonprecoded CSI-RS for Class A CSI Reporting Nokia, Alcatel-Lucent Shanghai Bell
Section 2
R1-166519 Performance comparison of CDM-4 and CDM-8 for CSI-RS Intel Corporation

R1-167980 WF on aggregation for NP CSI-RS ZTE Corporation, ZTE Microelectronics, Qualcomm, Xinwei, Potevio
R1-168056 WF on CDM-2 and CDM-4 for non-precoded CSI-RS LG Electronics, ITRI, Samsung, Ericsson, ZTE
R1-168049 WF on Class A CSI-RS Enhancement CATT, Alcatel-Lucent Shanghai Bell, Intel, InterDigital, Nokia, Huawei, HiSilicon
Also supported by Qualcomm

Agreements:
- For {24, 32} ports, $\sum_k M_k \in \{24, 32\}$, $M_k = 8$, where M_k is the same for all k
- For {20, 28} ports, $\sum_k M_k \in \{20, 28\}$, $M_k = 4$, where, at least for CDM-2, M_k is the same for all k
  - FFS whether $M_k = 8$ is also supported, and if so, whether M_k is the same or different for different k for CDM-4
- FFS port indexing
- In Rel-14, CDM-2 and CDM-4 is supported.
  - For CDM-2, port numbering in Rel-13 is reused in order to share CSI-RS with legacy UEs.
  - FFS CDM-4 port numbering

Working Assumption:
- CDM-8 is supported for at least {24,32} port CSI-RS
  - FFS CSI-RS aggregation and CDM mapping details
  - FFS additional REs other than legacy CSI-RS RE

R1-167996 WF on CDM aggregation for NP CSI-RS Samsung, Xinwei, Ericsson

CSI-RS overhead reduction

R1-166726 Discussions on NP CSI-RS overhead reduction Samsung
R1-167633 CSI-RS Design for Class A eFD-MIMO Ericsson
R1-166440 Discussion on CSI-RS overhead reduction for class A CATT
R1-166339 Nonprecoded CSI-RS for Class A CSI Reporting Nokia, Alcatel-Lucent Shanghai Bell
Section 3
R1-167635 Support of CSI-RS port sharing with Rel-13 and Rel-12 UEs Ericsson
R1-167652 On CSI-RS Overhead Reduction Schemes InterDigital Communications

R1-167981 WF on overhead reduction for Class A NZP CSI-RS ZTE Corporation, ZTE Microelectronics, Ericsson, Samsung, NTT DOCOMO

Agreement: At least for Class A NZP CSI-RS with more than 16 CSI-RS ports:
- All ports in a CSI-RS resource are transmitted within the same subframe
  - i.e. CSI-RS overhead reduction is done in the frequency domain
- CSI-RS density d ∈ {1,1/2, and at least one other value <= 1/3} RE/RB/port
  - Other values of d are not precluded (e.g. $^2/_3$, ¾)
  - FFS whether different ports in a CSI-RS resource may have different densities
- FFS PDSCH rate matching in the REs in PRBs with no CSI-RS ports within a group
  - Opt-1: comb like transmission
  - Opt-2: frequency domain measurement restriction
- FFS the detailed signalling design

Petitioners' Exhibit 1003, p. 935
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166325	Aperiodic CSI-RS for non-precoded CSI-RS	ZTE Corporation, ZTE Microelectronics
R1-166439	CSI-RS design for {20,24,28,32} ports	CATT
R1-166518	Discussion on CSI-RS for Class A FD-MIMO	Intel Corporation
R1-166577	Further discussion on non-precoded CSI-RS designs for eFD-MIMO	Beijing Xinwei Telecom Techn.
R1-166632	Discussion on CSI-RS with CDM8	NEC
R1-166633	Proposals for CSI-RS overhead reduction	NEC
R1-166727	Discussions on CDM-8 for NP CSI-RS	Samsung
R1-166840	Discussions on NP CSI-RS designs for eFD-MIMO	LG Electronics
R1-167092	Discussion on non-precoded CSI-RS enhancement	CMCC
R1-167346	Discussion on non-precoded CSI-RS design	NTT DOCOMO, INC.
R1-167618	CSI-RS design for eFD-MIMO	Potevio
R1-167634	Performance of CDM-8 for Non-Precoded CSI-RS	Ericsson

7.2.4.1.2 Beamformed CSI-RS

At least decide on:

- *Scheme 1 and/or 2 – if down selection is needed*
- *Additional FFS details on scheme 1 and/or 2*

R1-166442	**Support for aperiodic CSI-RS**	**CATT**
R1-166520	**Evaluation of CSI-RS overhead reduction for Class B using frequency decimation**	**Intel Corporation**
R1-166728	**Additional details on aperiodic CSI-RS**	**Samsung**

R1-167653	**On Rate-matching of A-CSI-RS**	**InterDigital Communications**
R1-167675	**Aperiodic CSI-RS transmission for beamformed CSI-RS**	**Huawei, HiSilicon**

R1-168046 WF on Aperiodic CSI-RS for Rel.14 Samsung, Nokia, Alcatel-Lucent Shanghai Bell, KT Corporation, Ericsson, LG Electronics, Interdigital, Qualcomm, AT&T, CHTTL, Xinwei, Straightpath, ITL

Agreement:
Aperiodic CSI-RS

- Two-step NZP CSI-RS resource configuration:
  - Step 1. RRC configuration with a newly defined Aperiodic CSI-RS-Resource-Config IE
    - Without Subframe_config
    - Configure a UE with ***K*** = {1, 2, .., 8} CSI-RS resources
  - Step 2. Activation/release mechanism
    - Activate ***N*** out of ***K*** CSI-RS resources per CSI process
      - Note: Activation refers to down selection of N out of K CSI-RS resources
      - Once activated, a CSI resource remains activated until released
      - FFS: Whether N is always equal to K or the case where K=N is not precluded
        - If N is always equal to K, step 2 is bypassed
    - Choose at least one of the following alternatives for activation/release mechanism (TBD in RAN1#86bis)
      - Alt1. Using UL grant(s)
        - FFS: Support for cross-carrier activation/release
      - Alt2. Using MAC CE
      - Other alternatives are not precluded
      - FFS the values of X and Y, max value of ***N*** (or the value of *N*), how to signal *N*
- One out of ***N*** CSI-RS resources is selected via the UL-related DCI
  - A UL grant carries a CSI request and indicates transmission of one CSI-RS resource if ***N***>1 aperiodic CSI-RS resources are activated for a CSI process for which the CSI is requested
    - A CSI request is for one CSI-RS resource per CSI process
    - Choose one out of the following alternatives for indicating transmission of **1** out ***N*** CSI-RS resources (TBD in RAN1#86bis)
      - Alt1. use code points from an existing DCI field to select **1** out ***N*** CSI-RS resources
      - Alt2. Introduce additional bit(s) in DCI
      - Note: The number DCI fields and number of code points for the combinations of CSI process, CC, and CSI-RS resource indication are FFS
- Only PUSCH based A-CSI reporting is supported
- Aperiodic CSI-RS transmission is in the same DL subframe as the associated UL-related DCI
  - FFS: Whether to CSI reference resource definition needs to change when aperiodic CSI-RS is used or not

Petitioners' Exhibit 1003, p. 936
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Whether and, if needed, how to support CSI processing relaxation for aperiodic CSI-RS are TBD
- FFS: Possibility to support aperiodic CSI-RS with *K*=1 and trigger (using UL-related DCI carrying A-CSI request) a subset of antenna ports.

"Multi-shot" CSI-RS

- Two-step NZP CSI-RS resource configuration:
  - Step 1. RRC configuration with a *Rel-13 periodic* CSI-RS-Resource-Config IE
    - Configure a UE with ***K*** = {1, 2, .., 8} CSI-RS resources
  - Step 2. Activation/release mechanism
    - Activate ***N*** out of ***K*** CSI-RS resources per CSI process
      - Note: Activation refers to transmission of N CSI-RS resources
      - Once activated, a CSI resource remains activated until released
    - Choose at least one of the following alternatives for activation/release mechanism (TBD in RAN1#86bis)
      - Alt1. Using UL grant(s)
        - FFS: Support for cross-carrier activation/release
      - Alt2. Using MAC CE
      - Other alternatives are not precluded
      - FFS the values of X and Y, max value of ***N*** (or the value of N), how to signal *N*
- CSI reporting
  - *N*=1: CQI/PMI/RI is reported
  - *N*>1: CRI (=0,1, …, *N* – 1) is reported along with CQI/PMI/RI associated with the reported CRI value

Overhead reduction for Class B – both for periodic and aperiodic CSI-RS

- Support CSI-RS frequency-domain density reduction for Class B
  - All antenna ports of a single CSI-RS resource configuration can be transmitted every N PRBs
    - *N* = 1 (existing CSI-RS design), 2, and >2
    - FFS: Exact mechanism

R1-168147 WF on Rate Matching Issue for Beamformed CSI RS LG Electronics, InterDigital, Samsung, Huawei, HiSilcon, Qualcomm, CATT

Agreement:

- A solution is to be selected from the following three alternatives for aperiodic ZP CSIRS resource indication (TBD RAN1#86bis)
  - Alternative-1: Aperiodic ZP CSIRS, dynamically indicated by a new common DCI.
    - The common DCI is monitored in common search space.
  - Alternative-2: Aperiodic ZP CSIRS, aperiodic ZP CSI-RS resource signaling field is introduced in DL DCIs for all TMs.
  - Alternative-3: Use the existing PQI states or increase the number of PQI states for TM10; no PDSCH RM solution for other TMs
    - In this case, aperiodic ZP CSIRS resource is not defined
- Definition of Aperiodic ZP CSIRS:
  - For PDSCH rate matching on BF CSIRS due to aperiodic CSI-RS and/or multi-shot CSI-RS, an aperiodic ZP CSIRS resource is indicated.
    - Aperiodic ZP CSIRS resource configuration is defined without Subframe_config
    - UE conducts PDSCH rate matching on aperiodic ZP CSIRS at the subframe when the DCI is signaled.
- Study the impact of collision between EPDCCH RE and aperiodic CSI-RS

R1-168148 WF on QCL issue for Beamformed CSI RS LG Electronics, Samsung, Intel

Agreement:

- Decide the need for QCL indication on DMRS to aperiodic and/or multi-shot CSI-RS NZP CSIRS (TBD RAN1#86bis)
- If needed, at least one solution is to be selected from the following alternatives (TBD RAN1#86bis)
  - Alt 1: UE is not expected that aperiodic and/or multi-shot NZP CSIRS is indicated in PQI for QCL purpose with DMRS.
  - Alt 2: aperiodic and/or multi-shot NZP CSIRS can be indicated in PQI for QCL purpose, and follow legacy QCL assumption
    - Periodic NZP CSI-RS can also be indicated for QCL purpose

Petitioners' Exhibit 1003, p. 937
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166270 Enhancements on Beamformed CSI-RS Qualcomm Incorporated
R1-166324 Enhancements on Beamformed CSI-RS ZTE Corporation, ZTE Microelectronics
R1-166340 Aperiodic CSI-RS and Overhead Reduction Nokia, Alcatel-Lucent Shanghai Bell
R1-166441 Discussion on CSI-RS overhead reduction for class B CATT
R1-166578 Further discussion on beamformed CSI-RS designs for eFD-MIMO Beijing Xinwei Telecom Techn.
R1-166841 Remaining details on beamformed CSI-RS enhancements LG Electronics
R1-167138 Rate matching enhancements for aperiodic CSI-RS in different transmission mode Huawei, HiSilicon
R1-167347 Discussion on Aperiodic CSI-RS NTT DOCOMO, INC.
R1-167636 Beamformed CSI-RS Design with Activation Mechanism Ericsson
R1-167637 UE specific Beamforming with Aperiodic CSI-RS Transmission Ericsson
R1-167651 Remaining Issues on A-CSI-RS InterDigital Communications
R1-167977 Overhead Reduction for Class B CSI-RS Ericsson

7.2.4.1.3 Uplink DM-RS

At least decide on:

- *Choosing one from IFDMA and DMRS sequence enhancements*
- *Additional details on the chosen scheme*

R1-166521 Remaining details of UL DMRS enhancement Intel Corporation
R1-166271 Discussion on uplink DMRS enhancements for FD-MIMO Qualcomm Incorporated
R1-166141 Uplink DMRS enhancement to support more orthogonal partial overlapped ports Huawei, HiSilicon

R1-166341 Control Signalling for UL DMRS with IFDMA Nokia, Alcatel-Lucent Shanghai Bell
R1-166326 Discussion on UL DMRS enhancement for eFD-MIMO ZTE Corporation, ZTE Microelectronics
R1-166742 Proposals on uplink DMRS design enhancements Samsung

R1-167087 UL DMRS Base Sequences with IFDMA Nokia, Alcatel-Lucent Shanghai Bell
R1-167139 Uplink DMRS sequence enhancement for IFDMA Huawei, HiSilicon

R1-166634 Discussion on IFDMA based scheme NEC
R1-166842 Discussion on uplink DMRS enhancements for eFD-MIMO LG Electronics
R1-166443 On UL DMRS enhancement CATT

R1-168050 WF on UL DMRS enhancement Intel

R1-167972 WF on UL DMRS Nokia, Alcatel-Lucent Shanghai Bell, Huawei, HiSilicon

Agreement:

- Support orthogonal DMRS (more than 2) for MU-MIMO with partial overlapping BW allocation by
  - IFDMA with at least RPF 2
    - FFS: RPF 4
- FFS during this week which new IFDMA sequence lengths (if any) shall be supported and designed
  - If any new lengths larger than 36 are supported, the corresponding DMRS sequences are generated by the legacy mechanism by extension of a Zadoff-Chu sequence
- FFS: whether and how CS of DMRS generation shall be modified to improve backward compatibility for the pairing with legacy UE.
- Additional power boosting shall be supported and applied to IFDMA DMRS depending on the value of RPF
  - FFS: x dB for RPF 2 and y dB for RPF 4

R1-168369 WF on UL DMRS Lengths Nokia, Alcatel-Lucent Shanghai Bell, Huawei, HiSilicon, Qualcomm, CATT, Samsung

Agreement:

- IFDMA Sequence Design for RFP=2,
  - New lengths larger than 36 are supported. The corresponding DMRS sequences are generated by the legacy mechanism by extension of a Zadoff-Chu sequence.
  - FFS: whether new lengths of 6, 18, 30 are supported

Petitioners' Exhibit 1003, p. 938
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.2.4.2 CSI reporting

7.2.4.2.1 Non-precoded CSI-RS codebooks

At least decide on:

- *Down selection of (N1, N2) and/or (O1, O2) configurations*

R1-166272 **Non-precoded CSI-RS Codebooks for eFD-MIMO** **Qualcomm Incorporated**
R1-167954 **Class A codebook design for eFD-MIMO** **ZTE Corporation, ZTE Microelectronics**
Revision of R1-166323
R1-166342 **Codebook Design for Class A CSI Reporting up to 32 Ports** **Nokia, Alcatel-Lucent Shanghai Bell**
R1-166444 **Reducing the number of combinations of codebook parameters** **CATT**
R1-166445 **Codebook design for {20,24,28,32} ports** **CATT**

R1-166729 **View on class A codebook extension** **Samsung**
R1-167639 **On 1D antenna port layouts in Rel-14** **Ericsson**

R1-168065 **Way Forward on 1D Antenna Port Layouts** **Ericsson, Verizon, Kathrein-Werke, Deutsche Telekom, AT&T**
Proposal:

- The following 1D antenna layouts are supported:
  - (N1,N2) = (16,1), (14,1) , (12,1), (10,1)

R1-166522 Performance evaluation of Class A codebooks with 32 ports Intel Corporation
R1-166523 Discussion on Class A codebook extension Intel Corporation
R1-166579 Discussion on codebook design to support up to 32 ports CSI-RS Beijing Xinwei Telecom Techn.
R1-167140 Codebook for up to 32 ports CSI-RS Huawei, HiSilicon
R1-167348 Codebook Enhancement for eFD-MIMO NTT DOCOMO, INC.
R1-167638 Antenna port layout support for up to 32 Ports in Rel-14 Ericsson
R1-167930 Discussions on non-precoded CSI-RS codebook design for eFD-MIMO LG Electronics

R1-168353 **Way Forward on Antenna Port Layouts** **Ericsson, Qualcomm, Intel, CATT, AT&T, NTT DOCOMO**
Offline discussion until Friday (Ericsson)

Friday
R1-168511 **Way Forward on Antenna Port Layouts** **Ericsson, QUALCOMM, Intel, CATT, ATT, DOCOMO, Verizon**

- Simplify 1D configuration
  - Drop the (1,N2) rows (with red text)
    - Single design can be used for (N1,1) and (1,N2).
- Reduce UE computational complexity
  - Remove (8,8) combinations for 20, 24, 28, 32 ports (with green text)
    - Reduces number of beams by 2
    - Limited performance gain from (8,8) vs. (8,4)

Petitioners' Exhibit 1003, p. 939
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Number of CSI-RS antenna ports, P	(N1,N2)	(O1, O2)
20 ports	(2,5)	(8,4), (8,8)
	(5,2)	(8,4), (4,4)
	(10,1)	(4,-),(8,-)
	(1,10)	(-,4),(-,8)
24 ports	(3,4)	(8,4), (8,8)
	(4,3)	(8,4), (4,4)
	(2,6)	(8,4), (8,8)
	(6,2)	(8,4), (4,4)
	(12,1)	(4,-),(8,-)
	(1,12)	(-,4),(-,8)
28 ports	(2,7)	(8,4), (8,8)
	(7,2)	(8,4), (4,4)
	(14,1)	(4,-),(8,-)
	(1,14)	(-,4),(-,8)
32 ports	(8,2)	(8,4), (8,8)
	(2,8)	(8,4), (4,4)
	(4,4)	(8,4),(4,4)
	(16,1)	(4,-),(8,-)
	(1,16)	(-,4),(-,8)

- The main concern of some companies is that the necessity or the complexity of all or a large group of codebook combinations is not justified by evaluation yet. Rel 13 does not support all possible layouts.
- However some UE vendors state that the complexity of codebook combination at the UE side is not a major issue. It is still an open question which codebook combination(s) are concerns.
- It is encouraged to indentify the problem or concern or redundancy for specific codebook combination(s).

Email discussion until next meeting – (Ericsson)

7.2.4.2.2 CSI reporting for hybrid CSI-RS

At least decide on:

- *Confirm working assumption of mechanism 1*
- *Additional mechanisms, if needed*
- *Reported CSI parameters, e.g. RI in the first and/or second report*

R1-168282 WF on hybrid CSI reporting LG Electronics, Samsung, LG Uplus, KT Corporation, ITRI, NTT Docomo, ITL, Ericsson, Xinwei, NEC, InterDigital

Agreement

- Confirm the working assumption of hybrid CSI
- Further details on Mechanism 1
  - Reporting content
    - For the 1st eMIMO-Type (CLASS A), $i1^{(1)}$ and x-bit $RI^{(1)}$ are reported, while $CQI^{(1)}$ and $i2^{(1)}$ are not reported
      - If UE supports up to 2 layers, x=0
      - If UE supports up to 8 layer, x=1 where $RI^{(1)}=\{1, 3\}$
    - For the 2nd eMIMO-Type (CLASS B K=1), $CQI^{(2)}$, $PMI^{(2)}$, $RI^{(2)}$ are reported
    - Note: Superscript (y) represents the y-th eMIMO-Type, where y=1,2.
    - FFS: Option for one eMIMO-Type to inherit RI reporting from another eMIMO-Type
  - Working assumption: No inter-dependence between CSI calculations across two eMIMO-Types
  - Reuse legacy CSI reporting mechanisms with the following refinement
  - For PUCCH-based P-CSI
    - Report $i1^{(1)}$ and $RI^{(1)}$ in one subframe
      - FFS: Using either PUCCH format 2 or 3
    - Periodicity of the CSI of 1st eMIMO-Type is an integer multiple of $RI^{(2)}$ periodicity of the 2nd eMIMO-Type.
    - Subframe offset of the 1st eMIMO-Type is defined relative to $RI^{(2)}$ subframe offset of the 2nd eMIMO-Type.
      - FFS: Whether subframe offset of the 1st eMIMO-Type can be fixed to 0
    - Priority rule for collision handling is FFS.
  - For PUSCH-based A-CSI
    - FFS: what CSI(s) will be reported from UE when aperiodic CSI reporting is triggered

Petitioners' Exhibit 1003, p. 940
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Option 1: UE reports both CSI of 1st eMIMO-type and CSI of 2nd eMIMO-type.
- Option 2: UE reports either one of the 2 eMIMO-types.

- CSI encoding/mapping mechanisms is FFS.

Support of at least one more mechanism

R1-168286 WF on Hybrid CSI Reporting NTT DOCOMO, KT corporation, ITL, KDDI, LG Electronics, Mitsubishi Electric, NEC, Samsung, Sharp, Softbank, Sony, Straightpath

R1-168339 Way Forward on Inclusive Hybrid CSI-RS Framework Ericsson, ZTE Corporation, ZTE Microelectronics, Nubia, Xinwei, ITRI, ASTRI

Conclusion:

- **Proposal I:** For hybrid CSI with one CSI process, support CLASS B with K>1 CSI-RS resources for the 1st eMIMO-Type and CLASS B with K=1 CSI-RS resource for the 2nd eMIMO-Type
  - For the 1st eMIMO-Type, two options
    - Option 1: CRI (without CQI/PMI/RI) is reported
    - Option 2 (only support K=2): PMI assuming RI=1 for each of the two CSI-RS resources are reported
  - For the 2nd eMIMO-Type
    - CQI/PMI/RI are reported
  - Working assumption: No interdependence in CQI calculation between 1st and 2nd eMIMO-Types
    - FFS: for option 1, dynamic CSI-RS resource configuration for the 2nd eMIMO-Type based on CRI reporting 1st eMIMO-Type.
- **Proposal II:**
  - Hybrid CSI reporting with eMIMO-Type pairs is supported
    - No restriction on the configuration for 1st and 2nd eMIMO-Types
    - UE supports eMIMO-Type pairs
    - For TM9, different CSI-RS resources and/or CSI reporting configurations can be used for PUCCH and PUSCH
    - UE calculates one CSI report for only one eMIMO-Type of a pair at a time and one eMIMO-Type at a time
      - FFS: Define the period of CSI-RS associated with the 1st eMIMO-Type as N times of the period of CSI-RS associated with the 2nd eMIMO-Type, where N>1
        - Configurable or fixed value of N needs to be specified
        - Whether new dropping rules need to be specified
    - Rel-13 CSI process configurations are supported
      - A report for either eMIMO-type contains all Rel-13 CSI parameters (CQI/PMI/RI/CRI)
- Study whether it is possible to simplify a combination, or to down select, between/within proposals I and II

R1-166142	Hybrid CSI reporting in one CSI process	Huawei, HiSilicon
R1-166273	Discussion on CSI reporting for hybrid CSI-RS	Qualcomm Incorporated
R1-166327	Discussion on CSI reporting for hybrid CSI-RS	ZTE Corporation, ZTE Microelectronics
R1-166343	Hybrid CSI Reporting Schemes based on Single CSI Process	Nokia, Alcatel-Lucent Shanghai Bell
R1-166580	Further discussion on hybrid CSI report for eFD-MIMO	Beijing Xinwei Telecom Techn.
R1-166730	Hybrid PMI codebook based CSI reporting and simulation results	Samsung
R1-166731	Supported schemes for hybrid CSI	Samsung
R1-166844	Discussion on CSI reporting enhancements for hybrid CSI-RS	LG Electronics
R1-167349	CSI reporting for hybrid CSI-RS	NTT DOCOMO, INC.
R1-167406	Discussion on CSI reporting for hybrid CSI-RS	ITRI
R1-167640	Hybrid CSI Reporting with One and Two CSI Processes	Ericsson
R1-167641	Performance of Hybrid CSI-RS with Large CSI-RS Overhead	Ericsson
R1-168047	Further considerations on CSI reporting for hybrid CSI-RS	CATT

7.2.4.2.3 Advanced CSI reporting and interference measurement

At least decide on:

- *Select one advanced CSI scheme (combination-based codebook enhancement vs. channel quantization)*
- *The need for interference measurement enhancement*

Framework

Petitioners' Exhibit 1003, p. 941
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-167971 WF on Advanced CSI feedback framework in Rel-14 Huawei, HiSilicon, Ericsson, Nokia, Alcatel-Lucent Shanghai Bell, Samsung, CATT, ZTE, NTT DOCOMO, Qualcomm, Intel, InterDigital, ITRI

Agreement:

- Specify CSI feedback enhancement with the following advanced CSI feedback framework:
  - Reduced space (eigenvectors)/W1 is constructed based on one of the following alternatives (TBD RAN1#86bis):
    - Alt1. Orthogonal basis (e.g. orthogonal DFT matrix)
    - Alt2. Non-orthogonal basis (e.g. Rel.13 Class A W1 for rank-1 and/or 2)
  - Reduced space representation/W2 is to further combine selected beams
  - Granularity of weighting(phase and/or amplitude) can be either wideband only or wideband/subband, and is constructed based on one of the following alternatives (TBD RAN1#86bis):
    - Alt1. Phase and amplitude
    - Alt2. Phase-only weighting
  - How the enhanced framework can be applicable for Class A and/or Class B eMIMO-Types is FFS
  - FFS: How to handle the relationship between advanced CSI feedback and legacy CSI feedback framework
- Companies are encouraged to provide results comparing the above alternatives, considering a mix of smaller and larger numbers of ports within the following antenna port configurations
  - {4,8,12,16,20,24,28,32} ports
  - Focus on rank<=2 scenario MU-MIMO for evaluation
  - Feedback overhead needs to be taken into account
  - For {4,8,12,16, 20,24,28,32}-port scenario, companies are encouraged to compare their proposals to dual-stage codebook enhancement with increased number of beams in W1

R1-166845 Performance evaluation on advanced implicit CSI LG Electronics
R1-167645 W1 design for implicit advanced CSI reporting Ericsson
R1-166734 Linear combination (LC) codebook based CSI reporting and simulation results Samsung

R1-166139 Advanced CSI feedback framework for LTE Huawei, HiSilicon
R1-166140 Uplink control channel enhancements for advanced CSI feedback Huawei, HiSilicon
R1-166274 Discussion on advanced CSI reporting and initial evaluation results Qualcomm Incorporated
R1-166322 Discussion on the design of linear combination codebook ZTE Corporation, ZTE Microelectronics
R1-166330 Discussion on interference measurement for MU-CSI ZTE Corporation, ZTE Microelectronics
R1-166447 On analog CSI feed back CATT
R1-166448 Discussion on advanced CSI reporting and interference measurement enhancement CATT
R1-166524 Further study of advanced CSI feedback Intel Corporation
R1-166525 Beam combining codebook enhancements for FD-MIMO Intel Corporation
R1-166526 Discussion on the performance of CQI reporting based on the NZP CSI-RS Intel Corporation
R1-166581 Advanced CSI feedback and simulation results Beijing Xinwei Telecom Techn.
R1-166656 Considerations on MU-CQI transmission Sony
R1-166732 Discussions on periodic CSI reporting for class A in eFD-MIMO Samsung
R1-166733 Discussions on interference measurement enhancement in eFD-MIMO Samsung
R1-166735 LC based explicit CSI feedback and simulation results Samsung
R1-166736 Comparison between implicit and explicit feedback Samsung
R1-167093 Enhancing interference measurement for MU transmissions CMCC
R1-167134 Uplink control channel enhancements for reduced space CSI feedback Huawei, HiSilicon
R1-167135 Superposition codebook for Class A CSI feedback Huawei, HiSilicon
R1-167136 Superposition codebook for Class B CSI feedback Huawei, HiSilicon
R1-167350 Enhancements on MU Interference Measurement and MU-CQI Reporting NTT DOCOMO, INC.
R1-167642 Discussion on Interference Measurement Enhancements Ericsson
R1-167643 Explicit versus implicit feedback for advanced CSI reporting Ericsson
R1-167644 On the need for W1 enhancements for advanced CSI Ericsson
R1-167674 Enhanced interference measurement Huawei, HiSilicon
R1-167967 WF on advanced CSI in Rel-14 Huawei
R1-167968 WF on interference measuremnt in Rel-14 Huawei
R1-168323 WF on Advanced CQI measurement and report NTT DOCOMO

Friday
R1-168504 WF on interference measuremnt in Rel-14 Huawei, HiSilicon, CATT, Samsung, Xinwei

- Specify interference measurement enhancements in Rel-14.

Petitioners' Exhibit 1003, p. 942
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Conclusions:

- Whether the need of interference measurement enhancement in Rel-14 shall be decided in next meeting.
- If needed, one or more schemes shall be supported in Rel 14. Possible schemes are:
  - Definition and configuration of a new type interference measurement
    - Interference measurement is based on cancellation of intended signals
    - Both inter-cell and intra-cell interference should be captured
    - FFS NZP CSI-RS or DMRS as CSI-IM or PDSCH
  - Definition and configuration of a new type interference measurement
    - Only intra-cell interference to be measured using NZP
  - Aperiodic CSI-IM, based on
    - The existing CSI-IM
    - The new CSI-IM type (see above, if specified).
  - New UE measurement behavior for CQI reporting based on DMRS ports when corresponding PDSCH is transmitting.
  - If needed, L1/RRC signaling to assist UE interference measurement
  - Other schemes are not excluded.

Conclusion: Companies are encouraged to investigate the usage of new or existing PUCCH format for the purpose of analog feedback to carry advanced CSI.

7.2.4.3 DMRS-based open-loop and semi-open-loop transmission

At least decide on:

- *CSI parameters to be reported*
- *Down selection of Tx enhancement scheme, if needed*

R1-168446 WF on semi-open-loop transmission Samsung, Nokia, ASB, ZTE, ZTE Microelectronics, CATT, KT

Agreement:

- Support both CLASS A and CLASS B with K≥1 CSI-RS resources for the eMIMO-Type of semi-open-loop
  - For dual-stage codebook,
    - RI, i_1 and CQI reporting is supported for {CLASS A} and {CLASS B with K=1 and 8Tx/alternate 4Tx codebooks}
      - FFS: reporting i11 and/or i12 for Class A codebooks
    - CRI, RI, i_1 and CQI reporting is supported for CLASS B with K>1
    - FFS: reporting i1 and subsampled i2
    - FFS: Hybrid CSI with semi-open-loop
    - FFS: Reporting multiple CRIs for CLASS B K>1
  - For single-stage codebook with 2 and 4 ports (CLASS B with K>1), CRI, RI and CQI are reported
  - For single-stage codebook with 2 and 4 ports (CLASS B with K=1), RI and CQI are reported
- Support RE level transmitter operation on PDSCH for both CSI reporting and PDSCH transmission
  - Down selection from the following transmission schemes in RAN1#86bis, including possible combination
    - Precoder cycling
    - Tx diversity
    - LD-CDD
    - Layer Permutation

R1-168048 WF on DMRS-Based Open-Loop/Semi-Open-Loop CATT, Nokia, Alcatel-Lucent Shanghai Bell, CATR, Huawei, HiSilicon, InterDigital, Intel, Qualcomm

Conclusion: RAN1#86bis: companies need to justify the need for introducing new DMRS pattern(s) to support open-loop/semi-open-loop transmission scheme. Otherwise the proposal in R1-168048 is agreed.

R1-166275	Discussion on DMRS based OL and Semi-OL Transmission	Qualcomm Incorporated
R1-166328	DMRS-based Semi-Open-Loop Transmission	ZTE Corporation, ZTE Microelectronics
R1-166344	DMRS-based Semi-open Transmission Schemes	Nokia, Alcatel-Lucent Shanghai Bell
R1-166449	Transmission scheme for OL-MIMO	CATT
R1-166450	CSI feedback for OL-MIMO	CATT
R1-166527	Remaining details of open loop techniques	Intel Corporation
R1-166737	Discussions on open and semi-open loop transmission in eFD-MIMO	Samsung
R1-166738	Simulation results for precoder cycling based on semi-open-loop transmission	Samsung

Petitioners' Exhibit 1003, p. 943
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166846 Initial performance evaluation on semi-OL MIMO LG Electronics
R1-167351 Enhancements for DMRS-based semi-open-loop MIMO schemes NTT DOCOMO, INC.
R1-167646 DMRS-based Open-loop MIMO Design Ericsson
R1-167676 DMRS based open loop transmission Huawei, HiSilicon
R1-167807 Evaluations on DMRS based Semi-open loop MIMO schemes CEWiT

7.2.5 Downlink Multiuser Superposition Transmission for LTE - *WID in RP-161019*

R1-168406 Chairman's notes of AI 7.2.5 on Downlink Multiuser Superposition Transmission for LTE Ad-Hoc chair (Qualcomm)
The document was presented by Wanshi Chen from Qualcomm.
Decision: The document is endorsed and incorporated as follows.

7.2.5.1 *Superposition transmissions*

Power ratios, modulation, etc

Power ratio
R1-166185 Further discussion on power ratios for MUST Huawei, HiSilicon
R1-166277 Power ratio set considerations for MUST Qualcomm Incorporated
R1-166847 Discussion on power ratio and modulation order LG Electronics
R1-167508 Selection of power ratios for MUST Case1 & 2 MediaTek Inc.
R1-167689 MUST Case 1 and 2 transmission schemes Nokia, Alcatel-Lucent Shanghai Bell

R1-168141 Way forward on Power Ratios ZTE, ZTE Microelectronics, MediaTek, ITRI
R1-168152 WF on power ratios for MUST Case 1/2 Nokia, ASB, Qualcomm
R1-168316 Way Forward MUST power ratios Huawei, HiSilicon, MediaTek

Agreement:
- For Case 1/2, numbers of power ratios should be decided based on system level simulation and analysis:
  - For QPSK + QPSK, number of power ratios is to be selected from 2/3/4
  - For QPSK + 16 QAM, number of power ratios is to be selected from 2/3/4
  - For QPSK + 64 QAM, number of power ratios is to be selected from 1/2/3/4

Conclusion:
Companies are encouraged to provide principle of generating power ratio, examples are:
- Super-constellation/grid coordinates
  - Supported: Huawei, HiSilicon, Qualcomm, MediaTek, Nokia, ASB, KT
- Evenly spaced
  - Supported: ZTE, Mediatek, LG

Note that final selection of power ratios can be a combination of the above examples.

R1-168280 Way Forward on the Gray conversion LG Electronics, ZTE, ZTE Microelectronics, Huawei, HiSilicon

Agreements:
- For Gray-mapped composite constellation:
  - Alt 1: Bit-level Gray conversion is specified
  - Alt 2: Symbol-level Gray conversion is specified
  - Alt 3: up to implementation (where the bits are mapped to the composite-constellation)
- Down-select one alternative till next meeting

R1-168142 Way forward on MUST Transmission ZTE, ZTE Microelectronics, MediaTek, Sharp
Continue discussion next meeting

R1-168279 Way Forward on MUST UE multiplexing Huawei, HiSilicon
Proposals:
- In all PDSCH REs, the composite constellation symbols transmitted in a given sub-frame and a given spatial layer to a same MUST-near UE carry the same number of MUST-near UE codeword bits

Continue discussion next meeting

R1-166276 Superposition transmissions Qualcomm Incorporated
R1-166424 Simulation for power ratio down selection ZTE

Petitioners' Exhibit 1003, p. 944
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166425 Specification for joint modulation Gray mapping ZTE
R1-166848 Discussion on Gray mapping for superposed constellation LG Electronics
R1-167121 Discussion on superposition transmission Intel Corporation
R1-167131 MUST UE multiplexing and resource allocation Huawei, HiSilicon
R1-167363 Discussion on power ratios optimization for MUST scheme NTT DOCOMO, INC.
R1-167407 Discussion on EVM constraint for MUST Case1&2 ITRI
R1-167408 Discussion on Power Ratios for MUST Case 1&2 ITRI
R1-167511 On power allocation for MUST MediaTek Inc.
R1-167775 On Considerations of Power Ratios for MUST KT Corp.
R1-168071 Performance of MUST with HARQ National Taiwan University
R1-168072 Design issues of MUST with HARQ National Taiwan University

7.2.5.2 Mechanisms for efficient operation

Related RRC signaling, DCI, UE blind detection etc.

R1-168328 Way Forward on MUST DCI Design for Case 1&2 Qualcomm, Nokia, ABS, NEC

Agreement:
- Consider the following options for providing MUST-near UE co-schedule information
  - Alt 1. Single DCI by adding bits in the self DCI
    - FFS details (particularly regarding RA alignment)
  - Alt 2. Use common companion DCI to carry all MUST-far UE information
    - FFS details (particularly regarding RA alignment)
  - Alt3. Use user-specific companion DCI to carry all MUST-far UE information within near-UE allocation
    - FFS details (particularly regarding RA alignment)
  - Other alternatives are not precluded
  - FFS the number of blind decodes
- Down-select one option until next meeting

R1-168241 Way Forward on MUST Assistance Information in Cases 1 and 2 MediaTek, Huawei, HiSilicon, NTT DOCOMO, CMCC

Agreements:
- The following assistance information is provided to MUST-near UE
  - For CRS based transmission schemes in MUST Case 1, the information of "existence of MUST interference" and "power ratio" is provided for each spatial layer
  - For MUST Case 2, "existence of MUST interference" and "power ratio" are signaled
  - FFS: how to signal "existence of MUST interference" (particularly the granularity) and "power ratio"

R1-168317 Way Forward on signaling design for MUST new DCI Huawei, HiSilicon, Media Tek, China Telecom, NTT DOCOMO, LG Electronics
R1-168149 WF on the Design Principle for a new DCI LG Electronics, MediaTek, Huawei, HiSilicon

Agreements:
- A new DCI should follow the design principles
  - In addition to assistance information, all legacy DCI contents should be able to be signaled to MUST UE.

R1-168376 WF on the number of MUST layers for Case 3 LG Electronics, MediaTek
Continue discussion next meeting

R1-168336 Way forward for Case 3 of MUST ZTE, ZTE Microelectronics, Qualcomm, Sharp

Agreements:
- For DMRS based Case 3, support multiuser superposition transmission with orthogonal ports
  - FFS non-orthogonal ports

R1-168150 WF on PDSCH starting symbol LG Electronics, MediaTek

Agreements:

Petitioners' Exhibit 1003, p. 945
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- The starting symbol of interfering PDSCH to be canceled or suppressed should be provided to MUST UE by one of the following the two options:
  - Option 1: it should be blindly detected or signaled (assuming potentially different starting symbols)
  - Option 2: MUST UE assumes the same starting symbol of interfering PDSCH as its own PDSCH
- Down-selection till next meeting

R1-166186	Discussion on signaling design for MUST	Huawei, HiSilicon
R1-166278	Mechanisms for efficient operation	Qualcomm Incorporated
R1-166279	MUST UE pairing with existing CQI feedback	Qualcomm Incorporated
R1-166426	Mechanism for MUST operation	ZTE
R1-166451	Support of downlink superposition transmission	CATT
R1-166646	Power control and configuration for MUST	NEC
R1-166647	New DCI design for MUST	NEC
R1-166849	Discussion on Signaling Assistance Information and remaining issues	LG Electronics
R1-167094	On signaling design for MUST case 3	CMCC
R1-167122	On downlink control signalling for MUST	Intel Corporation
R1-167167	Demodulation performance for MUST far UE	Huawei, HiSilicon
R1-167364	Discussion on remaining issues and signaling design for DL MUST	NTT DOCOMO, INC.
R1-167443	Power ratio and assistance information for MUST case 1 and case 2	China Telecommunications
R1-167513	On scheduling constraints for MUST operation	MediaTek Inc.
R1-167514	Supported TMs for MUST	MediaTek Inc.
R1-167610	Signaling for MUST	SHARP Corporation, MTI
R1-167688	On network assistance and operation of MUST	Nokia, Alcatel-Lucent Shanghai Bell
R1-168143	WF on DCI for case 1 and case 2	ZTE

7.2.5.3 Evaluation for MUST using up to 8Tx

Conclude evaluation etc.

Evaluations

R1-166427	**Discussion and evaluation for MUST Case 3**	**ZTE**
R1-167095	**Non-full buffer Evaluation for MUST case 3 DMRS-based TM**	**CMCC**
R1-167690	**System-level Evaluation of Case 3 MUST**	**Nokia, Alcatel-Lucent Shanghai Bell**
R1-167515	**System-level evaluation for MUST Case 3**	**MediaTek Inc.**

Revised in R1-167890

R1-168291	**WF on MUST supported TMs**	**CMCC, Nokia, ASB, MTK, ZTE**

Agreements:

- DMRS-based Case 3 is supported in
  - TM 8/9/10

Conclusion:

- Case 1&2 using up to 4Tx is not supported in DMRS-based TM

Possible working assumption:

- CRS-based Case 3 using 2Tx and 4Tx is supported in TM 4
  - Supported by: Nokia, ASB, ZTE, MTK, CMCC
  - Objected by: Huawei, HiSilicon, LG
  - Companies are encouraged to bring more results to confirm/abandon the WA.

Continue discussion next meeting

R1-168144	**Way forward on Mechanism for Case 3**	**ZTE, ZTE Microelectronics, Qualcomm, Sharp**

R1-167365	Evaluation for CRS-based MUST with 4 Tx antennas	NTT DOCOMO, INC.
R1-167890	System-level evaluation for MUST Case 3	MediaTek Inc.
R1-168292	WF on supporting MUST case 3	CMCC

7.2.5.4 Other

R1-166187	Implementation for MUST transmitter	Huawei, HiSilicon

Petitioners' Exhibit 1003, p. 946
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.2.6 eMBMS enhancements for LTE - *WID in RP-161297*

R1-168407 **Chairman's notes of AI 7.2.6 on eMBMS enhancements for LTE** **Ad-Hoc chair (Nokia)**
The document was presented by Matthew Baker from Nokia.
Decision: The document is endorsed and incorporated as follows.

7.2.6.1 *Longer cyclic prefix for MBSFN subframe*

R1-167090 **Background Information on Inter-site Distances** **BBC**

R1-167749 **Link level simulation assumptions** **Huawei, HiSilicon**
Note that delays in Table 1 should be a factor of 10 larger.

R1-168070 Summary of email discussion Ericsson

R1-166177 **Evaluations of longer CP for eMBMS** **Huawei, HiSilicon**
R1-166280 **System level Evaluation results for longer cyclic prefix** **Qualcomm Incorporated**
R1-167841 **System simulation results for longer CP in MBSFN subframes** **Ericsson**
R1-166281 **Design options for longer cyclic prefix and link level simulation results** **Qualcomm Incorporated**

R1-166528 **Considerations on longer cyclic prefix for MBSFN subframes** **Intel Corporation**

R1-167842 MBSFN reference signal design Ericsson

R1-168366 **WF on eMBMS Enhancements** **Qualcomm, Ericsson, BBC, EBU, Nokia, ASB, Dish, AT&T, Telstra, Fraunhofer IIS, Verizon, Telefónica, Intel**
Also supported by Nomor

Agreement:

- A single new numerology with a CP of at least 100us and core symbol duration of at least 400us is introduced for PMCH
  - Working assumption that the CP length is 200us and core symbol duration of 800us.
  - Link level results may be provided at RAN1#86bis.
  - Working assumption then to be confirmed at RAN1#86bis.

Agreements in respect of at least objectives a, b and c:

- If a carrier is operated with 100% MBSFN subframe allocation, the new CP length and legacy extended CP for 15kHz subcarrier spacing are supported
  - It is understood that 100% MBSFN subframe allocation does not preclude some resources being set aside for e.g. cell search
    - FFS: Any SI that may be needed on this carrier will also be broadcasted in these subframes
    - In these subframes, FDM between PMCH and other channels (potentially with a different numerology) is not precluded.
  - With the 100% MBSFN subframe confuguration, this carrier does not support unicast transmissions in the downlink
  - This carrier can be configured without a unicast control region in a subset of the MBSFN subframes (including all of them)
    - The UE is not expected to receive PMCH with legacy extended CP for 15kHz subcarrier spacing in the MBSFN subframes without unicast control region
    - The UE is not expected to receive PMCH with the new CP in MBSFN subframes with unicast control region
- If a carrier is operated with less than 100% MBSFN subframe allocation, the new CP length and legacy extended CP for 15kHz subcarrier spacing are supported
  - This carrier has at least subframes 0 and 5 of each radio frame as non-MBSFN subframes
    - FFS: Further CRS reductions
  - This carrier can be configured without unicast control region in a subset of the MBSFN subframes (including all of them)
    - The UE is not expected to receive PDSCH/(E)PDCCH in the MBSFN subframes without unicast control region
    - The UE is not expected to receive PMCH with numerologies other than the new CP length in the MBSFN subframes without unicast control region
    - The UE is not expected to receive PMCH with the new CP length in MBSFN subframes with unicast control region
- eMBMS enhancements do not require changes to any channels and signals needed for MBMS operation except PMCH and MBSFN-RS

Petitioners' Exhibit 1003, p. 947
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- FFS whether use of more REs, TTI extension and/or change in payload are needed for PBCH coverage enhancements.

R1-168449 **WF on the support of longer CP in MBSFN subframes** **Huawei, HiSilicon, Orange, ZTE**
Proposal:
- Whether to introduce a new CP beyond the existing LTE CPs for eMBMS transmissions in Rel-14 should be concluded after the mapping of the SINR achievable with a 95% coverage probability to the corresponding MCS is agreed.

R1-168029 **Draft LS regarding agreements for FeMBMS** **Qualcomm**
Decision: The document is noted and final LS is approved in R1-168200.

7.2.6.2 Increased number of MBSFN subframes per radio frame

R1-166193 **Radio frame design for increased number of MBSFN subframes** **Huawei, HiSilicon**
R1-166282 **Increased number of MBSFN subframes per radio frame** **Qualcomm Incorporated**
R1-167789 **eMBMS cell support of PSS/SSS/PBCH** **Nokia, Alcatel-Lucent Shanghai Bell**

R1-167843 Radio frame design for extended MBSFN subframe allocation Ericsson
R1-166529 Design guidelines to increase the number of MBSFN subframes per radio frame Intel Corporation

7.2.6.3 MBSFN subframes without a unicast control region and cell-specific reference signals

R1-167784 MBSFN subframe unicast control region considerations Nokia, Alcatel-Lucent Shanghai Bell
R1-167748 On MBSFN subframes without a unicast control region and cell-specific reference signals Huawei, HiSilicon
R1-166283 MBSFN subframes without a unicast control region and cell-specific reference signals Qualcomm Incorporated
R1-166530 On MBSFN subframes without a unicast control region and cell-specific reference signals Intel Corporation

7.2.6.4 Other

R1-166284 Standalone eMBMS carrier Qualcomm Incorporated
R1-166285 Simultaneous reception of broadcast and unicast Qualcomm Incorporated

7.2.7 SRS Carrier Based Switching for LTE - *WID in RP-160935*

R1-168408 **Chairman's notes of AI 7.2.7 on SRS Carrier Based Switching for LTE** **Ad-Hoc chair (Huawei)**
The document was presented by Weimin Xiao from Huawei.
Decision: The document is endorsed and incorporated as follows.

R1-168276 **Way Forward on SRS Carrier-Based Switching** **Huawei, HiSilicon, SoftBank Corp.**

7.2.7.1 SRS Transmission on TDD CCs without PUSCH

Including details for power control, timing advance, and possible new symbol positions

R1-166127 **SRS symbol positions for SRS switching** **Huawei, HiSilicon**
R1-166286 **SRS Transmission on TDD CCs without PUSCH** **Qualcomm Incorporated**
R1-166452 **Further considerations on SRS carrier based switching** **CATT**
R1-166531 On SRS transmission without PUSCH Intel Corporation

Agreement:
- No consensus to support in Rel-14 new SRS symbol position in addition to already agreed ones.

R1-167715 **Power control for SRS switching** **Nokia, Alcatel-Lucent Shanghai Bell**
R1-167485 **Support of power control mechanism for SRS transmission in cells without configured PUSCH transmission** **Ericsson Inc.**
R1-166128 Details on power control for SRS on TDD CCs without PUSCH Huawei, HiSilicon
R1-166739 SRS Transmission Aspects for Carrier Switching Samsung

Agreements:
- PC parameters
  - Configure open loop parameters Po and alpha for SRS-only CC
  - No need to have P_SRS_offset

Petitioners' Exhibit 1003, p. 948
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Down selection from TPC command options:
  - Option 1: by UL grant DCI 0/4 (with cross-carrier indication)
  - Option 2: by DL DCI (with cross-carrier indication)
  - Option 3: by group DCI
  - Adopt Option 3 and only apply to SRS-only CC without PUSCH
    - Joint group DCI for triggering and TPC
    - FFS: Number of bits for each UE and the meaning for the states of the field
    - Introduce RNTI for the group
- Support 2 types of PHR as in Rel-13
  - Details FFS
- Dropping/power scaling rules as in Rel-13

R1-167484 **Support of non-contention based PRACH transmission** **Ericsson Inc.**
R1-166129 Details on timing advance for SRS on TDD CCs without PUSCH Huawei, HiSilicon

Agreements:
- SRS-only CC without PUSCH needs to be configured in a TAG
- PRACH
  - PRACH trigger and SRS trigger for a SRS-only carrier are independent
  - Support all PRACH preamble formats

7.2.7.2 Details of periodic and/or aperiodic SRS

R1-166287 **Details of Periodic and/or aperiodic SRS** **Qualcomm Incorporated**
R1-166740 P-SRS and A-SRS Transmission with Carrier Switching Samsung

Agreements:
- For A-SRS, trigger is carried in:
  - DL scheduling DCI and group DCI
  - Group DCI is only used for SRS-only CC without PUSCH
- In addition to all existing parameter configurations
  - In case the UE supports multiple switching-from CCs, selected by
    - Option 1: rule(s) defined
    - Option 2: RRC configuration

R1-166130 Support of periodic SRS Huawei, HiSilicon
R1-167446 Further considerations on aperiodic SRS Ericsson Inc.
R1-166532 Remaing details of SRS triggering with CC switching Intel Corporation
R1-166131 Support of aperiodic SRS Huawei, HiSilicon

7.2.7.3 Details of collision handling

R1-166132 **Details on collision handling for SRS switching** **Huawei, HiSilicon**
R1-166288 **Collision Handling** **Qualcomm Incorporated**
R1-166533 Collision handling for SRS CC-based switching Intel Corporation
R1-166741 SRS Collisions in Carrier Switching Samsung
R1-167483 Impact of slot dropping in SRS switching Ericsson Inc.
R1-167757 Proposals on collision handling for SRS switching SoftBank Corp.

7.2.7.4 Other

R1-167716 **SRS switching UE capability** **Nokia, Alcatel-Lucent Shanghai Bell**

Agreements:
- UE reports the switching time/interruption time for SRS switching
  - FFS: Per band-pair or Per CC-pair
  - FFS: set of potential values

Agreements:
- R14 SRS switching supports RF retuning time no longer than X us
  - Option 1: X = 200
  - Option 2: X = 300
  - Option 3: X = 500
  - Option 4: X = 900

Petitioners' Exhibit 1003, p. 949
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Agreement: Send LS to RAN4 and RAN2 with the agreements achieved during this meeting

R1-166289 **Support of multiple antennas for SRS switching** **Qualcomm Incorporated**
R1-166133 **SRS switching for UEs with multiple antennas** **Huawei, HiSilicon**

Agreements:
- Support SRS from each of the multiple antennas with carrier switching for periodic and aperiodic SRS
  - For 2 antenna cases, supported if UE is capable of UL 2x2 MIMO or 2 antenna switching
  - For 4 antenna cases, supported if UE is capable of UL 4x4 MIMO or 4 antenna switching (if introduced)
  - Details FFS

Friday
R1-168470 **Draft LS for SRS Carrier-Based Switching** **Huawei**
Decision: The document is noted and final LS is agreed in R1-168556

7.2.8 Further Indoor Positioning enhancements for UTRA and LTE -WID in RP-160538

R1-168409 **Chairman's notes of AI 7.2.8 on Further Indoor Positioning enhancements for UTRA and LTE** **Ad-Hoc chair (Qualcomm)**
The document was presented by Wanshi Chen from Qualcomm.
Decision: The document is endorsed and incorporated as follows.

7.2.8.1 Remaining issues for OTDOA enhancements

R1-168266 **WF on PRS sequence generation per TP** **Huawei, HiSilicon, Nokia, Alcatel-Lucent Shanghai Bell**
Decision: The way forward is agreed. LS is to prepared in R1-168447.
Friday
R1-168447 **[Draft] LS on PRS sequence generation per TP** **Huawei**
Decision: The document is noted and final LS is agreed in R1-168557.

R1-168337 **Draft CR on PRS sequence generation per TP** **Huawei, HiSilicon**
R1-168086 **Way forward on CRS usage together with PRS** **Intel Corporation, Acorn Technologies, Huawei, HiSilicon**
Proposal:
- Support the use of CRS together with PRS for OTDOA enhancement
  - If CRS usage together with PRS is configured,
    - Signal CP information for CRS if PRS is present.
      - Note: this CP information signaling is additional one to the existing CP signaling for PRS.
    - Quasi-collocation between PRS and CRS is assumed.
- Send the LS for the above to RAN2 to be captured for their works

Study till next meeting

R1-168289 **WF on Rich RSTD reporting for OTDOA** **Ericsson, Nokia, Qualcomm**
Conclusion:
- RAN1 can further study the following for the OTDOA enhancement
  - Richer RSTD reporting by UE to E-SMLC

R1-166290 PRS sequence generation and value range for PRS-ID Qualcomm Incorporated
R1-166291 Introduction of UE inter-frequency RSTD calibration accuracy reporting Qualcomm Incorporated
R1-166952 RSTD Reporting Enhancement in OTDOA Nokia, Alcatel-Lucent Shanghai Bell
R1-166958 OTDOA Enhancement for Same PCI Issue Nokia, Alcatel-Lucent Shanghai Bell
R1-167148 Discussion on the PRS sequence generation per TP Huawei, HiSilicon
R1-167661 PRS sequence generation for same-PCI issue for enhanced indoor positioning Ericsson
R1-167662 Enhanced reference cell selection for enhanced indoor positioning Ericsson
R1-167663 Multipath RSTD reporting per cell for enhanced indoor positioning Ericsson
R1-167696 On range of virtual cell ID Intel Corporation
R1-167697 CRS Usage together with PRS Intel Corporation
R1-168087 Way forward on PRS sequence generation Intel Corporation

7.2.8.2 PRS-based beacons

R1-166292 PRS subframe configuration for PRS-based TBS Qualcomm Incorporated
R1-166293 PRS-only TBS Transmission Points Qualcomm Incorporated
R1-166954 Discussion of PRS-Based Beacon for Indoor Positioning Nokia, Alcatel-Lucent Shanghai Bell
R1-167664 PRS patterns for PRS-based TBS for enhanced indoor positioning Ericsson

Petitioners' Exhibit 1003, p. 950
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-168297 **WF on PRS-based TBS Qualcomm**
Decision: The way forward is agreed. LS is to RAN2 and RAN3 (cc-ing RAN4) prepared in R1-168466.
Friday
R1-168466 **[DRAFT] LS on PRS-based Terrestrial Beacon System (TBS) Qualcomm**
Decision: The document is noted and final LS is agreed in R1-168558.

7.2.8.3 E-CID enhancements

R1-167170 **WF on the same PCI for E-CID Huawei, HiSilicon, China Unicom**
R1-167665 **On CSI-RSRP reporting to E-SMLC for enhanced indoor positioning Ericsson**
R1-167149 **Further discussion on the same PCI case for E-CID enhancements Huawei, HiSilicon**
Conclusion

- Companies are encouraged to study E-CID enhancements according to the WID, especially considering existing techniques (e.g., cell portion)

R1-167150 Further discussion on the UE Rx-Tx measurement over multiple serving cells Huawei, HiSilicon

7.2.8.4 Other

R1-167666 Defining indoor/outdoor classification for enhanced indoor positioning Ericsson

7.2.9 Uplink Capacity Enhancements for LTE - *WID in RP-160664*

Specification of PUSCH in special subframe, with focus on the design of HARQ timing, TBS determination, UL DM-RS, TTI bundling, related signalling and procedure

R1-168410 **Chairman's notes of AI 7.2.9 on Uplink Capacity Enhancements for LTE Ad-Hoc chair (Ericsson)**
The document was presented by Sorour Falahati from Ericsson.
Decision: The document is endorsed and incorporated as follows.

R1-167100 **Work plan for UL capacity enhancement CMCC**
R1-166144 **Scheduling and HARQ timing for PUSCH on UpPTS Huawei, HiSilicon**
R1-166534 **PUSCH transmission in special subframe Intel Corporation**
R1-166294 **PUSCH in UpPTS Qualcomm Incorporated**
R1-166601 **Considerations on PUSCH design in special subframe ZTE Corporation**
R1-166635 **TTI bundling for uplink coverage enhancement NEC**
R1-167717 **HARQ timing for PUSCH transmission in special subframe Nokia, Alcatel-Lucent Shanghai Bell**

R1-166145 Signaling for PUSCH on UpPTS Huawei, HiSilicon
R1-166146 Transmission of PUSCH on UpPTS Huawei, HiSilicon
R1-166453 Support of PUSCH transmisison in UpPTS CATT
R1-167096 General Discussion on support of PUSCH in UpPTS CMCC
R1-167097 Timing for newly added PUSCH in UpPTS CMCC
R1-167098 Discussion on the TBS scaling design CMCC
R1-167099 Discussion on TTI bundling design for PUSCH in UpPTS CMCC
R1-167141 UCI in PUSCH on UpPTS Huawei, HiSilicon

R1-168096 **WF on new special subframe configuration CMCC, ZTE, CATT**
R1-168097 **WF on timing design for PUSCH in UpPTS CMCC**
R1-168098 **WF on TTI bundling for PUSCH in UpPTS CMCC, NEC**
R1-168099 **WF on TBS scaling design for PUSCH in UpPTS CMCC**

Agreement: Support a new special subframe configuration 10 as in the following table, with 6 DL symbols of NCP in DwPTS, together with 6 symbols of NCP in UpPTS or with 5 symbols of ECP in UpPTS

Petitioners' Exhibit 1003, p. 951
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Special subframe configuration	Normal cyclic prefix in downlink			Extended cyclic prefix in downlink		
	DwPTS	UpPTS		DwPTS	UpPTS	
		Normal cyclic prefix in uplink	Extended cyclic prefix in uplink		Normal cyclic prefix in uplink	Extended cyclic prefix in uplink
10	$13168 \cdot T_s$	$13152T_s$	$12800T_s$	-	-	-

- Send LS to RAN2 about the supported new special subframe configuration

Friday

R1-168396 **[Draft] LS on introducing a new special subframe configuration** **CMCC**

Decision: The document is noted and final LS is agreed in R1-168559.

Agreement: In UpPTS, independent transport block(s) is transmitted as a separate transmission resource

Agreement:

- Support synchronized HARQ timing
- For TDD UL/DL configuration 1~5, specify the timing from UL grant to PUSCH according to the following table, when supporting PUSCH transmission in UpPTS, i.e.,
  - *The UE shall upon detection of a PDCCH with DCI format 0/4 in subframe n intended for the UE, adjust the corresponding PUSCH transmission in subframe n+k, where the k is in the following table*

TDD UL/DL Configuration	DL subframe index *n*									
	0	1	2	3	4	5	6	7	8	9
1	6	6			4	6	6			4
2		5		4			5		4	
3	4							4	4	4
4								4	4	4
5								4	4	

Agreement: For TDD UL/DL configuration 0, reuse the UL index field in UL grant to schedule PUSCH in UpPTS.

Agreement:

- For TDD UL/DL configuration 1~5, down-select between the following options for HARQ transmission:
  - Option1: Only support adaptive HARQ transmission, i.e., the retransmission of a PUSCH in UpPTS is scheduled by a UL grant with NDI not toggled
  - Option2: Support both adaptive and non-adaptive HARQ transmission. For non-adaptive HARQ transmission, the PHICH is used, and the PHICH timing is designed based on the following principle:
    - Principle: To keep the backward compatibility, the PHICH corresponding to PUSCH in UpPTS can only be added in DL subframes including legacy PHICH region
- FFS if non-adaptive HARQ transmission is supported for TDD UL/DL configurations 0 and 6

Agreement:

- Support TTI bundling for TDD configuration 2 and 3 when supporting of PUSCH in UpPTS
- Specify the scheduling and HARQ timing for TTI bundling as follows
  - The UE shall upon detection of a PDCCH with DCI format 0 in subframe n intended for the UE, adjust the corresponding PUSCH transmission in subframe n+k, with k in the following table

TDD UL/DL Configuration	DL subframe number *n*									
	0	1	2	3	4	5	6	7	8	9
2		5		4			5		4	
3	4							4	4	4

7.2.10 Further Enhanced MTC for LTE - *SID in RP-161321*

R1-168411 **Chairman's notes of AI 7.2.10 on Further Enhanced MTC for LTE Ad-Hoc chair (Ericsson)**

Petitioners' Exhibit 1003, p. 952
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The document was presented by Johan Bergman from Ericsson.
Decision: The document is endorsed and incorporated as follows.

R1-167667 WI work plan for Further Enhanced MTC for LTE Ericsson

R1-168295 Draft LS regarding agreements for FeMTC Qualcomm, Huawei
Decision: The document is noted and final LS is agreed in R1-168300

7.2.10.1 Higher data rates

R1-166297 Support of larger data channel bandwidth Qualcomm Incorporated
R1-167892 Initial analysis on bandwidth and TBS increase for FeMTC Intel Corporation
Revision of R1-166536

Agreement:
- The wider bandwidth operation is enabled by eNB.
- Wider bandwidth PDSCH/PUSCH is cross subframe scheduled by MPDCCH.
- MPDCCH follows Rel-13 design, which implies that it can be decoded by a UE operating in narrowband operation (6RB).
- If a new grant is introduced for wideband PDSCH/PUSCH, the number of blind decodings of MPDCCH does not increase with respect to Rel-13 eMTC.

R1-166535 Views on support of higher data rates for FeMTC Intel Corporation
R1-167158 On supporting larger maximum TBS Huawei, HiSilicon
R1-168057 WF on support of larger maximum TBS and channel bandwidth for FeMTC Intel, Spreadtrum, Huawei, HiSilicon, Ericsson

Agreement:
- For Rel-14 FeMTC UEs, the maximum UL TBS for CEMode A UEs with maximum 1.4 MHz bandwidth in TDD/HD-FDD is increased to 2984 bits.
  - Idle mode operations reuse the Rel-13 eMTC design.
- Study till next meeting whether there are any issues with a maximum useable PDSCH/PUSCH channel bandwidth which is a multiple of 6 PRBs.
- For Rel-14 FeMTC UEs supporting larger UE channel BW for PDSCH and PUSCH:
  - The larger max. DL TBS is at least 2984 bits.
  - The larger max. UL TBS is at least 2984 bits.
- For Rel-14 FeMTC UEs with larger TBS and channel BW:
  - Idle mode operations reuse the Rel-13 eMTC design.

Agreement:
- For Rel-14 BL UEs in CE mode A (FFS for CE mode B), the single larger maximum UE channel BW for PDSCH and PUSCH in RRC connected mode is 5 MHz.
- For Rel-14 non-BL UEs in CE mode A (FFS for CE mode B), the single larger maximum UE channel BW for PDSCH and PUSCH in RRC connected mode is (FFS: 5 or 20) MHz.

R1-166296 Support of HARQ-ACK bundling in HD-FDD Qualcomm Incorporated
R1-166298 Support of higher data rates Qualcomm Incorporated
R1-166596 Higher performance targets for Further Enhanced MTC Apple Europe Limited
R1-166602 Consideration on larger channel bandwidth for FeMTC Nokia, Alcatel-Lucent Shanghai Bell
R1-166603 Increasing the number of HARQ processes in FeMTC Nokia, Alcatel-Lucent Shanghai Bell
R1-166625 Higher data rates for feMTC Sequans Communications
R1-166628 Techniques for supporting high data rate transmission for FeMTC NEC
R1-166660 Higher data rate for feMTC Sony
R1-166680 Ack Bundling Design Consideration Sierra Wireless, S.A.
R1-166850 Higher data rate support for FeMTC LG Electronics
R1-167159 On improving peak rate for HD-FDD in FeMTC Huawei, HiSilicon
R1-167161 Discussion on larger Max PDSCH/PUSCH channel bandwidth in FeMTC Huawei, HiSilicon
R1-167162 Analysis on increasing DL HARQ processes in CE mode A for FD-FDD Huawei, HiSilicon
R1-167195 Design for the higher data rates Kyocera Corporation
R1-167318 Support of HARQ-ACK bundling for MTC ZTE
R1-167319 Support of larger TBS and larger PDSCH/PUSCH bandwidth for MTC ZTE
R1-167352 Views on techniques to improve the data rate for Rel-14 MTC NTT DOCOMO, INC.

Petitioners' Exhibit 1003, p. 953
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-167418	Introduction of larger max TBS for MTC in TS36.213	Huawei
R1-167516	Discussion on Higher Data Rate for Further eMTC	Lenovo
R1-167668	Higher data rates for MTC	Ericsson
R1-167974	WF on supporting larger TBS in FeMTC	Huawei, HiSilicon
R1-168061	WF on harq bundling in hd-fdd for mtc	ZTE

7.2.10.2 Multicast

R1-168166 WF on Multicast for FeMTC Nokia, Alcatel-Lucent Shanghai-Bell, Ericsson, Qualcomm

Proposal:
- All BL/CE UEs supporting SC-PTM, are able to decode the SC-MCCH even if it is configured for worst case CE Mode B operation and the UE is only a CE Mode A capable UE
- A cell supporting FeMTC SC-PTM, has the option to configure multiple parallel SC-MTCH services.
- FFS: A BL/UE UE can receive SC-PTM services in:
  - Idle mode only
  - Connected mode only
  - Either Idle or connected modes
- A MPDCCH search space is used to schedule the SC-MCCH.
  - Both dynamic and SPS-like scheduling are supported
  - FFS: If the SS reuses existing definition or is a new SS.
- A MPDCCH search space is used to schedule the SC-MTCH.
  - Both dynamic and SPS-like scheduling are supported
  - FFS: If the SS reuses existing definition or is a new SS.

R1-166299	Support of multicast	Qualcomm Incorporated
R1-166537	On multicast support for Cat M1 UEs	Intel Corporation
R1-166605	SC-PTM for FeMTC General Considerations	Nokia, Alcatel-Lucent Shanghai Bell
R1-166606	SC-PTM for FeMTC Search Space Considerations	Nokia, Alcatel-Lucent Shanghai Bell
R1-167160	Consideration on SC-PTM transmission for FeMTC	Huawei, HiSilicon
R1-167320	Considerations on multicast support for MTC	ZTE
R1-167669	Overview of SC-PTM and common eMTC and NB-IoT aspects	Ericsson
R1-167670	Multicast support for MTC	Ericsson

7.2.10.3 Other

R1-166300	Paging channel enhancements	Qualcomm Incorporated
R1-167612	Power consumption reduction techniques for eMTC	Qualcomm Incorporated
R1-166607	VoLTE support for Cat-M1 UE	Nokia, Alcatel-Lucent Shanghai Bell
R1-166851	VoLTE support for FeMTC	LG Electronics

7.2.11 Enhancements of NB-IoT - WID in RP-161324.

The objectives apply to the in-band, guard-band, and standalone operation modes and the same coverage enhancement targets as defined in the Rel-13 NB-IoT work item.

R1-168412 Chairman's notes of AI 7.2.11 on Enhancements of NB-IoTAd-Hoc chair (Qualcomm)
The document was presented by Wanshi Chen from Qualcomm.
Decision: The document is endorsed and incorporated as follows.

R1-166189 NB-IoT Release 14 enhancements work plan Huawei, HiSilicon
Noted

7.2.11.1 Positioning

R1-168114 WF on observations on NB-IoT positioning performance Ericsson, ZTE
R1-168310 WF on simulation assumption for NB-IoT positioning ZTE, Ericsson, Nokia, Alcatel-Lucent Shanghai Bell

Agreement:
- R1-168310 is agreed with the following updates:
  - Slide 3, add UL transmission timing error modelling according to RAN4 requirements

The above agreement is captured in
R1-168363 WF on simulation assumption for NB-IoT positioning ZTE, Ericsson, Nokia, Alcatel-Lucent Shanghai Bell, Huawei, Hisilicon

Petitioners' Exhibit 1003, p. 954
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.2.11.1.1 Requirements

R1-167743 Requirements for NB IoT Positioning Enhancements Evaluations VODAFONE Group Plc
R1-167101 Discussion on positioning requirements for enhanced NB-IoT CMCC
R1-167790 Requirements for NB-IoT/eMTC positioning Deutsche Telekom AG

R1-167983 WF on requirements for NB-IoT positioning Huawei, HiSilicon

Agreed way forward for reporting to RAN#73

- Report the horizontal accuracy and TOA estimation accuracy at 67%.
- Report the operator requirement to strive towards horizontal accuracy of 50 m for 67% of NB-IoT UEs
- Report observations on positioning accuracy for stationary (i.e., 0 km/h) and pedestrian (i.e., 3 km/h) and 30km/h UEs. 120km/h may be evaluated during the design.
- Report observations for outdoor channel models, and outdoor-indoor channel models where they are available.
- Report observations on time to determine position according to MCL
  - This is the time from trigger for positioning to availability of a positioning estimate
- Report observations on impact of having a lower power class UE
- Report observations on network complexity/cost, for example including LMUs (as described in 36.111)
- Other requirements as for Rel-13 NB-IoT, including
  - Report changes UE complexity compared to Rel-13 NB-IoT
  - Report total impact to UE battery life
  - Report scalability to support massive numbers of UEs per cell
- Report dependency of accuracy performance on synchronous (E-SMLC is assumed to know the absolute timing of each involved eNB) or asynchronous networks
- Requirements are the same for all three operation modes (i.e. stand-alone/in-band/guard band) per the WID

- Companies can provide other inputs to RAN#73 on aspects outside the scope of RAN1 such as security, RAN sharing, etc.

R1-166171 NB-IoT positioning scenarios and requirements Huawei, HiSilicon
R1-166301 Requirements for narrowband positioning Qualcomm Incorporated
R1-167423 On requirements and assumptions for NB-IoT positioning Ericsson
R1-166587 NB-IoT positioning requirements Nokia, Alcatel-Lucent Shanghai Bell
R1-167321 Discussion of NB-IoT positioning requirement and evaluation methodology ZTE
R1-167424 A new system simulator for NB-IoT positioning Ericsson

7.2.11.1.2 Uplink-based narrowband positioning

R1-166173 Design of NB-IoT uplink positioning Huawei, HiSilicon
R1-166174 Evaluation of NB-IoT uplink positioning Huawei, HiSilicon
R1-166302 Uplink-based narrowband positioning Qualcomm Incorporated
R1-167322 UTDOA support for NB-IoT ZTE
R1-167425 On uplink-based positioning for NB-IoT Ericsson

R1-166588 UTDOA positioning in NB-IoT Nokia, Alcatel-Lucent Shanghai Bell
R1-166627 UTDOA based positioning for NB-IoT Fraunhofer IIS

R1-167426 On timing advance based multi-leg positioning for NB-IoT Ericsson

7.2.11.1.3 Downlink-based narrowband positioning

R1-167427 On Downlink-based narrowband positioning for NB-IoT Ericsson
R1-166303 Downlink-based narrowband positioning Qualcomm Incorporated
R1-166589 OTDOA positioning in NB-IoT Nokia, Alcatel-Lucent Shanghai Bell
R1-167323 OTDOA support for NB-IoT ZTE
R1-166172 Evaluation of NB-IoT downlink positioning Huawei, HiSilicon
R1-166852 Positioning support for eNB-IoT LG Electronics
Section 3

R1-167163 Design of NB-IoT downlink positioning Huawei, HiSilicon
R1-167740 Discussion on OTDOA for eNB-IoT III
R1-167752 Support of OTDOA in NB-IoT Innovative Technology Lab Co.

Petitioners' Exhibit 1003, p. 955
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.2.11.1.4 Comparison of uplink- and downlink-based methods

R1-168332 **WF on observations on performance aspects of NB-IoT positioning Huawei, HiSilicon**
Revision of R1-167984

Agreement: The WF is agreed with the following updates:
- Slide 5,
  - add "reusing of NPSS"
  - in ZTE's result, adding [.] for the sampling rate of 1920
  - Update the sentence from
    - For in-band operation, the positioning accuracy of OTDOA schemes evaluated by RAN1#86 reported by most companies is on the order of tens of meters. One evaluation found accuracy on the order of a few hundred meters
      To
    - For in-band operation, the positioning accuracy of OTDOA schemes evaluated by RAN1#86 reported by most companies is on the order of tens of meters.
      - One evaluation found accuracy on the order of a few hundred meters, which is under assumptions of Rel-13 UE complexity
- Slide 3, update the sentence from
  - (this sentence is not staying here) Companies have used differing simulation assumptions, which leads to the performance differences between companies. Comparisons can be made within each company's results.

  To
  - Companies have used different assumptions, which leads to the significant performance differences between companies. Results from different companies may not be comparable

R1-168333 **WF on observations on UE impact aspects of NB-IoT positioning Huawei, HiSilicon**
Revision of R1-167985
R1-168334 **WF on observations on network impact aspects of NB-IoT positioning Huawei, HiSilicon**
Revision of R1-167986

LS to RAN plenary (cc-ing RAN2/3/4) capturing the above 3 agreements to be drafted in R1-168552 (Huawei)
Friday:
R1-168552 **[DRAFT]LS on NB-IoT positioning Huawei**
Decision: The document is noted and final LS is agreed in R1-168553

R1-166175	Comparison of downlink and uplink positioning	Huawei, HiSilicon
R1-166176	UE complexity and power consumption analysis for NB-IoT positioning	Huawei, HiSilicon, Neul
R1-166304	Comparison of uplink and downlink based positioning	Qualcomm Incorporated
R1-166590	Comparison of UTDOA and OTDOA in NB-IoT	Nokia, Alcatel-Lucent Shanghai Bell
R1-166654	Considerations on NB-IoT positioning	Sony
R1-167164	Capacity limit evaluation	Huawei, HiSilicon
R1-167324	Comparison of NB-IoT positioning solution	ZTE
R1-167428	On uplink- and downlink-based positioning for NB-IoT	Ericsson
R1-167897	NB-IoT localization performance analysis and enhancement	Nokia, Alcatel-Lucent Shanghai Bell
R1-168094	Performance summary for NB-IoT Positioning	Nokia, Alcatel-Lucent Shanghai Bell

7.2.11.2 Multicast support

Extend Rel-13 SC-PTM to support multicast downlink transmission
R1-166178 **Physical layer design for multicast in NB-IoT Huawei, HiSilicon**
R1-166199 **Search space and collision handling for multicast in NB-IoT Huawei, HiSilicon**
R1-166538 **SC-PtM support for NB-IoT Intel Corporation**
R1-166591 **On Multicast support for NB-IoT Nokia, Alcatel-Lucent Shanghai Bell**

R1-167987 **WF on collision handling for NB-IoT SC-PTM Huawei, HiSilicon, ITL**

Agreement:
- SC-PTM in NB-IoT is supported at least in RRC_IDLE mode. FFS RRC CONNECTED mode.
- In RRC IDLE mode, priority between SC-PTM and the following needs to be decided at least for:
  - SC-PTM and paging, if there is a collision issue
  - SC-PTM and a random access procedure (e.g. for unicast BSR), if there is a collision issue
- If RRC_CONNECTED mode is supported, priority between SC-PTM and the following needs to be decided at least for:
  - SC-PTM and unicast, if there is a collision issue

Petitioners' Exhibit 1003, p. 956
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-167988 **WF on design principle of search space for NB-IoT SC-PTM** **Huawei, HiSilicon, ITL**
Continue discussion next meeting

R1-166305 Support of multicast Qualcomm Incorporated
R1-167325 Consideration for multicast support for NB-IoT ZTE
R1-167354 Discussion on multicast support for Rel-14 NB-IoT NTT DOCOMO, INC.
R1-167429 Multicast support for NB-IoT Ericsson
R1-167556 Discussion on SC-PTM in enhanced coverage MediaTek Inc.
R1-167753 Support of SC-PTM in NB-IoT Innovative Technology Lab Co., KT Corp.
R1-167877 Multicast support for eNB-IoT LG Electronics
R1-167883 Physical-layer processing for multi-segment transmission in NB-IoT Huawei, HiSilicon

7.2.11.3 Non-anchor PRB enhancements

Transmission of paging on non-anchor PRBs

R1-166306 **Non-anchor PRB enhancements Qualcomm Incorporated**
R1-168052 **WF on Paging on non-anchor PRBs Qualcomm Incorporated**
Also supported by Intel
R1-168062 **WF on Paging enhancement for Rel-14 NB-IoT ZTE, Nubia**
Also supported by ITL.

Agreements:

- For paging:
  - For a Rel-14 NB-IoT UE, both anchor and non-anchor PRB can be selected as the paging PRB
    - A Rel-14 UE chooses the PRB based on UE_ID
  - Paging message on NPDSCH is scheduled by NPDCCH on the same PRB**.**
- Send LS to RAN2 with these RAN1 agreements – (Qualcomm, ZTE)

Friday
R1-168362 **[DRAFT] LS regarding agreement on paging for NB-IoT Qualcomm**
Decision: The document is noted and final LS is agreed in R1-168554

R1-166854 **Non-anchor PRB enhancements for eNB-IoT LG Electronics**
Section 2
R1-167326 **Considerations to support paging on multiple PRBs ZTE**
R1-168344 **Paging PRB configuration for eNB-IoT LG Electronics, ITL**
Continue discussion next meeting.

R1-166179 On paging transmission on non-anchor NB-IoT PRB Huawei, HiSilicon
R1-166539 MCO enhancements for paging Intel Corporation
R1-166592 On non-anchor PRB enhancements for NB-IoT Nokia, Alcatel-Lucent Shanghai Bell
R1-167353 Initial views on the paging on non-anchor PRB for Rel-14 NB-IoT NTT DOCOMO, INC.
R1-167430 NB-IoT non-anchor carrier Paging Ericsson
R1-167431 Random Access on Non-Anchor Carriers in NB-IoT Ericsson

7.2.11.4 Other

R1-166593 Scheduling request multiplexing with ACK/NACK Nokia, Alcatel-Lucent Shanghai Bell
R1-166855 Low power UE support for eNB-IoT LG Electronics
R1-167557 Support of higher data rate for NB-IoT MediaTek Inc

7.2.12 Shortened TTI and processing time for LTE - *WID in RP-161299.*

R1-168413 **Chairman's notes of AI 7.2.12 on Shortened TTI and processing time for LTE Ad-Hoc chair (Nokia)**
The document was presented by Matthew Baker from Nokia.
Decision: The document is endorsed and incorporated as follows.

R1-167502 **Work plan for shortened TTI and processing time Ericsson**
R1-167069 **On LTE PHY processing time reduction Nokia, Alcatel-Lucent Shanghai Bell**

Petitioners' Exhibit 1003, p. 957
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.2.12.1 Shortened processing time for 1ms TTI

General

R1-167366 Views on shortened processing time for 1ms TTI NTT DOCOMO, INC.
R1-167497 Reduced processing for 1ms TTI Ericsson
Revised in R1-168307
R1-167501 Supported HARQ timings for 1ms TTI Ericsson
R1-167891 Processing time reduction and related procedures for 1ms TTI Huawei, HiSilicon
Revision of R1-166159
R1-166540 On reducing processing time for 1ms TTI Intel Corporation
R1-166692 Overview of latency reduction operation with subframe TTI for FS1 Samsung

Downlink

R1-166307 Shortened processing time for 1ms TTI for DL Qualcomm Incorporated
R1-167070 On processing time reduction between PDSCH transmission and DL HARQ feedback Nokia, Alcatel-Lucent Shanghai Bell
R1-166696 FDD DL HARQ-ACK feedback procedure for latency reduction with subframe TTI Samsung
R1-166454 HARQ and scheduling timing design for LTE processing timing reduction with 1ms TTI CATT

Uplink

R1-166308 Shortened processing time for 1ms TTI for UL Qualcomm Incorporated
R1-167500 Asynchronous HARQ for PUSCH Ericsson

R1-168230 WF on Tx timing for 1ms TTI LG Electronics, NTT DOCOMO, Ericsson, Qualcomm, ZTE Corp, ZTE Microelectronics, Panasonic, Sharp, Nokia, Alcatel-Lucent Shanghai Bell
R1-168192 WF on support of reduced processing time for 1ms TTI Intel, Ericsson, Huawei, HiSilicon, LG Electronics, Panasonic, Samsung, Nokia, Alcatel-Lucent Shanghai Bell, Sharp, NTT DOCOMO

Agreement:
- For FS1,2&3, a minimum timing n+3 is supported for UL grant to UL data and for DL data to DL HARQ for UEs capable of operating with reduced processing time with only the following conditions:
  - A maximum TA is reduced to x ms, where x <= 0.33ms (exact value FFS);
  - At least when scheduled by PDCCH
- For FS2, new DL HARQ and UL scheduling timing relations will be defined
  - Details FFS
- FFS:
  - Possible minimum timing of n+2 TTI
    - FFS max TA in this case
    - FFS what other restrictions (if any) on when reduced processing times of n+2 could be applied
  - Possibility of scheduling by EPDCCH.

R1-168243 WF on n+2 transmission timing for 1ms TTI Nokia, ASB

R1-168231 WF on fallback transmission for shortened processing time in 1ms TTI LG Electronics, Sharp, Huawei, HiSilicon, Qualcomm, Ericsson, Intel, NTT DOCOMO
Also supported by Nokia
Proposal:
- For UE capable of shortened processing time for 1ms TTI, the following fallback operations should be supported:
  - If PDCCH for DL assignment is transmitted in the common search space, use legacy processing timing with a minimum timing of 4ms for DL data to DL HARQ feedback
  - If PDCCH for UL grant is transmitted in the common search space, use legacy processing timing with a minimum timing of 4ms for UL grant to UL data
  - The above fallback operations are applied to both FS1 and FS2

Agreement:
- Reduced processing time(s) are RRC configured for the UE
- Working assumption: A mechanism for dynamic fallback to legacy processing timings (n+4) is supported
  - Details FFS
  - Working assumption can be revisited if it is not found to be feasible

Petitioners' Exhibit 1003, p. 958
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-168187 **WF on asynchronous UL HARQ Ericsson, Nokia, ASB**

Agreement:
- PHICH-less asynchronous HARQ for UL is used for 1 ms TTI with shortened processing time
  - For FS1 and FS2, bit fields are defined in the applicable DCI messages to indicate HARQ processes ID and RV
  - No change in FS3 asynchronous UL HARQ operation

Asynchronous HARQ: Qualcomm, Huawei, HiSilicon, Ericsson, LGE, ZTE, NTT Docomo, Nokia, ASB, Spreadtrum, Sharp
Synchronous HARQ: Samsung, CATT, ITRI,
Configurable by the network: Samsung, CATT, ITRI

R1-168261 **WF on support of Synchronous UL HARQ Samsung**
Proposal:
- PHICH-based synchronous HARQ for UL is supported for 1 ms TTI with shortened processing time for FS1 and FS2.
- For FS3, asynchronous UL HARQ is supported for 1 ms TTI with shortened processing time.

R1-166693 Overview of latency reduction operation with subframe TTI for FS2 Samsung
R1-166694 Overview of latency reduction operation with subframe TTI for FS3 Samsung
R1-166695 Processing time reduction for latency reduction with subframe TTI Samsung
R1-166697 TDD DL HARQ-ACK feedback procedure for latency reduction with subframe TTI Samsung
R1-166698 UL HARQ-ACK feedback procedure for latency reduction with subframe TTI Samsung
R1-166856 Consideration for shortened processing time for 1ms TTI LG Electronics
R1-166857 Discussion on CSI feedback for 1ms TTI with reduced processing time LG Electronics
R1-166995 Shortened Processing Time Analysis Spreadtrum Communications
R1-167016 Latency reduction for FS2 with 1ms TTI Nokia, Alcatel-Lucent Shanghai Bell
R1-167017 On HARQ-timing with 1-ms TTI and reduced processing times Nokia, Alcatel-Lucent Shanghai Bell
R1-167071 On processing time reduction between UL grant and UL data transmission Nokia, Alcatel-Lucent Shanghai Bell
R1-167083 System level study on processing time reduction with 1ms TTI Nokia, Alcatel-Lucent Shanghai Bell
R1-167084 Mechanism for indicating the processing time to the UE for 1ms TTI Nokia, Alcatel-Lucent Shanghai Bell
R1-167147 Performance evaluation of short TTI vs. 1ms TTI with processing time reduction Huawei, HiSilicon
R1-167367 HARQ/Scheduling timing for FS2 with Shortened processing time for 1ms TTI NTT DOCOMO, INC.
R1-167499 Fast CSI for 1ms TTI Ericsson
R1-167577 HARQ with shortened processing time for 1ms TTI ZTE Corp, ZTE Microelectronics
R1-167582 Some issues in 1ms TTI latency reduction operation ZTE Corp, ZTE Microelectronics
R1-167597 Considerations on processing time reduction for legacy TTIs Mediatek Inc.
R1-167611 Shortened processing time for 1ms TTI SHARP Corporation
R1-168232 WF on PUCCH resource allocation for shortened processing time for 1ms TTI LGE, Intel
R1-168275 WF on reduced processing time for 1ms TTI Samsung, Huawei, HiSilicon
R1-168307 Reduced processing for 1ms TTI Ericsson

7.2.12.2 Shortened TTI length together with shortened processing time

7.2.12.2.1 Design of sTTI for DL and UL

R1-168350 **WF on sPDCCH Huawei, HiSilicon, Qualcomm, Ericsson, Nokia, ASB, InterDigital, Xiaomi Communication, NTT DOCOMO, CATT, Samsung, Intel, LG, ZTE, ZTE Microelectronics, Spreadtrum, Sharp, CATR, Panasonic, Potevio, Mediatek, Motorola Mobility, Lenovo, NEC, SONY**

R1-168533 **WF on UL DMRS for sTTI Huawei, HiSilicon, Nokia, ASB, Ericsson, Potevio, Qualcomm, CATT, Intel, Spreadtrum, LG, Mediatek, Samsung, ZTE, ZTE Microelectronics, NTT DOCOMO, Panasonic, Sony**

R1-168500 **WF on short TTI lengths LG Electronics, Ericsson, Intel, NTT DOCOMO, CATT, Sharp, Samsung, Huawei, HiSilicon, Qualcomm, ZTE Corp, ZTE Microelectronics, Nokia, Alcatel-Lucent Shanghai Bell, MediaTek, Panasonic, KT Corp**

R1-168482 **Way forward on search space for sTTI Ericsson, Huawei, HiSilicon, Intel, CATT, Panasonic, NTT DOCOMO, LG Electronics**

Agreements:
- The DL sTTI length of a UE is indicated by eNB
  - FFS details of configuration (based on RRC or PDCCH)

Petitioners' Exhibit 1003, p. 959
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166143 Discussion on the HARQ issues for TTI length reconfiguration Huawei, HiSilicon
R1-166147 Discussion on sTTI length Huawei, HiSilicon
R1-166148 sPDCCH design for short TTI Huawei, HiSilicon
R1-166149 Details of two-level DCI schemes for short TTI Huawei, HiSilicon
R1-166150 Discussion on DCI design for short TTI Huawei, HiSilicon
R1-166151 PDSCH design for short TTI Huawei, HiSilicon
R1-166152 PUCCH design for short TTI Huawei, HiSilicon
R1-166153 PUSCH design for short TTI Huawei, HiSilicon
R1-166154 UCI on sPUSCH Huawei, HiSilicon
R1-166155 Discussion on DL RS for short TTI Huawei, HiSilicon
R1-166156 Discussion on UL RS for short TTI Huawei, HiSilicon
R1-166309 Dl design for shortened TTI Qualcomm Incorporated
R1-166310 UL design for shortened TTI Qualcomm Incorporated
R1-166455 sPDCCH design for LTE short TTI CATT
R1-166457 sPUSCH design for LTE short TTI CATT
R1-166458 Discussion on UL sTTI operation CATT
R1-166459 sPUCCH design for LTE short TTI CATT
R1-166460 Discussion on the simultaneous transmissions of normal TTI and sTTI CATT
R1-166541 DCI formats for shorten TTI Intel Corporation
R1-166542 On sPDCCH design for shoten TTI Intel Corporation
R1-166543 UL channes design for shorten TTI Intel Corporation
R1-166629 sPDSCH/sPDCCH with 2-symbol sTTI and 1-slot sTTI NEC
R1-166661 Discussion on sPDCCH for shortened TTI Sony
R1-166699 Overview of sTTI operations Samsung
R1-166700 sDCI design for sTTI operations Samsung
R1-166701 sPDCCH for 2-symbol sTTI Samsung
R1-166702 sPDCCH for 1-slot sTTI Samsung
R1-166703 sPDSCH for 2-symbol and 1-slot sTTI Samsung
R1-166704 sPUCCH for 2-symbol, 4-symbol and 1-slot sTTI Samsung
R1-166705 sPUSCH for 2-symbol, 4-symbol and 1-slot sTTI Samsung
R1-166706 TDD-specific issues on sTTI operations Samsung
R1-166707 Coexistence between subframe TTI and sTTI operations for DL and UL Samsung
R1-166858 Discussions on sPDCCH for latency reduction LG Electronics
R1-166859 Discussions on sPDSCH for latency reduction LG Electronics
R1-166860 sPUCCH design for HARQ-ACK feedback with shortened TTI length LG Electronics
R1-166861 sPUCCH design for CSI feedback with shortened TTI length LG Electronics
R1-166862 Discussion on UL design for shortened TTI LG Electronics
R1-166966 Discussion on single level DCI and two-level DCI Panasonic
R1-166968 UL simultaneous transmission between sTTI and TTI Panasonic
R1-166972 Discussion on reference signal design for shortened TTI Panasonic
R1-166973 Discussion on multiplexing between sTTI and TTI in the same subframe Panasonic
R1-166996 Discussion on sPDCCH design for sTTI Spreadtrum Communications
R1-166997 Discussion on sPUSCH design for sTTI Spreadtrum Communications
R1-167018 On requirements of DM-RS design for UL shorter TTI Nokia, Alcatel-Lucent Shanghai Bell
R1-167019 Simultaneous Transmissions of UL Signals for Shortened TTI Operation Nokia, Alcatel-Lucent Shanghai Bell
R1-167021 sPUCCH design for shortened TTI Nokia, Alcatel-Lucent Shanghai Bell
R1-167022 Considerations of slot-level sTTI for FS2 Nokia, Alcatel-Lucent Shanghai Bell
R1-167072 On simultaneous unicast PDSCH and sPDSCH operation Nokia, Alcatel-Lucent Shanghai Bell
R1-167081 On DL control channel design for shorter TTI operation Nokia, Alcatel-Lucent Shanghai Bell
R1-167082 On two-level DL control channel design for shorter TTI operation Nokia, Alcatel-Lucent Shanghai Bell
R1-167085 On details of DMRS design for DL shorter TTI Nokia, Alcatel-Lucent Shanghai Bell
R1-167102 Discussion on HARQ timing for shortened TTI in TDD CMCC
R1-167189 Discussion on CA issues for shortened TTI operation Huawei, HiSilicon
R1-167334 Discussions on DCI design consideration for shortened TTI SPS operation Beijing Xiaomi Mobile Software
R1-167368 sPDCCH for shortened TTI NTT DOCOMO, INC.
R1-167369 sPDSCH for shortened TTI NTT DOCOMO, INC.
R1-167370 sPUCCH for shortened TTI NTT DOCOMO, INC.
R1-167371 sPUSCH for shortened TTI NTT DOCOMO, INC.
R1-167486 DL DMRS design for TTI shortening Ericsson
R1-167487 sPDCCH search space design Ericsson
R1-167488 Design aspects of sPDCCH Ericsson

Petitioners' Exhibit 1003, p. 960
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-167489 DL control for short TTI Ericsson
R1-167490 Design aspects of sPDSCH Ericsson
R1-167491 Design aspects of sPUSCH Ericsson
R1-167492 UCI on sPUSCH with short TTI Ericsson
R1-167493 Design aspects of sPUCCH Ericsson
R1-167495 TDD aspects of short TTI Ericsson
R1-167496 On the operation with different TTI lengths Ericsson
R1-167498 Asynchronous HARQ for UL retransmissions with short TTI Ericsson
R1-167503 Handling overlapping allocations with short and 1 ms TTI Ericsson
R1-167504 Puncturing sTTI in legacy TTI Ericsson
R1-167596 Considerations on short TTI design Mediatek Inc.
R1-167598 UL RS design for short TTI Mediatek Inc.
R1-167599 DL channel design for short TTI Mediatek Inc.
R1-167620 sPUCCH design for shortened TTI Potevio
R1-167628 Shortened TTI design Motorola Mobility
R1-167629 Multiplexing of Regular TTI and shortened TTI Motorola Mobility
R1-167654 On sPDCCH Design InterDigital Communications
R1-167655 On sPDSCH Design InterDigital Communications
R1-167656 On sPUCCH Design InterDigital Communications
R1-167658 On sPUSCH Design InterDigital Communications
R1-167774 Views on short PUSCH design KT Corp.
R1-167865 Discussion on sPDCCH for sTTI ZTE Corp., ZTE Microelectronics
R1-167866 Study on PDSCH transmission in sTTI ZTE Corp., ZTE Microelectronics
R1-167867 Study on PUSCH transmission in sTTI ZTE Corp., ZTE Microelectronics
R1-167868 PUCCH to carry HARQ-ACK for sTTI ZTE Corp., ZTE Microelectronics
R1-167873 sPDSCH design for LTE short TTI CATT
R1-168188 Way Forward on DCI monitoring for sTTI Ericsson
R1-168195 WF on sPDSCH and sPUSCH transmission Huawei, HiSilicon, Ericsson
R1-168196 Way forward on sPUCCH Huawei, HiSilicon, Ericsson
R1-168197 Way forward on sTTI patterns Huawei, HiSilicon, CATR, Intel
R1-168233 WF on short TTI lengths for FS1 LGE

7.2.12.2.2 Processing time

Including maximum TA, CSI processing and minimum data processing time

R1-166157 Discussion on CSI feedback for short TTI Huawei, HiSilicon
R1-166158 Processing time reduction and related procedures for short TTI Huawei, HiSilicon
R1-166311 Processing time reduction and related procedures for DL Qualcomm Incorporated
R1-166312 Processing time reduction and related procedures for UL Qualcomm Incorporated
R1-166313 TDD-specific design for shortened TTI Qualcomm Incorporated
R1-166461 HARQ and scheduling timing design for LTE short TTI CATT
R1-166708 Processing time reduction for sTTI operations Samsung
R1-166863 Consideration for shortened processing time for shortened TTI length LG Electronics
R1-166864 Discussion on HARQ timing with shortened TTI length LG Electronics
R1-166967 Evaluation results on processing time reduction in physical layer Panasonic
R1-167120 On the processing time reduction for latency reduction Intel Corporation
R1-167372 Views on processing time reduction and related procedures NTT DOCOMO, INC.
R1-167613 Processing time reduction for TDD with 1-slot sTTI SHARP Corporation
R1-167614 Reduced processing time for different UL and DL sTTI lengths SHARP Corporation, MTI
R1-167650 Processing time reduction and related procedures ZTE Corp, ZTE Microelectronics
R1-167657 On Processing Time Reduction for sTTI InterDigital Communications
R1-168306 On reduced processing time for short TTI Ericsson

7.2.12.3 Other

R1-166314 Link evaluation of DL data transmission under symbol--dependent impact Qualcomm Incorporated
R1-167342 Reduced timing for retransmission request HTC Corporation

7.2.13 Performance enhancements for high speed scenario - *WID in RP-160172*

R1-168414 Chairman's notes of AI 7.2.13 on Performance enhancements for high speed scenario Ad-Hoc chair (Qualcomm)
The document was presented by Wanshi Chen from Qualcomm.
Decision: The document is endorsed and incorporated as follows.

Petitioners' Exhibit 1003, p. 961
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-168354 **PRACH enhancement in high speed scenario** **Huawei**
Revision of R1-167171
R1-167773 **PRACH for very high speed UEs** **Nokia, Alcatel-Lucent Shanghai Bell**

R1-166315 PRACH enhancements Qualcomm Incorporated
R1-167416 Introduction of PRACH enhancement for high speed scenario Huawei
R1-168248 Modified Option 3-2 Results Qualcomm

Agreements:
- Study until next meeting to down-select one of the following options:
  - Alt 1: Set 3 in R1-168354 as the new restricted set of cyclic shifts for PRACH
  - Alt 2: The PRACH method described in 6.5.3.1 of RAN4 TR 36.878 for very high speed scenario is specified in 36.211
- Study further how to enable Rel 8 – 13 UEs to access the cell that supports new very high speed scenario

7.2.14 Study on Further enhancements to Coordinated Multi-Point Operation - *SID in RP-160954*

R1-168415 **Chairman's notes of AI 7.2.14 on Study on Further enhancements to Coordinated Multi-Point Operation** **Ad-Hoc chair (Intel)**
The document was presented by Alexei Davydov from Intel.
Decision: The document is endorsed and incorporated as follows.

R1-166335 **TP on TR 36.741 Study on FeCoMP** **ZTE Corporation, Intel Corporation**

Agreement:
- Endorse TP for TR36.741 in R1-166335

R1-167622 TP for TR36.741 on Section 5 ZTE Corporation, Intel Corporation
R1-167648 feCoMP Motivations and Techniques Ericsson

7.2.14.1 Remaining details of the deployment scenarios and system-level evaluation assumptions

R1-166331 **Remaining details of evaluation assumptions for FeCoMP** **ZTE Corporation, ZTE Microelectronics**
R1-167647 **feCoMP evaluation assumption omissions and errata** **Ericsson**
R1-166544 Remaining details of evaluation assumptions Intel Corporation
R1-166709 **Remaining details for simulation assumptions for feCoMP** **Samsung**
R1-167088 Simulation assumptions related to new measurements and LTE architecture IAESI, Thales, Fairspectrum

R1-168253 **WF on further details of simulation assumptions for FeCoMP** **ZTE Corporation, ZTE Microelectronics, Intel, ASTRI, Qualcomm, Ericsson, Nokia, Alcatel-Lucent Shanghai Bell, Samsung**

Agreements:
- Add the following details into the simulation assumptions:
  - Performance Metric / Parameter
    - Mean, 5%, 50%, 95% user throughput
    - Served cell throughput
    - Resource utilization (RU)
    - Packet arrival rate λ
  - Overhead
    - 3 symbols for DL CCHs, 2 CRS ports and DM-RS overhead according to number of scheduled layers
  - Antenna Polarization Model
    - Model -2 from 36.873
  - Feedback
    - PUSCH 3-2 for non-reciprocity operation (PUSCH 3-0 for reciprocity based operation)
    - CQI, PMI and RI reporting triggered per 5ms
    - Feedback delay is 5 ms
    - Other parameters can be also used
- Baseline schemes are at least below:
  - Rel-13 FD-MIMO without coordination for CS/CB
  - DPS/DPB for NCJT
  - Other option can be also used
- Support M=1 in antenna configuration only for small cell layer in evaluation of Scenario D
- Fix the reference errors proposed in R1-167647

Petitioners' Exhibit 1003, p. 962
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.2.14.2 Potential enhancements for non-coherent joint transmission

Include initial evaluation results

R1-166865	**Discussion on enhancements for non-coherent JT**	**LG Electronics**
R1-167142	**Discussion on non-coherent JT schemes for FeCoMP**	**Huawei, HiSilicon**
R1-166317	Enhamcements for non-coherent JT	Qualcomm Incorporated
R1-166332	Initial evaluation results of non-coherent JT	ZTE Corporation, ZTE Microelectronics
R1-166333	Potential enhancements for non-coherent JT	ZTE Corporation, ZTE Microelectronics
R1-166334	QCL Issues of Joint Transmission	ZTE Corporation, ASTRI
R1-166462	Enhancement for non-coherent joint transmission	CATT
R1-166545	CSI feedback enhancements for non coherent JT	Intel Corporation
R1-166546	Control signalling enhancements for non coherent JT	Intel Corporation
R1-166547	Evaluation results for non coherent JT	Intel Corporation
R1-166710	Discussion on potential enhancements for non-coherent JT	Samsung
R1-167143	Potential enhancements for non-coherent JT	Huawei, HiSilicon
R1-167144	Initial simulation results of non-coherent JT	Huawei, HiSilicon

R1-168267 **WF on non-coherent JT schemes for FeCoMP** **Huawei, HiSilicon, Intel, SoftBank Corp, ZTE, CATT, Qualcomm**

Agreements:

- Capture the following non-coherent JT definition and classification in the TR
  - Definition: Non-coherent JT scheme corresponds to the transmission scheme where transmission of the MIMO layer(s) is performed from two or more transmission points (TPs) without adaptive precoding across the TPs.
  - Non coherent JT schemes can be classified based on the CWs transmitted from TPs:
    - **Case 1:** Different CWs are transmitted from different TPs. Each TP perform adaptive precoding independently
    - **Case 2a:** The same CW is transmitted from different TPs with spatial diversity (e.g. SFBC) coding/ spatial multiplexing.
    - **Case 2b:** The same CW is transmitted from different TPs with SFN.
  - Non coherent JT schemes can be classified based on overlapping of resource allocations from different TPs:
    - **Scheme1:** Fully overlapping scheme
      - In this scheme the resource allocations from different TPs for a UE are fully overlapped
    - **Scheme 2:** Partly overlapping scheme
      - In this scheme the resource allocations from different TPs for a UE are partly overlapped
    - **Scheme 3:** Non overlapping scheme,
      - In this scheme the resource allocations from different TPs for a UE are not overlapped

7.2.14.3 Potential enhancements for coordinated scheduling/beamforming with FD-MIMO

Include initial evaluation results

R1-166318	Enhancements for coordinated scheduling/beamforming with FD-MIMO	Qualcomm Incorporated
R1-166336	Potential enhancements for CS/CB with FD-MIMO	ZTE Corporation, ZTE Microelectronics
R1-166463	Coordinated beamforming with FD-MIMO	CATT
R1-166548	Enhancements and evaluation of CS/CB CoMP	Intel Corporation
R1-166712	Discussion on potential enhancements for CS/CB with FD-MIMO	Samsung
R1-166866	Discussion on enhancements for CS/CB with FD-MIMO	LG Electronics
R1-167145	Potential enhancements for CS/CB with FD-MIMO	Huawei, HiSilicon
R1-167146	Initial simulation results of CS/CB with FD-MIMO	Huawei, HiSilicon
R1-167649	Preliminary FeCoMP Results for Indoor Hotspot Scenario	Ericsson
R1-168269	Summary of Evaluation Results of CS/CB	Huawei, HiSilicon

7.2.15 Study on Enhancement of VoLTE - *SID in RP-160902*

R1-168416 **Chairman's notes of AI 7.2.15 on Study on Enhancement of VoLTEAd-Hoc chair (CMCC)**
The document was presented by Hui Tong from CMCC.
Decision: The document is endorsed and incorporated as follows.

7.2.15.1 VoLTE/video quality improvements

R1-167442 **Performance evaluation of coverage enhancements for VoLTE/video quality** **China Telecommunications**

Agreement:

Petitioners' Exhibit 1003, p. 963
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Capture the following text in the reply LS to RAN2 (see R1-168256 under AI 5):

- VoLTE coverage can be effectively enhanced by relaxing the air interface delay budget. As an example, if the delay budget is extended to 100ms, about 1~3dB coverage gain can be achieved compared with 50ms delay budget for full duplex UEs. Extending maximum packet transmission time beyond 100ms can further improve the coverage. Techniques that can be used to extend the coverage if the air interface delay budget is relaxed are asynchronous UL HARQ transmission and different repetition levels in combination with RTP packet bundling.
  - Note that the performance can be significantly impacted by the assumption of header compression.
- The multi-subframe frequency hopping technique that was specified in CE mode A, which enables cross-subframe channel estimation, can be used to enhance the VoLTE coverage effectively.
- The coverage for half-duplex FDD UEs is less than the coverage for full-duplex UEs. In order to maximize the VoLTE coverage that can be achieved in half-duplex FDD, opportunities to optimize the UL/DL resource utilization have been identified e.g. through techniques to reduce DL repetitions, new repetition factors, and adjusted scheduling delay.

ACTION: RAN1 respectfully asks RAN2 to take the above into account.

R1-168168 **Text proposal for the RAN1 coverage enhancement for eVoLTE** **Sierra Wireless, Sony, AT&T**
R1-168064 **Text proposal for the RAN1 coverage enhancement for eVoLTE** **Huawei, HiSilicon**

R1-166319 Coverage enhancement techniques Qualcomm Incorporated
R1-166320 On eNB and UE awareness of EVS codec for coverage and mobility enhancement Qualcomm Incorporated
R1-167103 Evaluation results of coverage enhancement schemes for eVoLTE CMCC
R1-167798 VoLTE Enhancements Nokia, Alcatel-Lucent Shanghai Bell
R1-167893 Evaluation of VoLTE support for Cat M1 UEs Intel Corporation
R1-167907 VoLTE quality improvements Ericsson
R1-167982 Sub-PRB Method to Improve UL Coverage, UL Capacity, and Battery Life Sierra Wireless, Sony
R1-168063 Overview of the eVoLTE coverage enhancement technologies Huawei, HiSilicon

8 NR

8.1 Study on New Radio Access Technology - SID in RP-161214

R1-167373 **Workplan for Study on NR Access Technology** **NTT DOCOMO, INC.**
Decision: The document is noted.
R1-167374 **Draft TR 38.802 Study on New Radio (NR) Access Technology - Physical Layer Aspects** **NTT DOCOMO, INC.**
The document (draft v0.0.4) was presented by Kazuaki Takeda from NTT DOCOMO.
Decision: The document is noted. Companies are encouraged to contact rapporteur until Wednesday.
Friday: Draft TR is revised in:
R1-168523 **Draft TR 38.802 Study on New Radio (NR) Access Technology - Physical Layer Aspects** **NTT DOCOMO, INC.**
Decision: The document is endorsed as v.0.1.0 in R1-168526.

8.1.1 Forward compatibility for new radio interface

General principles to achieve forward compatibility with Phase II specification and beyond

R1-166345 **NR service multiplexing requirements** **Qualcomm Incorporated**
The document was presented by Tingfang Ji from Qualcomm and provides Qualcomm's view on forward compatibility requirements, design and timeline for difference service multiplexing scenarios:

- eMBB networks + future URLLC services
- eMBB network + future mMTC services
- WAN network + future side link services
- eMBB non-standalone (NSA) + standalone (SA)
- eMBB licensed + unlicensed
- eMBB + positioning
- Other scenarios

Discussion: Chair suggested companies using the tables as shown in this contribution and get their feedback on the different scenarios.
Samsung → objection on NSA and SA
Decision: The document is noted. Revised in R1-168088.

Petitioners' Exhibit 1003, p. 964
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166868 NR operation in unlicensed spectrum LG Electronics

The document was presented by … from LGE.

- Proposal 1: With on-going work on LTE LAA for 5 GHz frequency, NR study can first focus on 60 GHz for unlicensed spectrum. For 5 GHz, it seems desirable to consider tight interworking between NR and LAA.
- Proposal 2: 120 kHz (FFS: 240 kHz) sub-carrier spacing can be considered for candidate numerologies for 60 GHz, the same as for 70 GHz.
- Proposal 3: The frame structure containing UL channel/signal in unlicensed spectrum should be designed considering channel access procedure.
- Proposal 4: For UL control design in unlicensed spectrum, consider regional regulation such as PSD, symbol duration, and multiplexing with UL sounding signal.
- Proposal 5: Consider how to transmit cell/beam identification related signals based on channel access procedure.

Decision: The document is noted.

R1-166682 Forward Compatibility of Broadcasted Signals and Channels for mMTC Sierra Wireless, S.A.

The document was presented by Serkan Dost from Sierra Wireless.

- Observation: In LTE, adding support for narrowband UEs required the duplication of many broadcasted signals/channels/info, resulting in >45% broadcasted resource usage in some cases.
- Conclusion: In LTE, it would have been advantageous if the legacy broadcasted signals/channels/info could have been decodable by narrowband UEs.
- Proposal: To avoid duplication, the NR broadcasted signals/channels/info should be decodable by both wideband and narrowband UEs
- Proposal: To optimize wideband UE performance, it shall be possible for NR broadcasted signals/channels/info to use wideband resources not decodable by narrowband UEs.

Decision: The document is noted.

R1-167119 Forward compatibility considerations on NR Integrated Access and Backhaul Qualcomm Incorporated

- Proposal 1: NR design should allow for multiple-hop self-backhauling without dictating hard limits on the hop count.
- Proposal 2: NR design should allow for topological redundant self-backhauling without confining the degree of inter-node connectivity.
- Proposal 3: NR design should allow for dynamic load balancing between backhaul links as well as between backhaul- and access links.
- Proposal 4: NR design should allow for accommodation of local changes in network topology while the remaining self-backhaul network carries traffic.

Decision: The document is noted.

R1-167235 Forward compatibility on duplexing Huawei, HiSilicon

The document was presented by Zukang Shen from Huawei.

- Proposal 1: NR should support unified duplex, fulfilling the following design targets:
  - It should allow traditional FDD operation on a paired spectrum
  - It should allow both DL and UL in either part of a paired spectrum
  - It should allow TDD operation on an unpaired spectrum where the DL/UL configuration is not dynamically changing;
  - It should allow TDD operation on an unpaired spectrum where the transmission direction of most subframes can be dynamically changing;
  - It should allow support of full duplex in the future in a forward compatible way
- Proposal 2: NR should support band-agnostic and duplex-agnostic frame structure.

Decision: The document is noted.

R1-166745 Dynamic Bandwidth Considerations for NR Samsung

The document was presented by … from Samsung.

- Observation 1: Provision of a low complexity and low cost system is necessary in order to overcome the limitations on the NR deployment that may be imposed by the requirement of a large number of RF chains to support very wide bandwidths.
- Observation 2: CA and CB can be considered to achieve freedom of spectrum usage by supporting dynamic BW configuration with CA/CB.
- Proposal: RAN1 should study a potential benefit of channel bonding scheme for unlicensed and shared spectrum in NR deployments.

Decision: The document is noted.

R1-168059 WF on unified duplex Huawei, HiSilicon, CMCC, NTT DOCOMO, CATR, Deutsche Telekom, Softbank

Petitioners' Exhibit 1003, p. 965
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The document was presented by Zukang Shen from Huawei.

- NR should support unified duplex, fulfilling the following design targets:
  - It should allow traditional FDD operation on a paired spectrum
  - It should allow different transmission directions in either part of a paired spectrum
  - It should allow TDD operation on an unpaired spectrum where the transmission direction of time resources is not dynamically changing;
  - It should allow TDD operation on an unpaired spectrum where the transmission direction of most time resources can be dynamically changing;
  - It should allow support of full duplex in a forward compatible way
  - Note: transmission directions include all of downlink, uplink, sidelink, and backhaul link

Discussion: Samsung concern with second sub-bullet and the timing for that one → make clear that it relates to forward compatibility target and not a design target without additional feasibility study (suggested LS asking RAN4 about it)
Decision: The document is noted, modified as follows:

Agreements:

- NR should support at least following design targets:
  - It should allow FDD operation on a paired spectrum
  - It should allow different transmission directions in either part of a paired spectrum
  - It should allow TDD operation on an unpaired spectrum where the transmission direction of time resources is not dynamically changing
  - It should allow TDD operation on an unpaired spectrum where the transmission direction of most time resources can be dynamically changing
  - FFS: It should allow support of full duplex in a forward compatible way
  - Note: transmission directions include all of downlink, uplink, sidelink, and backhaul link
  - Note that additional discussion is needed about the timing to support above targets, particulally the second sub-bullet
  - Note that some design targets may or may not be transparent to UE

Wednesday

R1-168106 WF on Forward Compatibility for Broadcast Signals/Channels Sierra Wireless, Sony, Ericsson, Mediatek

The document was presented by GustavVos from Sierra Wireless.

- Whether wideband and narrowband UEs can decode the same NR broadcasted signals and channels, should be considered.
  - This doesn't mean the broadcasted signals/channels need to be narrowband

Discussion: Also supported by Panasonic.
Decision: The document is noted and agreed as follows:

Agreements:

- Whether wideband and narrowband UEs can decode either all or partially the same NR broadcasted signals and channels, should be considered
  - This doesn't mean the broadcasted signals/channels need to be narrowband

Friday

R1-168132 Way forward on the forward compatibility for NR unlicensed Intel, Interdigital, Ericsson, Nokia, ASB, Qualcomm, Huawei, HiSilicon, ZTE

- At least 5 GHz and 60 GHz unlicensed bands are considered for NR unlicensed operation.
- RAN1 to start studying regulatory aspects of potential unlicensed spectrum from forward compatibility perspective.
- Note: Other unlicensed bands are not precluded for NR unlicensed operation.

Decision: The document is noted.

Not treated.

R1-166210	On forward compatibility for new radio interface	ZTE Corporation, ZTE Microelectronics
R1-166346	Forward compatibility consideration for numerology and frame structure	Qualcomm Incorporated
R1-166347	Forward compatibility consideration on service multiplexing	Qualcomm Incorporated
R1-166464	NR on-demand access for forward compatiblity	CATT
R1-166465	NR time inverval and system design for forward compatibility	CATT
R1-166550	Forward compatibility for new radio interface	Intel Corporation
R1-166608	Discussion on forward compatibility of subframe structure for NR	Guangdong OPPO Mobile Telecom.
R1-166636	Proposals for forward compatibility	NEC
R1-166648	On the aspects of waveform multiplexing requirements	NEC
R1-166743	Discussion on forward compatibility for NR	Samsung

Petitioners' Exhibit 1003, p. 966
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166744 Discussion on sync. signal considering forward compatibility aspects Samsung
R1-166867 Further considerations for forward compatibility support LG Electronics
R1-166998 Reference signal design to support bandwidth flexibility Spreadtrum Communications
R1-167123 Forward compatibility considerations for NR unlicensed operation Intel Corporation
R1-167124 Multiplexing of different numerologies for forward compatibility Intel Corporation
R1-167220 Forward compatibility consideration on symmetric design across multiple links for unified duplex Huawei, HiSilicon
R1-167327 Forward compatible control channel framework for NR INTERDIGITAL COMMUNICATIONS
R1-167541 Discussion on Supported Carrier Bandwidth for Forward Compatible NR design MediaTek Inc.
R1-167797 Baseline design for forward-compatible lean carrier in NR Nokia, Alcatel-Lucent Shanghai Bell
R1-168088 NR service multiplexing requirements Qualcomm Incorporated

8.1.2 Waveform and multiple access schemes for new radio interface

R1-168417 Chairman's notes of AI 8.1.2 on waveform and multiple access schemes for NR Ad-Hoc chair (Qualcomm)
The document was presented by Wanshi Chen from Qualcomm.
Decision: The document is endorsed and incorporated as follows.

8.1.2.1 Waveform

Including remaining evaluation assumptions for waveform evaluation

R1-166092 Waveform evaluation results for above 6GHz bands Huawei, HiSilicon
R1-166355 WOLA and filtered-OFDM comparison beyond link level performance Qualcomm Incorporated
R1-166487 Link Level Evaluation of Waveforms for NR AT&T GNS Belgium SPRL
R1-166494 Low PAPR Single Carrier Circularly Pulse Shaped Waveform Idaho National Laboratory
R1-166748 Evaluation results of OFDM-based waveform in DL and UL mixed numerology case (case 2 and 4) Samsung
R1-167104 Preliminary evaluations of f-OFDM and w-OFDM CMCC
R1-167376 Comparison of candidate waveforms NTT DOCOMO, INC.
R1-167529 An RX based interference mitigation method for waveform with multiple numerologies MediaTek Inc.
R1-167550 Filter delay impact of filtered OFDM on fast feedback Ericsson
R1-167595 OTFS Performance Evaluation for High Speed Use Case Cohere Technologies
R1-167794 Waveform proposal for carrier frequencies beyond 40 GHz Nokia, Alcatel-Lucent Shanghai Bell

R1-167963 Way forward on waveform Huawei, HiSilicon, NTT DOCOMO, Nokia, ASB, Ericsson, Qualcomm, China Unicom, CATT, Samsung, CATR, Vodafone, InterDigital, LG Electronics, Softbank, Deutsche Telekom
Also supported by CT, Verizon

Agreement:

- At least up to 40 GHz for eMBB and URLLC services, NR supports CP-OFDM based waveform with Y greater than that of LTE (assuming Y=90% for LTE) for DL and UL, possibly with additional low PAPR/CM technique(s) (e.g., DFT-S-OFDM, etc.)
  - Y (%) = transmission bandwidth configuration / channel bandwidth * 100%
  - RAN1 specification will support transmission bandwidth configuration corresponding to Y up to approximately100%
  - Some evaluations in RAN1 show that Y for a NR carrier can be up to 98% of the evaluated channel bandwidths for both DL and UL without complexity and latency constraints [R1-166093]
  - Note: additional pre-processing techniques on top of CP-OFDM are not precluded, e.g., OTFS
- Additional waveforms may be supported by NR for e.g. other services (e.g. mMTC)
- It is recommended that RAN4 should target to support eNB/UE with Y significantly higher than 90% when defining the RAN4 requirements where the specification of Y should consider complexity and latency constraints
- In-band frequency multiplexing of different numerologies is supported in NR for both DL and UL, at least from the network perspective
  - It is expected that spectrum confinement on sub-band basis is specified as requirements on
    - Transmitter side in-band emission and EVM requirements
    - Reception performance in presence of other-subband interferer
    - The definition of sub-band is FFS
- From RAN1 perspective, spectral confinement technique(s) (e.g. filtering, windowing, etc.) for a waveform at the transmitter is transparent to the receiver
- Inform RAN4 the above agreements
  - RAN1 plans to perform more evaluations on waveform and will inform RAN4 with future updates, if any

Petitioners' Exhibit 1003, p. 967
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-168422 WF on low-PAPR/CM technique Ericsson, Huawei, Panasonic, Vodafone, Qualcomm, ZTE, ZTE Microelectronics

Agreements:

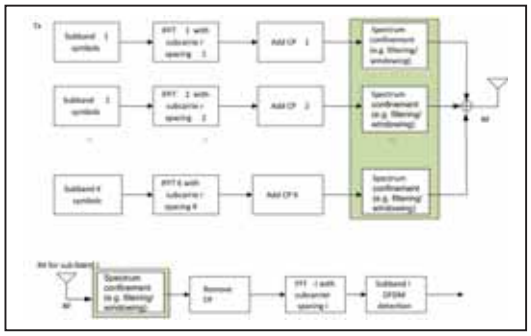
- At least up to 40 GHz for eMBB and URLLC services,
  - CP-OFDM without specified low-PAPR/CM technique(s) is recommended to be supported for uplink
  - For data transmission, additional low-PAPR/CM technique(s) is only considered for uplink from RAN1 specification perspective
    - Additional low-PAPR/CM technique(s) for special downlink signals such as sync signals is FFS
    - Additional low-PAPR/CM technique(s) for other uplink signals/channels is FFS
  - Additional low PAPR/CM technique(s), if specified, and CP-OFDM without specified low-PAPR/CM technique(s) for uplink are considered *as complementary to each other*

R1-168240 LS on NR waveform Huawei

Conclusion:

- The LS is agreed in R1-168258, with the following update (figure 1 is deleted):

~~For clarification, Figure 1 gives an exemplary illustration of spectrum confinement on a sub-band basis.~~



~~Figure 1 Illustration of spectrum confinement on a sub-band basis for downlink~~

R1-168051 WF on Low PAPR Techniques for NR Uplink Qualcomm Inc., Samsung, MediaTek, Interdigital, Idaho National Lab, IITH, CEWiT, Reliance-jio, Tejas Networks, Oppo, Vodafone, Straightpath, LG Electronics, National Taiwan University, [AT&T], Verizon Wireless, National Instrument, Spreadtrum

Also supported by ZTE, ZTE Microelectronics

Agreement:

- NR uplink should target at least the same link budget (i.e. MCL) as LTE uplink, under the same usage scenarios and similar deployment configurations (e.g., same carrier frequency)
  - Details FFS
  - Techniques can be evaluated for the uplink scenarios
    - E.g., low PAPR/CM techniques (including DFT-s-OFDM)

R1-168392 WF on Guard-Band in NR Samsung, CEWiT, IITH, Tejas Networks, Reliance-jio, MediaTek, Ericsson, Nokia, ASB, CMCC, KDDI

Agreement: RAN1 should continue study whether/how to support guard-band for inter-subband interfering scenarios (e.g., cases 2/3/4) with considerations of the specification/performance impact

R1-168525 Way forward on the waveform for above 40GHz Nokia, ASB, Intel, InterDigital, Mitsubishi Electric, Qualcomm, MediaTeK, Ericsson, NTU, National Instruments

Agreements:

- When considering DL and UL waveforms for spectrum band above 40GHz, RAN1 should at least consider the impact of
  - Low PA efficiency
  - Phase Noise and Doppler impairments

R1-166090 Waveform evaluation results for case 3 Huawei, HiSilicon
R1-166091 Waveform evaluation results for case 4 Huawei, HiSilicon

Petitioners' Exhibit 1003, p. 968
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166093 Waveform evaluation updates for case 1a and 1b Huawei, HiSilicon
R1-166119 Summary of email discussion on calibration for NR waveform Huawei, HiSilicon
R1-166120 Waveform evaluation updates for case 2 Huawei, HiSilicon
R1-166121 Summary on NR waveform evaluation results Huawei, HiSilicon
R1-166226 UW DFTsOFDM link level evaluation results below 6GHz Mitsubishi Electric
R1-166227 UW DFTsOFDM link level evaluation results above 30GHz Mitsubishi Electric
R1-166348 PA model measurements and F-OFDM/WOLA measurements Qualcomm Incorporated
R1-166350 NR Spec implication for Filter/windowing OFDM Qualcomm Incorporated
R1-166351 Updated simulation assumptions for Cases 3 and 4 Qualcomm Incorporated
R1-166352 Simulation results for Cases 3 and 4 Qualcomm Incorporated
R1-166353 Waveform proposal for > 6GHz Qualcomm Incorporated
R1-166354 OFDM and SC-FDM support for Uplink Qualcomm Incorporated
R1-166356 Simulation assumptions for OFDM and SC-FDM waveform comparison Qualcomm Incorporated
R1-166400 Simulation results of new waveform in case 1 and high speed ZTE
R1-166401 Simulation results of new waveform in case 2, 3 and 4 ZTE
R1-166594 Discussion on the window processing of FC-OFDM and WOLA ORANGE
R1-166595 FC-OFDM enhanced receiver design for very long delay spread ORANGE
R1-166650 Discussion on OFDM based waveform Sony
R1-166669 Discussion on real domain OFDM for mMTC Fujitsu
R1-166746 Discussion on multi-window OFDM for NR waveform Samsung
R1-166747 Evaluation results of OFDM-based waveform in DL and UL single numerology case (case 1a and 1b) Samsung
R1-166749 Evaluation results of OFDM-based waveform in UL single numerology and asynchronous case (case 3) Samsung
R1-166869 Waveform evaluation results in case 3 LG Electronics
R1-166870 Waveform evaluation results in case 4 LG Electronics
R1-166999 Detailed configuration of f-OFDM and W-OFDM for LLS evaluation Spreadtrum Communications
R1-167000 LLS evaluation results of NR waveforms Spreadtrum Communications
R1-167001 Link-level simulation cases for evaluating waveforms in mMTC UL with relaxed synchronization Spreadtrum Communications
R1-167029 On NR spectral confinement Ericsson
R1-167030 Mixed Numerology with PA impairment Ericsson
R1-167031 On OFDM in NR for Coverage-Limited Scenarios Ericsson
R1-167032 On OFDM in NR for Non-Coverage Limited Scenarios Ericsson
R1-167033 On resource allocation and guard subcarriers for mixed numerologies Ericsson
R1-167034 On PA impact to in mixed numerology with narrow band allocation Ericsson
R1-167035 On PA impact to in mixed numerology with wide band allocation Ericsson
R1-167036 On PAPR and CM reduction in NR Ericsson
R1-167086 GPO Based BPSK and QPSK modulation schemes with Low PAPR IITH
R1-167125 Single carrier based waveform for high frequency bands above 40 GHz Intel Corporation
R1-167126 Further discussion on GI-DFT-s-OFDM for high frequency bands above 40 GHzIntel Corporation
R1-167193 Views on multiple NR waveform proposals for high bands Intel Corporation
R1-167201 Further evaluation for NR waveforms Huawei, HiSilicon
R1-167241 Summary of email discussion on collecting information for NR waveform Huawei, HiSilicon
R1-167243 On uplink waveform below 40 GHz Nokia, Alcatel-Lucent Shanghai Bell
R1-167244 Uplink performance results with extended settings for the New Radio waveforms below 6 GHz Nokia, Alcatel-Lucent Shanghai Bell
R1-167245 Downlink performance results for the New Radio waveforms below 6 GHz including PA models Nokia, Alcatel-Lucent Shanghai Bell
R1-167246 On independent design of Tx and Rx units for NR Nokia, Alcatel-Lucent Shanghai Bell
R1-167337 NR waveform evaluation and proposals Panasonic Corporation
R1-167530 Spectral Efficiency Evaluation for NR Uplink Waveforms Operating at High Frequency MediaTek Inc.
R1-167558 Comparison of UW DFT-s-OFDM and windowed OFDM InterDigital Communications
R1-167559 Simulation set-up for email discussion [85-17] on UW DFT-s-OFDM InterDigital Communications
R1-167560 Channel estimation and phase tracking for UW DFT-s-OFDM InterDigital Communications
R1-167593 Performance evaluation of OTFS waveform in single user scenarios Cohere Technologies
R1-167594 Performance evaluation of OTFS waveform in multiuser scenarios Cohere Technologies
R1-167604 Evaluation of OFDM with companding Qualcomm Incorporated
R1-167746 Guardband for mixed numerologies Ericsson
R1-167778 Spectrum emission considerations for 5G NR waveform proposals Nokia, Alcatel-Lucent Shanghai Bell
R1-167779 On DL Rapp PA model for waveform evaluation below 6 GHzNokia, Alcatel-Lucent Shanghai Bell
R1-167791 Performance Evaluation of Cyclic-Prefix-less Precoded OFDM KDDI Corporation
R1-167795 Potential for system level gains with low PAPR waveforms Nokia, Alcatel-Lucent Shanghai Bell
R1-167796 On the RAN1 goals for waveform design Nokia, Alcatel-Lucent Shanghai Bell

Petitioners' Exhibit 1003, p. 969
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-167808 flexi-OFDMA, a new waveform for NR CEWiT
R1-167820 Fundamentals of CPS-OFDM waveform for 5G new radio National Taiwan University
R1-167874 Evaluation results of OFDM-based waveforms in Case 1a and Case 1b National Taiwan University
R1-167875 Preliminary evaluation of CPS-OFDM waveform in Case 2, Case 3, and Case 4 National Taiwan University
R1-167905 Generalized Root Raised Cosine (GRRC) Nyquist Filters for Filtered Modulation National Instruments Corp.
R1-167915 Tx&Rx structure of FB-OFDM ZTE

8.1.2.2 Multiple access scheme

Including remaining evaluation assumptions for multiple access scheme evaluation

R1-166094 LLS Results for UL MA schemes Huawei, HiSilicon
R1-166405 Discussion on grant free concept for UL mMTC ZTE
R1-166493 Low Latency Scheduling-based UL Access Idaho National Laboratory
R1-166551 Views on UL multiple access for NR Intel Corporation
R1-167253 On system level evaluation of multiple access schemes for mMTC and eMBB use cases Nokia, Alcatel-Lucent Shanghai Bell
R1-167554 General framework for efficient access in NR Ericsson

R1-168073 WF on UL LLS for MA Huawei, HiSilicon, CATR, CATT, Fujitsu, Spreadtrum, China Telecom, InterDigital

R1-168427 WF on UL LLS for MA Huawei, HiSilicon, CATR, CATT, Spreadtrum, Fujitsu, CMCC, InterDigital, China Telecom

Observations:

- The following non-orthogonal multiple access schemes have been reported up to RAN1#86 for at least UL NR MA (listed in the order of proposed time, i.e., increasing tdoc number)
  - Sparse code multiple access (SCMA) (e.g., R1-162153)
  - Multi-user shared access (MUSA) (e.g., R1-162226)
  - Low code rate spreading (e.g., R1-162385)
  - Frequency domain spreading (e.g., R1-162385)
  - Non-orthogonal coded multiple access (NCMA) (e.g., R1-162517)
  - Non-orthogonal multiple access (NOMA) (e.g., R1-163111)
  - Pattern division multiple access (PDMA) (e.g., R1-163383)
  - Resource spread multiple access (RSMA) (e.g., R1-163510)
  - Interleave-Grid Multiple Access (IGMA), (e.g., R1-163992)
  - Low density spreading with signature vector extension (LDS-SVE) (e.g., R1-164329)
  - Low code rate and signature based shared access (LSSA), (e.g., R1-164869)
  - Non-orthogonal coded access (NOCA), (e.g., R1-165019)
  - Interleave Division Multiple Access (IDMA), (e.g., R1-165021)
  - Repetition division multiple access (RDMA), (e.g., R1-167535)
  - Group Orthogonal Coded Access (GOCA), (e.g., R1-167535)
- Based on the contributions and the assumptions listed in Tables 1/2/3 in R1-168427, it is observed that non-orthogonal MA outperforms OFDMA in terms of UL link-level sum throughput (R1-163560) and overloading capability in the evaluated scenarios

Agreement: NR should target to support UL non-orthogonal multiple access, in addition to the orthogonal approach, targeting at least for mMTC

Proposal:

- In the UL LLS evaluation of non-orthogonal multiple access for mMTC, it is recommended to consider at least the following
  - MA signature (e.g., code, codebook, sequence, interleaver, etc) collision
- FFS Channel correlation between UEs
  - FFS detailed channel correlation model

Continue offline discussion

R1-168074 WF on support of UL grant-free for N Huawei, HiSilicon, China Telecom, Fujitsu, InterDigital
R1-168067 WF on Clarification of Grant-free Transmission for mMTC ZTE, ZTE Microelectronics, Qualcomm, LGE
Revised in R1-168257

Petitioners' Exhibit 1003, p. 970
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Agreement: NR should target to support UL "autonomous/grant-free/contention based" at least for mMTC

Conclusion: In RAN1 discussion for MA, grant-free is used to represent "autonomous/grant-free/contention based"

R1-168257 WF on Clarification of Grant-free Transmission for mMTC ZTE, ZTE Microelectronics, Qualcomm, LGE, Convida, InterDigital

Agreement:

- At least the following options for "autonomous/grant-free/contention based" UL transmission should be studied
  - Opt. 1: a UE performs random resource selection
    - Details FFS
  - Opt. 2: a UE's resource is pre-configured by eNB or pre-determined
    - Details FFS
  - Other options are not precluded

R1-168075 WF on further considerations of UL grant-free for mMTC Huawei, HiSilicon, CMCC, Fujitsu
R1-168428 WF on study of UL grant-free Huawei, HiSilicon, CATR, CATT, China Telecom, CMCC, Convida Wireless, Fujitsu, Intel, Spreadtrum, InterDigital, Oppo, Orange, ZTE,
Also supported by Nokia, NTT DoCoMo

Agreements:

- Continue study at least the following:
  - Handling of potential collisions of MA signatures
  - Retransmission/repetition and potential combining, e.g. HARQ
  - Potential link adaptation, e.g. MCS/signature re-assigning
  - Relationship between grant-free and grant-based transmissions and associated UE behavior
  - Advanced receiver capabilities including complexity analysis

R1-168426 WF on definition of UL grant-free resource Huawei, HiSilicon, CATR, CATT, China Telecom, CMCC, Convida Wireless, Fujitsu, Intel, Spreadtrum, InterDigital, Oppo, Orange
R1-168423 WF on some definition of terminologies for "autonomous/grant-free/contention-based" MA LG Electronics, ETRI
R1-168325 WF on MA resource clarification ZTE, ZTE Microelectronics, Qualcomm

Agreements:

- A MA physical resource for "grant-free" UL transmission is comprised of a time-frequency block
  - Note: spatial dimension is not considered as a physical resource in this context
- A MA resource is comprised of a MA physical resource and a MA signature, where a MA signature includes at least one of the following:
  - Codebook/Codeword
  - Sequence
  - Interleaver and/or mapping pattern
  - Demodulation reference signal
  - Preamble
  - Spatial-dimension
  - Power-dimension
  - Others are not precluded
- Details on MA physical resource and MA signature resource FFS

R1-168538 WF on further clarification on grant-free transmission for mMTC LG Electronics, Huawei, HiSilicon, ETRI
Continue discussion next meeting

R1-168076 Way forward on physical layer abstraction for UL non-linear receiver Huawei, HiSilicon, CMCC, Samsung, CATT

Agreement:

- For calibration purpose ONLY:
  - For ML-type receiver, the PHY abstraction method discussed R1-168076 can be used at least for some MA schemes

Petitioners' Exhibit 1003, p. 971
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

        - If a different PHY abstraction method is used by a company, it has to be stated clearly and individually verified
    - Otherwise, the PHY abstraction method is up to each company
        - The PHY abstraction method is to be stated and individually verified by each company
- For evaluation purpose, PHY abstraction method is up to each company
    - A same method is used for calibration and evaluation by a given company, unless a single method can be agreed in RAN1 during evaluation phase

R1-168068 WF on UL Multiple Access Scheme Categorization for mMTC ZTE, ZTE Microelectronics, Qualcomm

R1-168069 WF on System Level Simulation Parameters for mMTC ZTE, ZTE Microelectronics, Qualcomm
R1-168326 WF on System Level Simulation Parameters for grant-free MA ZTE, ZTE Microelectronics, Qualcomm
Continue discussion next meeting especially regarding the motivation for overhead modeling and how to model the overhead

R1-168123 Way forward on non-orthogonal multiple access evaluation Samsung, Qualcomm, LGE
Revision of R1-168116

Agreement:
- For NR non-orthogonal multiple access evaluation, realistic channel estimation is prioritized and the following aspects are considered
    - The proposed DMRS pattern(s), if any, for channel estimation
        - FFS: DMRS overhead. E.g., LTE UL DMRS overhead can be used as a reference.
        - FFS: DMRS contamination due to inter-cell interference
        - FFS: Impact of DMRS collision in case of "autonomous/grant-free/contention based" multiple access
- Note: companies report the DMRS settings used for the LLS/SLS evaluation.

R1-168115 Way Forward on SLS assumptions for autonomous/grant-free/contention-based MALG Electronics, ZTE, ZTE Microelectronics

R1-168540 WF on SLS baseline for NR MA Huawei, HiSilicon

Agreements:
- For providing absolute system level evaluation results for UL mMTC, for calibration purpose only
    - CP-OFDM as the UL waveform
        - UL DMRS overhead, 1 OFDM symbol out of 7 OFDM symbols
    - A UE selects a MA physical resource randomly from a pool of orthogonal MA physical resources
        - There is no partial overlapping between the MA physical resources selected by more than one UE
        - All orthogonal MA physical resources are of same size
    - Rx MMSE receiver, assuming realistic channel estimation
        - No blind decoding assumed
    - Same MCS for all UEs,
        - MCS is reported by each company
    - Open loop power control
        - Alpha=1, P0= -90 dBm
    - Packet size is fixed by 20 bytes
    - FFS other parameters, if any
        - Email discussion on any other potential parameters until 9/2 – Yi Wang (Huawei)
- Note: The above assumptions only apply to the calibration purpose, i.e. other assumptions can be used for evaluation of proposed non-orthogonal multiple access scheme(s)

R1-168541 WF on work plan for NR MA Huawei, HiSilicon

Conclusion:
- Target the following in RAN1#86bis:
    - Summary of preliminary LLS comparisons
    - Summary of preliminary SLS comparisons

Friday
R1-168551 Email discussions on NR MA Huawei, HiSilicon

Petitioners' Exhibit 1003, p. 972
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Huawei will provide initial template for preliminary simulation results summary by Sept 9th, template for email discussion Sept 16th (Huawei)
  - Note that SLS and LLS will have different templates
- Email discussion on SLS calibration until Sept 16th – (Huawei).
- Email discussion on potential categorization of NR MA schemes until RAN1 #86bis – (ZTE)

R1-166095 Discussion on grant-free transmission Huawei, HiSilicon
R1-166096 SLS methodology for MA evaluation in mMTC scenario Huawei, HiSilicon
R1-166097 SLS Results for MA evaluation in mMTC scenario Huawei, HiSilicon
R1-166098 Discussion on the feasibility of advanced MU-detector Huawei, HiSilicon
R1-166111 On traffic model and evaluation method for mMTC evaluation Huawei, HiSilicon
R1-166357 mMTC B2024UE battery life evaluation assumption and methodologies Qualcomm Incorporated
R1-166358 RSMA and SCMA comparison Qualcomm Incorporated
R1-166359 Resource spread multiple access Qualcomm Incorporated
R1-166402 Remaining issues on multiple access evaluation assumption ZTE
R1-166403 Grant-free multiple access schemes for mMTC ZTE
R1-166404 Receiver details and link performance for MUSA ZTE
R1-166466 Usage scenarios of non-orthogonal multiple access CATT
R1-166467 Discussion on traffic model of mMTC CATT
R1-166468 Remaining issues on evaluation assumption and methodology of MA CATT
R1-166470 Initial SLS results of PDMA CATT
R1-166552 On UL non-orthogonal multiple access schemes Intel Corporation
R1-166651 Non-orthogonal multiple access for uplink Sony
R1-166670 Further LLS results for UL non-orthogonal multiple access Fujitsu
R1-166671 DM-RS considerations for UL non-orthogonal multiple access Fujitsu
R1-166672 Filter design for filtered OFDM Fujitsu
R1-166750 Link level performance evaluation for IGMA Samsung
R1-166751 System level performance evaluation for non-orthogonal multiple access Samsung
R1-166752 Discussion on grant-free/contention-based non-orthogonal multiple access Samsung
R1-166871 NoMA scheme based on NCMA LG Electronics
R1-166872 Traffic model for evaluation of contention based MA LG Electronics
R1-166873 Discussion on Categorization of MA schemes and target scenarios LG Electronics
R1-166874 Discussion on Non-orthogonal Spreading Sequences for NoMA LG Electronics
R1-166875 Considerations on the receiver types and NoMA schemes LG Electronics
R1-166876 Performance evaluation of NCMA LG Electronics
R1-166877 Considerations on contention based MA LG Electronics
R1-167002 Performance analysis on the effect of spreading signature matrix in NR MA schemes Spreadtrum Communications
R1-167105 Results and Remaining Issues of LLS evaluation on Multiple Access CMCC
R1-167206 HARQ timing relationships for grant-free transmission Huawei, HiSilicon
R1-167247 Overview of the proposed non-orthogonal MA schemes Nokia, Alcatel-Lucent Shanghai Bell
R1-167248 Contention-based non-orthogonal multiple access with frequency hopping for mMTC uplink Nokia, Alcatel-Lucent Shanghai Bell
R1-167249 Non-orthogonal coded access (NOCA) Nokia, Alcatel-Lucent Shanghai Bell
R1-167250 Receiver considerations on UL MA Nokia, Alcatel-Lucent Shanghai Bell
R1-167251 Synchronization requirement and performance analysis on UL MA Nokia, Alcatel-Lucent Shanghai Bell
R1-167252 Basic principles of Contention Based access Nokia, Alcatel-Lucent Shanghai Bell
R1-167254 Channel structure for contention based access Nokia, Alcatel-Lucent Shanghai Bell
R1-167255 Procedure design for contention based access Nokia, Alcatel-Lucent Shanghai Bell
R1-167256 Collision handling for contention based access Nokia, Alcatel-Lucent Shanghai Bell
R1-167257 Preamble transmission procedures for the mMTC uplink Nokia, Alcatel-Lucent Shanghai Bell
R1-167335 LLS Results for DL MA schemes Huawei, HiSilicon
R1-167336 SLS Results for SCMA in DL eMBB scenario Huawei, HiSilicon
R1-167339 Signature pattern generation of LSSA ETRI
R1-167340 LLS results for UL low-rate code and signature based shared access scheme ETRI
R1-167392 Discussion on multiple access for UL mMTC NTT DOCOMO, INC.
R1-167393 Discussion on multiple access for eMBB NTT DOCOMO, INC.
R1-167444 Usage scenario and physical layer design for UL non-orthogonal MA China Telecommunications
R1-167445 Classification of candidate UL non-orthogonal MA schemes China Telecommunications
R1-167517 Uplink Multiple Access for 5G mMTC Lenovo
R1-167518 Discussion on contention based UL transmission Lenovo
R1-167524 Downlink Multiple Access in NR MediaTek Inc.
R1-167535 New uplink non-orthogonal multiple access schemes for NR MediaTek Inc.

Petitioners' Exhibit 1003, p. 973
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-167536 LLS results for RDMA,GOCA,RSMA and IDMA schemes MediaTek Inc.
R1-167538 Evaluation on PAPR for UL multiple access schemes MediaTek Inc.
R1-167555 NR Multiple Access Ericsson
R1-167561 On the performance of IDMA and RSMA multiple access schemes InterDigital Communications
R1-167562 Further performance evaluation of UL NOMA InterDigital Communications
R1-167563 On categorization of MA schemes for NR InterDigital Communications
R1-167602 Link level simulation results of new multiple access scheme CATR
R1-167615 Multiple access schemes for NR SHARP Corporation
R1-167698 Grant-less and non-orthogonal UL transmissions in NR Intel Corporation
R1-167700 Link-level analysis of UL NOMA transmissions Intel Corporation
R1-167742 Discussion on multiple access for mMTC III
R1-167870 Update of LLS results of PDMA CATT
R1-167872 Evaluation on SC-FDMA (NB-IoT) based multiple access scheme MediaTek Inc.
R1-167894 Modeling of timing offsets for UL non-orthogonal multiple access Intel Corporation

8.1.3 Numerology and frame structure for new radio interface

8.1.3.1 Numerology

*Focus on the set of scale factors n in fc=15*2^n that will be supported in Phase I, whether we have symbol alignment across the scalings or not*

Tuesday

R1-168090 WF on alignment among different numerologies LG Electronics, Qualcomm

The document was presented by Yunjung Yi from LGE.

- For different numerology alignment, define the following two cases
  - Inband case: different numerologies are multiplexed in the same NR carrier
  - Outband case: different numerologies are not multiplexed in the same NR carrier
- Symbol level alignment is assumed in the following cases
  - Different subcarrier spacings with the same CP overhead in inband case
- In other cases, symbol level alignment is not assumed.
  - FFS: Slot/subframe level alignment for outband case
- For normal CP family, choose one option from the followings for symbol-level alignment
  - For $F_s = F_0 * 2^n$ (n is a positive integer, F_0 = 15 kHz),
    - Each symbol length (including CP) of F_0 equals the sum of the corresponding 2^n symbols of F_s
    - Option 1: The first 2^n symbols of F_s have equal symbol length
    - Option 2: Except for the first symbol of F_s, all symbols of F_s have equal symbol length. The length of first symbol of F_s is sum of length of the second symbol and 0.51 us
      - Option 2-1. 0.51us can be reserved, and all symbols have the equal length

Discussion: Intel requested looking at 6553.
Decision: The document is noted.

R1-166553 Time interval alignment between different numerologies Intel Corporation

The document was presented by Joonyoung Cho from Intel.

- Proposal 1 (even split of 1 ms duration)
  - Duration of a time interval X for a given subcarrier spacing for cases of 15 kHz or larger is identical throughout the 1ms duration.
- Proposal 2 (single numerology for each subcarrier spacing and CP type)
  - Time interval X for a given subcarrier spacing and CP type has a single and identical numerology in all instances of the time interval X within the 1ms duration.
- Proposal 3 (1 ms boundary alignment for <15 kHz subcarrier spacing cases)
  - The start and end of a time interval X for a subcarrier spacing smaller than 15 kHz are aligned with 1 ms boundaries of 15 kHz subcarrier spacing subframes.

Decision: The document is noted.

Possible agreements:

- Symbol level alignment across the different subcarrier spacing is assumed in the case of the same CP overhead in the same subframe duration on the same NR carrier
- Extended CP is supported in NR

Continue offline discussion until Wednesday – (Qualcomm, Huawei)

Wednesday

Petitioners' Exhibit 1003, p. 974
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-168321 **Way forward on Cyclic Prefix Huawei, HiSilicon, LGE, Sony, Vodafone, Intel, CATR, CMCC Ericsson, Orange, Mediatek, Verizon, InterDigital, OPPO, CATT, China Telecom, AT&T**
The document was presented by Zhenfei Tang from Huawei.

- More than one CP length should be supported for a given sub-carrier spacing
  - The different CP lengths for a given sub-carrier spacing should be of substantially different lengths.
  - For 60 kHz subcarrier spacing, at least one CP length is similar to the normal CP length of 15 kHz corresponding to LTE numerology
- Note: FFS whether all of sub-carrier spacings support more than one CP length or not
- Note: FFS whether supporting more than one CP length for a given sub-carrier spacing is mandatory or optional for a given UE

Decision: The document is noted.

R1-168338 **WF on CP overhead ZTE, ZTE Microelectronics, Qualcomm**
The document was presented by Thorsten Schier from ZTE.

- CP overhead should be studied, especially for the case of 60 kHz subcarrier spacing.
- NR should support solutions with the same or better performance than LTE in all channel conditions

Decision: The document is noted.

Agreements:

- NR design should allow potentially defining multiple CP lengths for a given subcarrier spacing in Phase I or later
  - Multiple CP lengths do not mean the normal CP have 2 different CP lengths in the LTE
- It should be possible to deploy NR with 60 kHz subcarrier spacing in the channel that have the same delay spread that LTE can handle with the normal CP length as one use case
  - Other subcarrier spacing solution can be considered with an equal priority in the further study
- More than one CP length should be studied for a given subcarrier spacing
  - The different CP lengths for a given subcarrier spacing can be of substantially different lengths
  - For 60 kHz subcarrier spacing, at least one CP length can be similar to the normal CP length of 15 kHz corresponding to LTE numerology
  - Other proposals are not precluded
- Note: FFS whether all of subcarrier spacings support more than one CP length or not
- Note: FFS whether supporting more than one CP length for a given subcarrier spacing is mandatory or optional for a given UE

R1-168305 **WF on alignment among different numerologies LG Electronics, Intel, Ericsson, Qualcomm, Samsung, Verizon**

Agreements: Subframe duration in ms for a reference numerology with subcarrier spacing (2^m*15)kHz is exactly $1/2^m$ ms

Working assumption:

- Alignment within a subframe
  - Symbol level alignment across different subcarrier spacings with the same CP overhead is assumed within a subframe duration in a NR carrier
  - FFS: Unlicensed spectrum case

R1-168503 **Way forward on slot alignment Huawei, HiSilicon, MediaTek**
R1-168524 **Way forward on slot alignment Huawei, HiSilicon, MediaTek**
R1-168548 **Way forward on slot alignment Huawei, HiSilicon, MediaTek**

Agreement: RAN1 strives how to enable efficient time alignment between transmissions with different CP overheads

R1-167040 **On scalable numerology Ericsson**
R1-167394 **Views on NR numerology NTT DOCOMO, INC.**
R1-167527 **Discussion on NR Numerology MediaTek Inc.**
R1-167106 **Phase Noise Measurement/Modeling and LLS for High Frequency Numerology CMCC**

Agreements:

- NR numerology scalability should allow at least from [3.75 kHz] to480 kHz subcarrier spacing
- Necessity of support for less than 15 kHz subcarrier spacing (e.g., 3.75 kHz) should be studied
- Note that scalability does not mean everything should be scalable (e.g., RS density, UE/gNB processing time, signalling overhead)

R1-166100 Evaluation on CP types for NR Huawei, HiSilicon
R1-166101 Comparison and evaluation on scaling factors for subcarrier spacing Huawei, HiSilicon

Petitioners' Exhibit 1003, p. 975
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166225 Considerations on numerology for support of flexible guard lengths Mitsubishi Electric
R1-166360 URLLC numerology and frame structure design Qualcomm Incorporated
R1-166363 Scaled Numerology Control Design for NR Qualcomm Incorporated
R1-166406 Consideration of cyclic prefix for NR ZTE
R1-166471 Discussion of NR numerology CATT
R1-166490 Numerology impact on power efficiency for mMTC ZTE
R1-166491 Considerations about symbol boundary alignment ZTE
R1-166492 Frequency multiplexing of numerologies ZTE
R1-166554 Capability to support multiple numerologies Intel Corporation
R1-166609 Subcarrier spacing design for data and reference signal Guangdong OPPO Mobile Telecom.
R1-166614 Discussion of the UE support of multiple numerologies Guangdong OPPO Mobile Telecom.
R1-166637 Discussion on numerology multiplexing NEC
R1-166652 Discussion on multiple CP types Sony
R1-166753 Discussion on symbol alignment across scaled numerology Samsung
R1-166754 Discussion on numerology support Samsung
R1-166755 Discussion on candidate subcarrier spacing values in NR Samsung
R1-166878 Discussion on alignment for different numerology multiplexing LG Electronics
R1-166879 Further evaluation results on different numerology LG Electronics
R1-166938 High speed train scenario at 30GHz: link level evaluation results for RRH and relay Mitsubishi Electric Co.
R1-166939 Numerology evaluation results for high speed scenario ETRI
R1-167004 Discussion on numerology Spreadtrum Communications
R1-167027 NR numerologies KT Corp.
R1-167041 On extended CP Ericsson
R1-167107 Discussion and Evaluation on Numerology Design for High Speed Train Scenario CMCC
R1-167108 Discussion and evaluation of CP design for NR CMCC
R1-167258 On System Design for Multiple Numerologies - Initial Access Nokia, Alcatel-Lucent Shanghai Bell
R1-167259 On symbol boundary alignment in New Radio Nokia, Alcatel-Lucent Shanghai Bell
R1-167260 Resource block and guard band arrangement supporting mixed numerology Nokia, Alcatel-Lucent Shanghai Bell
R1-167328 UE support for multiple numerologies with NR INTERDIGITAL COMMUNICATIONS
R1-167329 Symbol alignment across numerologies INTERDIGITAL COMMUNICATIONS
R1-167439 Use of multiple numerologies in NR Panasonic Corporation
R1-167528 On the alignment of OFDM symbol boundary MediaTek Inc.
R1-167564 Impact of numerology on the non-CP based waveforms InterDigital Communications
R1-167673 Impact of multiplexing multiple numerologies on initial access ASUSTEK COMPUTER (SHANGHAI)
R1-167730 Study of PN Models for above 6 GHz with experimental data National Instruments Corp.
R1-167770 CP length for NR VODAFONE Group Plc
R1-167969 WF on Scalable Numerology Symbol Boundary Alignment Qualcomm Incorporated

8.1.3.2 Frame structure

R1-166364 NR numerology scaling and alignment Qualcomm Incorporated

The document (Sections 3 and 4 only) was presented by Qualcomm.

- Proposal 2: tones of scaled numerology have center of subcarrier aligned on the grid of base numerology with wider SCS being a subset of narrower SCS in a nested manner
- Proposal 3: fixed number of tones per RB regardless of numerology
- Proposal 4: RB partition is fixed for each numerology, and schedule allocates RB based on user-specific numerology in the unit of integer number of RBs for that numerology

Decision: The document is noted.

R1-166765 Discussion on resource block size in NR Samsung

The document was presented by Young Han Nam from Samsung.

- Observations
  - NR should support much wider range of transmission bandwidth than LTE
  - Minimum payload size gives an impact on determining the PRB size and the minimum size of payload could be different depending on the potential applications and use cases to be identified.
  - Fixed time and frequency granularity approach would provide limited scalability and flexibility.
  - Scalable time and frequency granularity would sufficiently provide scalability and flexibility.
- Proposal: PRB size to be specified in NR should support scalable time/frequency granularity.

Decision: The document is noted.

R1-167338 Discussion on physical resource block for NR numerologies Panasonic Corporation

The document was presented by … from Panasonic.

Petitioners' Exhibit 1003, p. 976
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Proposal 1: The number of REs in a PRB is roughly same as LTE regardless of subcarrier spacing for eMBB and mMTC.
- Proposal 2: The number *M* of subcarriers in a PRB is same regardless of subcarrier spacing for eMBB and mMTC.
- Proposal 3: PRB boundary is aligned among numerologies. Possible guard is realized by rate matching and/or puncturing..
- Proposal 4: Centre DC subcarrier handling is same among downlink, uplink and sidelink.
- Proposal 5: PRB boundary position should not be influenced by DC subcarrier insertion. If one carrier needs to be nulled, it is realized by rate matching and/or puncturing.
- Proposal 6: Common PRB boundary position should be used regardless of the system bandwidth is odd number of PRBs or even number of PRBs.
- Proposal 7: PRB size well aligned with channel raster could be consider to simplify the RF component of UE.

Decision: The document is noted.

R1-167261 On resource block grouping and multicell coordination aspects for mixed numerology support Nokia, Alcatel-Lucent Shanghai Bell

The document was presented by Karri Ranta-aho from Nokia.

- Observation 1: Previous results indicate performance benefits when using UE/service-specific numerology, e.g. for mixing use cases with different velocities or latency requirements.
- Proposal 1: Grouping of resources into resource block groups (RBG) with same numerology should be considered as a solution for enabling mixed numerology and a configurable air interface.
- Proposal 2: The RBG has a common absolute size in both time and frequency and it defines the minimum granularity for variable numerology within a same NR carrier bandwidth.
- Proposal 3: The size of one physical resource block (PRB) in terms of number of resource elements is common for all numerologies.
- Observation 2: Different levels of coordination of numerology among cells are possible. The need for coordination depends on the processing technique.
- Proposal 4: New Radio should provide possibilities of at least partial numerology coordination via the inter-base-station interface (the NR variant of the X2 interface).
- Proposal 5: New Radio should provide possibilities of reference- and sounding symbol numerology alignment across multiple cells. For those reference and sounding symbols time-multiplexing with the option of full numerology alignment across different cells should be considered.

Decision: The document is noted.

R1-166941 On design of mixed numerology in a NR carrier ETRI

The document was presented by … from ETRI and investigates several issues in the NR carrier design under the mixed numerology framework.

Decision: The document is noted.

R1-166104 Discussion on time domain structures Huawei, HiSilicon

The document was presented by David Mazzarese from Huawei.

Proposal 1: Three time domain structures should be supported for the new radio.

- DL-only time domain structure composed of a DL transmission part
- UL-only time domain structure composed of an UL transmission part
- Mixed DL and UL time domain structure composed of a DL transmission part (located at the beginning), a guard and an UL transmission part (located at the end)
  - DL-dominant: a DL transmission part (mainly for data assignments and data), a guard, a configurable short UL transmission part (mainly for UCI and SRS).
  - UL-dominant: a configurable short DL transmission part (mainly for data assignments), a guard, a UL transmission part (mainly for data, UCI and SRS)

Proposal 2: NR should support both dynamic TDD operation and semi-static TDD operation.

- Candidate TDD UL/DL configurations could be defined in NR for semi-static TDD operation. FFS the detailed candidate TDD UL/DL configurations.
- The “direction” (uplink or downlink) of a subframe can change on subframe basis for dynamic TDD operation. FFS the indication of the “direction” of a subframe.

Proposal 3: The basic length of a time domain structure is equal to the subframe durartion, which is defined from a basic time unit of 1 ms corresponding to a basic subcarrier spacing f_0 with a given number of OFDM symbols for a given CP length, and the subframe duration scales with subcarrier spacing.

- Shorter subframe durations with 0.5ms, 0.25ms and 0.125ms are supported with the subcarrier spacing increasing.
- Longer subframe duration with the subcarrier spacing decreasing is FFS.

Proposal 4: A first DL control channel located at the front of each time interval of a basic length (i.e. subframe) of a time domain structure should be supported in NR. A second DL control channel embedded in the data region in DL subframe or DL-dominant structure can also be considered for NR.

Petitioners' Exhibit 1003, p. 977
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Proposal 5: The reference signals used for demodulating a control channel or a data channel are contained only within the same time/frequency resource for that channel, and are transmitted only when that channel is present.
Decision: The document is noted.

R1-166365 Advanced frame structure Qualcomm Incorporated
The document was presented by … from Qualcomm.
- Observation 1. Advanced frame structures should allow for low priority links to yield to higher priority links to enable dynamic and decentralized UL-DL switching.
- Observation 2. Advanced frame structures should allow some gaps for sensing to enable control interval transmission on unlicensed spectrum.
- Observation 3. Advanced frame structures should allow for UE's to establish sidelink and exchange traffic while managing interference. This may apply to both broadcast and unicast sidelink transmissions.

Decision: The document is noted.

R1-166664 Frame Structure Design for NR Sony
The document was presented by Martin Beale from Sony.
- Proposal 1: RAN1 agree on (1) basic atomic building blocks of NR and (2) the time to process the building blocks.
- Proposal 2: During the NR study phase, RAN1 create some reference physical structures that are used for the purposes of evaluation.
- Proposal 3: Combinations of building blocks that span an Interval-X should be signaled semi-statically.
- Proposal 4: The DL transmission part, guard and UL transmission part can exist in any order within an Interval-X.
- Proposal 5: Within an Interval-X, there can be a guard region after the uplink transmission region.
- Proposal 6: RAN1 evaluates UE timing constraints before defining bidirectional self-contained TDD physical structures (Interval-X).
- Proposal 7: The basic physical structure of NR should allow the creation of NR subframes of a length that is either an integer multiple of the LTE subframe length or a common divisor of the LTE subframe length.

Decision: The document is noted.

R1-167946 Outcome of off line discussion NTT DOCOMO, Inc.
The document was presented by Fred Takeda from NTT DOCOMO.
- A subframe duration is defined by *x* OFDM symbols for a given CP overhead.
  - *x* is the same for all subcarrier spacing values.
  - This does not preclude multiple scheduling occasions within a subframe duration.
  - This does not preclude that one scheduling occurs over multiple subframe durations.
- A UE assumes at least one reference numerology in a given NR carrier which defines subframe duration.
- Specification supports multiplexing numerologies in TDM and/or FDM within/across (a) subframe duration(s).

Decision: The document is noted, modified as follows:

Agreements:
- A subframe duration is defined by the duration of *x* OFDM symbols given a reference numerology
  - With the same CP overhead, a single value of *x* is specified irrespective of the subcarrier spacing value chosen for the reference numerology
  - This does not preclude multiple data transmission opportunities in time within a subframe duration
  - This does not preclude multiple control transmission opportunities in time for both DL and UL within the subframe duration
  - This does not preclude one data transmission to span over multiple subframe durations
- A UE has one reference numerology in a given NR carrier which defines subframe duration for the given NR carrier
  - FFS: In a given NR carrier, whether different UEs may have different reference numerologies or may not
- Specification supports multiplexing numerologies in TDM and/or FDM within/across (a) subframe duration(s) from a UE perspective

Agreement:
- PRB definition where the number of subcarriers per PRB is the same for all numerologies is supported
  - Examples of the number of subcarriers per PRB for NR study are 12, ~~10~~, 16
  - Additional PRB definition with the different number of subcarriers is not precluded

---

Agreement: The number of subcarriers per PRB for NR study are 12, 16

Conclusion: RAN1 will down select the number of subcarriers per PRB in the next meeting

---

Agreement:

Petitioners' Exhibit 1003, p. 978
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- For subcarrier spacing of 2^n * 15kHz, subcarriers are mapped on the subset/superset of those for subcarrier spacing of 15kHz in a nested manner in the frequency domain

R1-167956 Way Forward on RB allocation for mixed numerologies ZTE, ZTE Microelectronics, Ericsson, Qualcomm

The document was presented by Patrick Svedman from ZTE.

- Subcarriers from scaled numerologies are aligned such that their center frequencies coincide
- RBs for different numerologies have a fixed grid
- Resources are allocated in integer numbers of resource blocks (RBs)
- For numerologies that are derived by sub-carrier spacing scaling from the same basic numerology, their RB grids are allocated according to the enclosed figure

Decision: The document is noted. Continue offline discussion until Tuesday

Tuesday: Revised in

R1-167978 Way Forward on RB allocation for mixed numerologies ZTE, ZTE Microelectronics, Ericsson, Qualcomm, Nokia, Alcatel-Lucent Shanghai Bell

- For one NR carrier
  - Each numerology has a fixed RB grid
  - Resources are allocated in integer numbers of resource blocks (RBs).
  - For subcarrier spacing of 2^n * 15kHz, RBs are mapped on the subset/superset of RBs for subcarrier spacing of 15kHz in a nested manner in the frequency domain

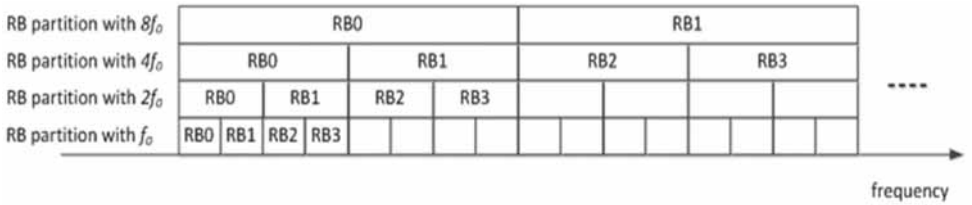
Decision: The document is noted. Further revised in:

R1-168140 Way Forward on RB allocation for mixed numerologies ZTE, ZTE Microelectronics, Ericsson, Qualcomm, Nokia, Alcatel-Lucent Shanghai Bell, Panasonic

Decision: The document is noted

Agreements:

- In one carrier when multiple numerologies are time domain multiplexed,
  - RBs for different numerologies are located on a fixed grid relative to each other
  - For subcarrier spacing of 2^n * 15kHz, the RB grids are defined as the subset/superset of the RB grid for subcarrier spacing of 15kHz in a nested manner in the frequency domain
  - Note that following numbering in the figure is just an example
  - FFS: frequency domain multiplexing case



Continue offline discussion until Wednesday – Thorsten (ZTE)

R1-168309 Way Forward on RB grid definition for mixed numerologies ZTE, ZTE Microelectronics, Ericsson, Qualcomm, Nokia, Alcatel-Lucent Shanghai Bell, Panasonic, Convida Wireless

Conclusions:

- Proponents are encouraged to study followings
  - Alt. 1: Adopt RB grid for FDM as it is agreed in TDM
  - Alt. 2: Use RB grid corresponding to the reference numerology for FDM, applied the same grid to TDM, and revisit above agreements for TDM

Possible agreements:

- No explicit DC subcarrier reserved
- DL and UL have the same DC subcarrier handling

Continue offline discussion until Tuesday

Tuesday Agreement: No explicit DC subcarrier is reserved both for DL and UL

R1-166362 Self-contained subframe timeline analysis Qualcomm Incorporated

The document was presented by Jing Jiang from Qualcomm.

- Observation 1: A fundamental sustainability threshold for UE modem processing throughput on the downlink is one symbol processed per symbol time.

Petitioners' Exhibit 1003, p. 979
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Observation 2: In a self-contained DL subframe, the amount of gap between the end of the data channel to the beginning of ACK/NACK heavily impacts modem processing pipeline architecture and the hardware capability requirement.
- Observation 3: Even with symbol-by-symbol processing, the pipeline depth may span more than one symbol time. This in turn imposes a requirement for the amount of gap. Reducing the payload towards the end of the data channel is an effective way to decouple pipeline design and the amount of gap required.
- Proposal 1: UE capability framework should be designed to be flexible to facilitate hardware-efficient support for self-contained subframe.
- Observation 4: Scaled numerology facilitates better pipelined processing and offers significant timeline advantage, which is especially crucial for self-contained UL centric subframe.
- Proposal 2: Scaled numerology for the downlink control channel should be studied with applicability for uplink-centric and downlink centric self-contained subframe types.
- Observation 5: Symbol-by-symbol construction and transmission of uplink data is crucial for reducing the latency in UE responses.
- Proposal 3: Uplink reference signal and data channel should be designed to facilitate symbol-by-symbol processing on the UE. This study should extend up the protocol stack to ensure there is no roadblock and to identify potential cross-layer optimizations.
- Proposal 4: UL burst channel structure should be designed with considerations for processing timeline to feedback ACK/NACK.
- Observation 6: Self-contained subframe operation may be feasible with gaps on the order of ~1 OFDM symbol, and equivalently with X and Y on the order of 10s of us.
- Proposal 5: Downlink control and data channels should be designed with flexibility to support single-interlace transmission to allow time-critical processing on the eNB side for immediate ACK processing and potential retransmission.

Decision: The document is noted.

R1-167523 Timing Relationship for NR Frame Structure MediaTek Inc.

The document was presented by Peikai Liao from MediaTek.

- Proposal 1: For eMBB, the time separation, X, between the end of the DL data transmission and the beginning of corresponding acknowledgement reporting should be ≥ 160μs.
- Proposal 2: For eMBB, the time separation, Y, between the end of UL grant transmission and the beginning of the corresponding uplink data transmission should be ≥ 160μs.
- Proposal 3: For eMBB, the following timing relationship should be the baseline.
  - Timing relationship between DL data reception and its corresponding acknowledgement in UL: Subframe N→N+2+K or N+4+K, where K is signalled to a UE dynamically and/or semi-statically; FFS K values
  - Timing relationship between UL assignment and its corresponding UL data transmission: Subframe N→N+2+K or N+4+K, where K is signalled in DCI; FFS K values
  - Timing relationship between DL scheduler and its corresponding DL data: Subframe N→N
- Proposal 4: For URLLC, further evaluate whether self-contained operation is necessary.
- Proposal 5: For self-contained operation, DL physical data channel structure should enable on-the-fly decoding with the following design considerations.
  - Demodulation pilots for the physical DL control channel should be located at the beginning of the physical DL control channel.
  - Decoding complexity of physical DL control channel should be reduced with high reliability, compared to LTE.
  - Demodulation pilots for the physical DL data channel should be located at the beginning of the physical DL data channel but other additional demodulation pilots at later location are not precluded.
  - Demodulation pilots for the physical UL data channel should be located at the beginning of the physical UL data channel but other additional demodulation pilots at later location are not precluded.
  - Coded bit to RE mapping should be frequency first and then time in DL data channel.
  - Code block size for DL data should be equal to or less than 3000 bits.
- Proposal 6: For self-contained operation, UL physical data channel structure should enable on-the-fly encoding with the following additional design considerations.
  - Demodulation pilots for the physical UL data channel should be located at the beginning of the physical UL data channel but other additional demodulation pilots at later location are not precluded.
  - Coded bit to RE mapping should be frequency first and then time in UL data channel.
  - Code block size for UL data should be equal to or less than 3000 bits.

Decision: The document is noted.

R1-167299 Timing requirements and scenarios for 5G NR Hybrid ARQ Nokia, Alcatel-Lucent Shanghai Bell

The document was presented by Karri Ranta-aho from Nokia.

- Observation 1: The timing of ACK/NACK's and the number of SAW channels shall be configurable to efficiently support for different network implementations (e.g. to account for L1-L2 latencies for C-RAN implementations). The range of timing values from uplink data transmission until reception of the corresponding ACK/NACK by the UE should be configurable to equal values of sub-ms up to values of ~6 ms.

Petitioners' Exhibit 1003, p. 980
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Observation 2: The HARQ scheme shall support asymmetric link operation, where the transmission time interval (TTI) and/or time of ACK/NACK transmissions can be configured differently for the uplink and downlink per UE.
- Observation 3: For URLLC, various HARQ enhancements such options for early ACK/NACK feedback, automatic retransmissions until reception of ACK, and potential joint UL/DL HARQ design shall be supported.
- Observation 4: For mMTC use cases, options for simplified HARQ operation are desirable, including support for low cost mMTC devices with half-duplex capabilities and relaxed timing requirements.
- Observation 5: The minimum supported timing relationship between DL data reception and the corresponding UL ACK/NACK transmission, as well as the minimum ttiming relationship between the UE receiving an UL scheduling assignment and corresponding UL data transmission, could be UE category dependent.
- Proposal 1: The following timing relationships shall be flexibly configurable per UE; (i) timing relationship between DL data reception and corresponding ACK/NACK, (ii) time-duration of the ACK/NACK transmission, and (iii) timing relationship between the UL assignment and corresponding UL data transmission. Configured per UE, using either dedicated RRC-, MAC-, or PHY-level control signalling,
- Proposal 2: It shall be studied if there are attractive complexity and cost tradeoffs from having UE categories with different minimum timing relationships for DL data reception and the corresponding UL ACK/NACK transmission, and between the UE receiving an UL scheduling assignment and corresponding UL data transmission.

Decision: The document is noted.

Observations:

- At least followings are potentially identified as mean to realize the short processing delay and RAN1 will continue to study it
  - Frequency-first and time-second mapping
  - Code block segmentation that facilitates symbol-by-symbol processing
  - Reduce symbol durations
  - DL assignment and UL grant before and/or at the beginning of its scheduled data duration
  - TBS restriction
  - Timing advanced restriction
  - Channel coding
  - Front loaded RS mapping for control channel
  - Grant free transmission

Tuesday

Agreements:

- Unless otherwise specified or indicated to the UE, the UE shall make no assumption on whether to transmit or to receive at least within the data region(s) in a given time interval X
  - Indication to the UE may include
    - Dynamic L1 signaling
    - RRC configuration
    - Broadcast signaling
    - …

Agreements:

- The following is supported for NR
  - From UE perspective, HARQ ACK/NACK feedback for multiple DL transmissions in time can be transmitted in one UL data/control region is supported
  - Some or all of the following timing relationships can be indicated to a UE dynamically by the L1 DL signaling (FFS: explicit or implicit)
    - Timing relationship between DL data reception and corresponding acknowledgement
    - Timing relationship between UL assignment and corresponding UL data transmission
    - Note: Default value, if any, for each timing relationship is FFS (agreement from RAN1 #85)
    - Note: Potential values for each timing relationship has to be studied further considering e.g., UE processing capability, gap overhead, UL coverage, and etc. (agreement from RAN1 #85)
    - Note: Other means of indicating the timing relationship are not precluded
  - Some or all of the following timing relationships can be indicated to a UE semi-statically (FFS: explicit or implicit)
    - Timing relationship between DL data reception and corresponding acknowledgement
    - Timing relationship between UL assignment and corresponding UL data transmission
    - Note: Default value, if any, for each timing relationship is FFS (agreement from RAN1 #85)
    - Note: Potential values for each timing relationship has to be studied further considering e.g., UE processing capability, gap overhead, UL coverage, and etc. (agreement from RAN1 #85)
    - Note: Other means of indicating the timing relationship are not precluded

Petitioners' Exhibit 1003, p. 981
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Possible agreements:

- NR design at least supports the following
  - Fixed default timing relationship between DL assignment and corresponding DL data transmission
  - FFS: Additionally, a UE is indicated dynamically and/or semi-statically on timing relationship between DL assignment and corresponding DL data reception
    - Note: This additional signalling can overrides the fixed default timing
  - FFS: A UE is indicated dynamically and/or semi-statically on the duration for DL data reception and UL data transmission

Continue offline discussion within Wednesday – (LGE)

Wednesday

R1-168304 WF on Data Scheduling LG Electronics, Qualcomm

The document was presented by Yunjung Yi from LGE.

- NR design supports the following
  - A UE is indicated dynamically and/or semi-statically on timing relationship between DL assignment and corresponding DL data reception
  - FFS whether there is a fixed timing relationship between DL assignment and corresponding DL data transmission
  - A UE is indicated dynamically and/or semi-statically on the duration for DL data reception and UL data transmission

Decision: The document is noted.

R1-168290 WF on Legacy UEs Blank Resource Indication Qualcomm Incorporated, Samsung, Ericsson

The document was presented by Tingfang Ji from Qualcomm.

- Proposal 1: Study signalling describing blank resources in time- and/or frequency-domains in each "slot".
- Proposal 2: Consider broadcast and unicast signalling options
  - Unicast signalling could be in the DCI for scheduled legacy UEs to implicitly describe blank resources
  - Broadcast signalling could be used for scheduled and non-scheduled UEs

Decision: The document is noted.

Continue offline discussion until Thursday – Yunjung (LGE), Tingfang (Qualcomm)

Thursday

R1-168434 WF on Resources for data scheduling LG Electronics, Qualcomm

R1-168502 WF on Resources for data scheduling LG Electronics, Qualcomm

Conclusion: Further study

- how to multiplex mini slot and slot
- the benefit and mechanism of indicating blank resources at least for forward compatibility perspective

R1-168058 Way Forward on Slot Types Huawei, HiSilicon, Docomo, Nokia, Alcatel-Lucent Shanghai Bell

The document was presented by David Mazzarese from Huawei.

- Basic slot types are shown in enclosed figure (seen from the network)
  - Basic slot type is defined by the number of (N) OFDM symbols using the same numerology
    - N=7 for normal CP, N=6 for extended CP
    - This means there can be 0, 1 or 2 DL/UL switching points within 1 ms at 15 kHz subcarrier spacing, depending on network choice
  - Shorter slots are obtained with larger subcarrier spacing
- Additional slot types are not precluded

Decision: The document is noted.

R1-167441 Comparison of time domain frame structure Panasonic Corporation

The document was presented by Hidetoshi Suzuki from Panasonic.

- Proposal: For 15 kHz subcarrier spacing of self-contained allocation with sufficient DL or UL data length cases, 2 HARQ process within 1ms and 1 DL to UL switching point should be used. In the other cases, 1 HARQ process within 1ms and 0 or 1 DL to UL switching period should be used.

Decision: The document is noted.

R1-168108 WF on time-domain structure in NR LGE, Panasonic

The document was presented by Yunjung Yi from LGE.

- Within a subframe of x OFDM symbols, at least the following are supported
  - DL portion
    - DL portion size can be from 0 to 14 symbols from the start of the subframe
  - UL portion
    - UL portion size can be from 0 to 14 symbols
    - The time-location of UL portion within a subframe can be flexible
- x = 14 with 15 kHz normal CP

Petitioners' Exhibit 1003, p. 982
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Decision: The document is noted.

Possible agreements:

- Within a time transmission duration of y OFDM symbols, at least the following are supported
  - DL portion
    - DL portion size can be from 0 to y time transmission duration from the start of the time transmission duration
    - At least 0 and y are supported
  - UL portion
    - UL portion size can be from 0 to y time transmission durations
    - At least 0 and y are supported
    - The time-location of UL portion within a time transmission duration can be flexible
  - DL/UL portion is contiguous

Possible agreement:

- x = 14 with 15 kHz normal CP

Continue offline discussion within Tuesday – (Panasonic)

R1-168154 WF on time-domain structure in NR Panasonic

The document was presented by Hidetoshi Suzuki from Panasonic.

Decision: The document is noted and:

Possible agreements:

- In case of the same numerology between DL and UL, within a time duration of y OFDM symbols, the following are supported
  - DL portion
    - DL portion size can be from 0 to y symbol time duration from the start of the time duration
    - At least 0 and y are supported
  - UL portion
    - UL portion size can be from 0 to y symbol time duration
    - At least 0 and y are supported
    - The time-location of UL portion within a time transmission duration can be flexible
  - y symbols are contiguous
- FFS: Start from UL portion case
- At least following is supported.
  - y = 14 in 15 kHz subcarrier spacing in normal CP
  - FFS: y= 7 with 15 kHz subcarrier spacing in normal CP
- FFS: a time duration y is same as a subframe duration or multiple time duration present in a subframe duration.
- FFS: different numerology between DL and UL

Continue offline discussion within Tuesday – (Panasonic)

Wednesday

R1-168167 WF on time-domain structure in NR Panasonic, LGE

Decision: The document (update of R1-168154) is noted. Further revised in:

R1-168341 WF on time-domain structure in NR Panasonic

Decision: The document is noted.

Possible agreements:

- In case of the same numerology between DL and UL, within a time duration of y OFDM symbols, the following are supported
  - DL portion
    - DL portion size can be from 0 to y symbol time duration from the start of the time duration
    - At least 0, y, one value within the range (0,y) are supported
    - Within a DL portion, one or multiple mini slots can be available.
  - UL portion
    - UL portion size can be from 0 to y symbol time duration
    - At least 0, y, one value within the range (0,y) are supported
    - The time-location of UL portion within a time transmission duration can be flexible
    - Within a UL portion, one or multiple mini slots can be available.
  - Each of DL portion and UL portion is contiguous.
  - The spec should allow DL portion and UL portion is TDMed with a gap (in case of non-full duplex)
- At least following is supported.
  - y = 14 in 15 kHz subcarrier spacing in normal CP
  - FFS: y= 7 with 15 kHz subcarrier spacing in normal CP

Petitioners' Exhibit 1003, p. 983
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- FFS: The time duration y is the same as the subframe duration and/or a multiple of the time durations present in the subframe duration.
- FFS: different numerology between DL and UL
- FFS: time duration of y starts from UL
- FFS: whether and how to extend the discussion on DL portion/UL portion length required for the coexistence with LTE TDD

Continue offline discussion until Thursday – Suzuki (Panasonic)

Thursday

R1-168368 WF on time-domain structure in NR Panasonic

Agreements:

- A slot can contain all downlink, all uplink, or {at least one downlink part and at least one uplink part}
  - FFS regarding the number of switching points, multiplexing of different use cases (e.g., multiplexing eMBB and URLLC use cases) and/or numerologies in the time domain

R1-168469 WF on slot and time interval X Huawei, HiSilicon, Sharp, Panasonic

R1-168294 WF on Frame Structure Ericsson, Huawei, Qualcomm, Nokia, Sony, DoCoMo, MediaTek, Fujitsu, CATT, Intel, ZTE, InterDigital

The document was presented by Stefan Parkvall from Ericsson.

› Subframe
  – Already agreed upon
  – Assume x=14 in the reference numerology for subframe definition (for normal CP)
  – FFS: y=x and/or y=x/2
› Slot
  – Slot of duration y OFDM symbols in the numerology used for transmission
  – An integer number of slots fit within one subframe duration (at least for transmission numerologies shorter than or equal the reference numerology)
  – The structure allows for ctrl at the beginning
  – The structure allows for ctrl at the end
  – The structure allows for ctrl at the end and at the beginning
  – One possible scheduling unit
› Mini-slot
  – Should at least support transmission shorter than y OFDM symbols in the numerology used for transmission
  – May contain ctrl at the beginning and/or ctrl at the end
  – The smallest mini-slot is the smallest possible scheduling unit (FFS: smallest number of symbols)
› Note: the names are for the purpose of discussion. Whether some terms can be merged or not is FFS

Decision: The document is noted and modified as follows:

Agreements:

- Followings are considered as starting points of NR frame structure at least within the CP overhead
  - Subframe
    - Already agreed upon
    - Assume x=14 in the reference numerology for subframe definition (for normal CP)
    - FFS: y=x and/or y=x/2 and/or y is signalled
  - Slot
    - Slot of duration y OFDM symbols in the numerology used for transmission
    - An integer number of slots fit within one subframe duration (at least for subcarrier spacing is larger than or equal the reference numerology)
    - The structure allows for ctrl at the beginning only
    - The structure allows for ctrl at the end only
    - The structure allows for ctrl at the end and at the beginning
    - Other structure is not precluded
    - One possible scheduling unit
  - Mini-slot
    - Should at least support transmission shorter than y OFDM symbols in the numerology used for transmission
    - May contain ctrl at the beginning and/or ctrl at the end
    - The smallest mini-slot is the smallest possible scheduling unit (FFS: smallest number of symbols)
  - Note: the names are for the purpose of discussion. Whether some terms can be merged or not is FFS
  - FFS whether NR frame structure needs to support both slot and mini-slot or these can be merged

Petitioners' Exhibit 1003, p. 984
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-168191 **WF on different time intervals for NR frame structure ZTE, ZTE Microelectronics, Qualcomm**

- For a reference numerology, multiple durations are defined in number OFDM symbols for time interval
  - A minimum duration is defined in x1 OFDM symbols
- At least from network perspectives, different durations of time intervals can be multiplexed in TDM and/or FDM
  - FFS: Whether or not NR support nested time interval structure for different duration.
  - Resources already allocated for a longer time interval may also be used for a shorter time interval
    - E.g. for URLLC operation

Decision: The document is noted. Further revised in:

R1-168331 **WF on different time intervals for NR frame structure ZTE, ZTE Microelectronics, Qualcomm, Sharp, InterDigital**

Discussion: .Also supported by MTI

Decision: The document is noted.

Possible agreements:

- At least for DL, it should be possible to override the ongoing transmission with a short transmission at least from NW perspective

Possible agreements:

- For a reference numerology, multiple durations are defined in number OFDM symbols for time interval
  - A minimum duration is defined in x_1 OFDM symbols

Possible agreements:

- At least from network perspectives, different durations of time interval can be multiplexed in TDM and/or FDM
  - FFS: Whether or not NR supports nested time interval structure for different duration
- Resources already scheduled for a longer time interval may be rescheduled for a shorter time interval , e.g. for URLLC operation
  - Option1: Ongoing transmission for longer interval is punctured
  - Option2: Ongoing transmission for longer interval is dropped
  - Other solutions are not precluded

Continue offline discussion until Thursday – Zhisong (ZTE)

R1-168438 **WF on Supporting URLLC in NR LG Electronics, ZTE**

R1-168499 **WF on different time intervals for NR frame structure ZTE, ZTE Microelectronics, Qualcomm, LGE Sharp, MTI, InterDigital, CATT**

R1-168545 **WF on Supporting URLLC in NR LG Electronics, ZTE, Sharp, MTI**

R1-168550 **WF on Supporting URLLC in NR LG Electronics, ZTE, Sharp, MTI**

Agreements:

- At least the following potential options should be considered
  - At least for shorter transmission UL, semi-static resource sharing between URLLC and eMBB
    - FDM and/or TDM manner
      - UL grant-free transmission for URLLC
      - Other schemes are not precluded
  - Dynamic resource sharing between URLLC and eMBB
    - For DL, mechanisms to schedule a transmission where the resources of it can overlap with resources of ongoing/scheduled longer transmission at least from network perspective
      - FFS: A similar or same mechanism applicability to UL
      - Preemption or superposition
      - Other schemes are not precluded
    - Scheduling based approaches (e.g., by adapting transmission duration or by using different subbands) to allow multiplexing of different durations of transmission
    - UL grant-free transmission for URLLC
    - Other schemes are not precluded
  - Other mechanisms are not precluded

R1-166488 **Wireless backhaul/relay for NR AT&T GNS Belgium SPRL**

R1-166368 **UE Power Consideration based on Days-of-Use Qualcomm Incorporated**

R1-168352 **WF on NR UE Power Consumption Reduction Qualcomm**

Agreements:

- Impact of UE DL reception energy consumption should be studied also considering the total power consumption mainly focusing on DoU

Petitioners' Exhibit 1003, p. 985
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- e.g., UE decoding power consumption in the physical layer DL control blind decoding in lack of grant
- e.g., UE decoding power consumption in the slot with the data
- e.g., UE decoding power consumption in the data reception process
- e.g., UE decoding power consumption in the measurement
- e.g., UE decoding power consumption in the SS

- UE power reduction techniques also should be studied

R1-168430 **WF on number of HARQ processes for NR** **Qualcomm, DCM, ZTE, ~~Verizon~~**
R1-168342 **Way Forward on HARQ Process for NR** **MediaTek, Intel, Samsung, Nokia, ASB**

R1-168532 **Way Forward on HARQ Process for NR** **Mediatek**

R1-168395 **WF on DL and UL transmission for NR** **CMCC, China Telecom, China Unicom, Softbank, CATT, Huawei, HiSilicon, OPPO, Nokia, Alcatel-Lucent Shanghai Bell, MediaTek, Qualcomm, Samsung, ZTE, ZTE Microelectronics, LG Electronics, CATR**
Also supported by Ericsson, Convida, Xiaomi

Agreements:

- NR supports at least semi-statically assigned DL/UL transmission direction as gNB operation
  - The assigned DL/UL transmission direction can be signalled to UE by higher layer signalling

R1-168347 **WF on additional RS for NR** **LG Electronics, Samsung, NTT DOCOMO**

Agreements:

- In addition to the front-loaded RS agreed to study in RAN1#85, same or extended/additional RS is studied in NR of at least the following:
  - Estimate/compensate Doppler parameters
  - Compensate phase rotation and frequency offset
  - Note that RS may or may not be UE-specific

R1-168489 **Use Cases/Scenarios for Slot Structure Discussion** **Qualcomm**

R1-168531 **WF on Use Case Discussion for Time Domain Structure Use Cases** **Qualcomm**

- Email discussion for proponents to provide further input on use cases with completion target by Sept 15th – (Qualcomm); e.g.,
  - What specific cases to support the particular numerologies such as 15 kHz subcarrier spacing
  - How often can DL control appear? UL control?
    - How is this associated with the transmission duration mentioned in R1-168489?
  - How often can user be scheduled?
    - What is smallest possible scheduled duration?
  - How often may gaps appear w/in transmission duration? How much overhead?
  - Note: please provide all lengths in terms of symbols for each intended SCS.
    - SCS as provided (or updated from) R1-168489 "Use Cases/Scenarios for Slot Structure Discussion"
    - Absolute times (e.g, ms or us) should also be supplied for clarification
    - Any other questions may be added

R1-168534 **Way forward on time-domain structure** **NTT DOCOMO**

R1-168491 **Way forward on control channel for NR** **LG Electronics, Samsung, Panasonic**
R1-168429 **WF on Integrated Backhaul and Access** **Huawei, HiSilicon, AT&T, Samsung, Qualcomm, Ericsson, ASTRI**
Conclusions:

- Mechanisms for joint operation of backhaul link and access link should be studied by NR, including
  - Study dynamic resource allocation among backhaul and access links, including TDM and FDM and SDM approaches under half-duplex constraint
  - Study multi-hop backhauling and multi-site connectivity in backhauling
  - Mechanism for integration of new TRPs/RNs carrying integrated backhaul and access functionalities
  - Mechanisms for discovery and management of backhaul links for the connected TRP/relay nodes (if supported) with integrated backhaul and access links

Petitioners' Exhibit 1003, p. 986
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

  - Other aspects/functionalities such as forward compatibility to study full duplex operation on backhaul and/or access links are FFS
- RAN1 should strive for a common mobility handling and beam management framework for mobile TRP/relay nodes (if supported) carrying joint operation of backhaul and access functionalities and the usual UEs
- Note: No assumption on particular RAN architecture

R1-166102 Overview of frame structure for NR Huawei, HiSilicon
R1-166103 Discussion on flexible frame structure with different numerologies Huawei, HiSilicon
R1-166105 Discussion on timing relations for NR frame structure Huawei, HiSilicon
R1-166106 Support of flexible bandwidth Huawei, HiSilicon
R1-166117 Wideband support for NR Huawei, HiSilicon
R1-166122 Evaluation parameters for unified duplex study Huawei, HiSilicon
R1-166361 Control interval and scheduling interval Qualcomm Incorporated
R1-166367 Multi-TTI frame structure and utility for short subframes in MMW Qualcomm Incorporated
R1-166407 Uplink data scheduling and transmission for NR frame structure ZTE
R1-166408 Multiplexing of eMBB and URLLC ZTE
R1-166409 UL part in NR Frame structure for the unlicensed spectrum ZTE
R1-166410 Consideration on URLLC in NR frame structure ZTE
R1-166472 NR frame structure design CATT
R1-166555 Frame structure design for NR Intel Corporation
R1-166556 Requirements and solutions for LTE/NR Coexistence Intel Corporation
R1-166610 On DL HARQ for NR Guangdong OPPO Mobile Telecom.
R1-166613 Pairing or combining the two types of self-contained subframes Guangdong OPPO Mobile Telecom.
R1-166615 Discussion of the UE processing time on the support of multiple numerologies and frame structures Guangdong OPPO Mobile Telecom.
R1-166638 Proposals for frame structure NEC
R1-166662 MU-MIMO impact on frame structure for NR Sony
R1-166673 NR Frame structure considerations for low latency TDD operation Fujitsu
R1-166674 Discussion on flexible/dynamic TDD Fujitsu
R1-166675 Guard period setting in TDD based NR frame structure Fujitsu
R1-166676 TDD frame structure with mixed numerology Fujitsu
R1-166756 Discussion on UL control channel structure for NR Samsung
R1-166757 Discussion on frame structure and HARQ timing Samsung
R1-166758 Discussion on time interval X Samsung
R1-166759 Discussion on URLLC support in NR Samsung
R1-166760 Discussions on reference signal design for NR Samsung
R1-166761 Dynamic TDD for NR Samsung
R1-166762 PDCCH Design Considerations Samsung
R1-166763 Discussion on wireless backhaul support Samsung
R1-166764 Discussion on NR subframe structure and control signaling Samsung
R1-166766 Discussion on measurement support for single/multi-beam NR operation Samsung
R1-166767 Framework for multiplexing different verticals Samsung
R1-166880 Discussion on minimum HARQ-ACK and retransmission timing LG Electronics
R1-166881 Subframe and mini-subframe definition for frame structure of NR LG Electronics
R1-166882 Overall discussion on URLLC LG Electronics
R1-166883 Discussion on flexible duplex operation in NR design LG Electronics
R1-166884 Inter-cell interference coordination for flexible duplex operation LG Electronics
R1-166886 Handling URLLC in new RAT LG Electronics
R1-166887 Discussion on relay operation in NR LG Electronics
R1-166888 Discussion on multi-carrier operation between LTE and NR LG Electronics
R1-166889 On MBMS support in NR LG Electronics
R1-166940 Discussion on numerology multiplexing in NR ETRI
R1-166942 Frame structure for new radio interface ETRI
R1-167005 Discussion on frame structure Spreadtrum Communications
R1-167037 Demodulation reference signal design principles Ericsson
R1-167038 DMRS reuse for data and control Ericsson
R1-167039 On different HARQ reporting modes Ericsson
R1-167042 On FDD frame structure Ericsson
R1-167043 On sidelink frame structure Ericsson
R1-167044 On dynamic TDD Ericsson
R1-167045 On low-latency frame structure Ericsson
R1-167046 Summary ofn NR subframe design Ericsson
R1-167047 On smallest schedulable unit Ericsson

Petitioners' Exhibit 1003, p. 987
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-167048 On subframe description Ericsson
R1-167049 On subframe scaling Ericsson
R1-167050 On symbol scaling Ericsson
R1-167051 On time interval X Ericsson
R1-167052 On multi-subframe scheduling for uplink transmissions Ericsson
R1-167053 On the number of HARQ processes Ericsson
R1-167079 Frame structure and DMRS positions Ericsson
R1-167080 Concatenated block RS design Ericsson
R1-167089 Discussion on NR operation in unlicensed spectrum ZTE
R1-167109 Discussion on frame structure design for NR CMCC
R1-167110 Discussion on Time Interval and TTI for NR CMCC
R1-167127 Frame structure considerations for URLLC Intel Corporation
R1-167203 Discussion on control channel design Huawei, HiSilicon
R1-167204 Discussion on reference signal design Huawei, HiSilicon
R1-167218 Numerology and Frame Structure for NR-Unlicensed Huawei, HiSilicon
R1-167262 Basic frame structure principles for New Radio Nokia, Alcatel-Lucent Shanghai Bell, Verizon Wireless
R1-167263 On HARQ and scheduling timing for New Radio Nokia, Alcatel-Lucent Shanghai Bell
R1-167264 On flexible RS design principles Nokia, Alcatel-Lucent Shanghai Bell
R1-167265 Frame Structure Support for Beam Based Common Control Plane Nokia, Alcatel-Lucent Shanghai Bell, Verizon Wireless
R1-167266 On the unlicensed band operation in NR Nokia, Alcatel-Lucent Shanghai Bell
R1-167267 On the wireless relay / self-backhauling operation in NR Nokia, Alcatel-Lucent Shanghai Bell
R1-167268 On the sidelink operation in NR Nokia, Alcatel-Lucent Shanghai Bell
R1-167269 On the URLLC transmission formats for New Radio TDD Nokia, Alcatel-Lucent Shanghai Bell
R1-167330 Frame structure in NR INTERDIGITAL COMMUNICATIONS
R1-167331 Efficient multiplexing of traffic for different use cases INTERDIGITAL COMMUNICATIONS
R1-167395 Views on NR frame structure NTT DOCOMO, INC.
R1-167397 Views on NR demodulation RS NTT DOCOMO, INC.
R1-167440 NR time domain structure Panasonic Corporation
R1-167521 Latency Analysis for NR Frame Structure MediaTek Inc.
R1-167522 Flexible Frame Structure for New Radio Access Technology MediaTek Inc.
R1-167584 Frame Structure for Channel Reciprocity Based Downlink MIMO in NR National Instruments Corp.
R1-167600 Discussions on the frame structure design for URLLC CATR
R1-167616 The feasible gap duration and association timing in NR SHARP Corporation
R1-167632 Signalling Framework to enable flexible Frame Structure for NR Motorola Mobility
R1-167732 Design Considerations on Guard Period for NR Frame Structure National Instruments Corp.
R1-167733 Discussion on NR frame structure CHTTL
R1-167739 Discussion on frame structure for NR III
R1-167744 IC friendliness vs configurable DMRS Ericsson
R1-167754 On Frame Structure for NR Innovative Technology Lab Co.
R1-167777 Considerations on Frame Structure for NR KT Corp.
R1-167975 WF on Dynamic TDD in NR Intel, Ericsson, MediaTek, Sharp, NTT Docomo, Qualcomm, Samsung, Verizon, Nokia, ETRI
R1-167976 WF on NR Frame Structure Intel, Ericsson, Huawei, Sharp, Interdigital, Nokia, CATT, Verizon, Samsung, ETRI
R1-167979 Way Forward on Ack/Nack feedback of DL HARQ for NR ZTE, ZTE Microelectronics, Ericsson, Qualcomm, NTT Docomo, InterDigital
R1-168092 WF on number of HARQ processes to support for NR Qualcomm
R1-168265 WF on subframes and slots Ericsson
R1-168435 WF on SLS evaluation methodologies for autonomous/grant-free/contention-based MA LG Electronics

8.1.4 Channel coding and modulation for new radi'o interface

R1-168418 Chairman's notes of AI 8.1.4 on channel coding and modulation for NR Ad-Hoc chair (Nokia)
The document was presented by Matthew Baker from Nokia.
Decision: The document is endorsed and incorporated as follows.

8.1.4.1 Channel coding

Complexity comparisons
R1-166372 Channel coding evaluation of performance and implementation for EMBB Qualcomm Incorporated
R1-166557 Comparison of channel coding schemes for NR Intel Corporation
R1-166774 Discussion on complexity of NR candidate FECs Samsung
R1-166932 Implementation Consideration of Channel Coding Candidates for NR Ericsson

Petitioners' Exhibit 1003, p. 988
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166936 **Survey of Channel Decoder Implementations Ericsson**
R1-167213 **Computational and implementation complexity of channel coding schemes Huawei, HiSilicon**
R1-167272 **Implementation aspects of eMBB coding schemes Nokia, Alcatel-Lucent Shanghai Bell, Verizon Wireless, Xilinx**
R1-167531 **Area, Power and Latency Comparison for NR High Throughput Decoder MediaTek Inc.**

R1-166413 **Consideration on channel coding for NR ZTE**
Revised in R1-17901

R1-168103 **WF on implementation complexity for eMBB coding scheme Nokia, ASB, Samsung, Ericsson, LG**

Performance comparisons
R1-167895 **Performance evaluation on channel coding candidates for NR ZTE**
Revision of R1-166411
R1-166559 **Performance of channel coding schemes for NR Intel Corporation**

R1-167212 **Performance of polar and LDPC codes for eMBB scenarios Huawei, HiSilicon**
R1-167239 **Field test results of channel coding schemes Huawei, HiSilicon**
R1-167270 **Performance of eMBB channel coding candidates Nokia, Alcatel-Lucent Shanghai Bell**
R1-167601 **Some simulation results for different coding schemes CATR**

R1-168163 **WF on further channel coding simulation data sharing InterDigital, Qualcomm, Huawei, Ericsson, Samsung, MediaTek, LG, Nokia, ASB, ZTE, Intel, Sharp**

Conclusion:
- Combined channel coding simulation data sharing is needed by filling in the base excel spreadsheets from participating companies
  - Example base excel spreadsheets are attached
  - Participating companies may add their data upon the combined excel spreadsheet and update the file version
    - Offline emails can be used to track the updates: Moderator: Chunxuan Ye, Interdigital
  - Simulation curves may not be aligned given the same configuration, probably due to different codes or decoding algorithms
    - May need to specify further details of different channel codes
- Companies encouraged to further contribute, update and align their simulation results for RAN1 #86bis

R1-168285 **WF on channel code evaluation for URLLC Qualcomm**

Other comparisons
R1-168169 **WF on Flexibility of Channel Coding Techniques Ericsson, Nokia, ASB, LG, Orange, IMT**
Also supported by NEC.

Agreement:
- Channel coding techniques for NR, should support the following:
  - Info block size K flexibility:
    - Granularity at lower end of range of K = [D1] bits
      - D1 may be different for control and data channels
      - FFS whether D1 may be different for different code rates
    - FFS whether the granularity is coarser at higher values of K
    - Shortening (i.e. assigning info bits to known values, e.g. 0) may be used to provide info block size flexibility
  - Codeword size flexibility:
    - Basic code design with rate matching (i.e., puncturing and/or repetition) supports 1-bit granularity in codeword size

R1-167999 **WF on Channel Coding Selection Qualcomm Incorporated, Samsung, Nokia, ASB, ZTE, MediaTek, Intel, Sharp, MTI, Interdigital, Verizon Wireless, KT Corporation, KDDI, IITH, CEWiT, Reliance-jio, Tejas Networks, Beijing Xinwei Telecom Technology, Vivo, Potevio, WILUS, Sony, Xiaomi**
Also supported by Oppo.
Revision of R1-166376
Proposal:
- LDPC should be selected for eMBB data channel to provide performance and implementation advantages at high rate and large blocklength

Petitioners' Exhibit 1003, p. 989
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-168040 **WF on channel coding selection Huawei, HiSilicon, CMCC, CUCC, Deutsche Telekom, Orange, Telecom Italia, Vodafone, China Unicom, Spreadtrum**
Not supported by Orange.
Proposal:
- Polar code is a candidate channel coding technique for NR for eMBB, URLLC, mMTC

R1-168164 **WF on turbo code selection LG Electronics, Ericsson, CATT, NEC, Orange, IMT**
Proposal:
- LTE turbo code should be supported for NR for at least low throughput including eMBB, mMTC, and URLLC
  - It can support flexibilities of information block sizes and code rates
  - Turbo code enhancement can be considered
- FFS: high throughput

Conclusion:
- The eMBB data channel coding scheme will be chosen at RAN1#86bis
  - including agreeing on the observations that led to the decision.
- Companies are encouraged to:
  - continue analysis and comparison in order to inform the final decision at RAN1#86bis
  - provide any remaining details, especially focusing on LDPC (in view of the situation in this meeting)
  - provide any remaining details of the flexibility requirements and how they can be satisfied, and corresponding implementation complexity and any impact on performance
- Note that consideration of combinations of coding schemes is not precluded.
- In case of changes to proposals already available, companies are encouraged to provide them at least 1 week before the normal submission deadline for RAN1#86bis.

R1-168171 **WF on HARQ for NR Ericsson, Nokia, ASB, LG, CATT, ZTE, Qualcomm, MediaTek, InterDigital, Intel, Orange, IMT**

Agreement:
- Channel coding technique(s) designed for data channels of NR support both Incremental Redundancy (IR) (or similar) and Chase Combining (CC) HARQ

LDPC details
R1-166771 **Preliminary evaluation results on Quasi-Cyclic LDPC codes Samsung**
R1-166890 **LDPC code design LG Electronics**

Coding for small blocks
R1-167277 **Evaluation criteria for control channel coding Nokia, Alcatel-Lucent Shanghai Bell**
R1-166373 **Short blocklength design Qualcomm Incorporated**
R1-166926 **Further Discussion on Performance and Complexity of Enhanced TBCC Ericsson**
R1-167992 **Evaluation of Enhanced TBCC and Polar Codes Ericsson**
Revision of R1-166927
R1-166935 **Channel Coding Techniques for Control Information in NR Ericsson**
R1-167216 **Channel coding for control channels Huawei, HiSilicon**
R1-167703 **Channel coding scheme for URLLC, MMTC and control channels Intel Corporation**

R1-168170 **WF on coding technique for control channel of eMBB Ericsson, Nokia, ASB, LG, NEC, Orange, IMT**
Proposal:
- At least for control channel of eMBB UL and DL, tail-biting convolutional code (TBCC) is adopted as channel coding technique for NR
  - FFS: enhancements to LTE TBCC
  - FFS: if other coding techniques should also be included for control channel with info block size outside of 10-100 bits

R1-168024 **WF on code selection for control channel Huawei, HiSilicon, CMCC, CUCC, Deutsche Telekom, Vodafone, MTK, Interdigital, Spreadtrum**

Petitioners' Exhibit 1003, p. 990
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Revision of R1-168042
Proposal:

- Polar code is considered as channel coding technique for NR for control channel UL and DL
  - Even a low complexity small list size polar decoder is shown to have a performance advantage over TBCC
- Further comparison of Polar and TBCC is encouraged

R1-168298 WF on control channel coding Nokia, ASB, LG, CATT, MediaTek
Revision of R1-168102

Agreement:

- Simulation Assumptions for eMBB control channel coding
  - Evaluate the block error rate (BLER) performance versus SNR
  - Evaluate the false alarm rate versus SNR

Channel	AWGN						
Modulation	QPSK						
Coding Scheme	Repetition	Simplex	TBCC	Turbo	LDPC	Reed-Muller	Polar
Code rate (for evaluation purposes)	1/24*, 1/12, 1/6, 1/3, 1/2, 2/3						
Decoding algorithm**	ML	ML	List-Viterbi	Scaled max log MAP	Adjusted min-sum	FHT	SC list
Info. block length (bits w/o CRC) (for evaluation purposes) ***	1, 2, 4, 8, 16, 32, 48, 64, 80, 120, 200						

* Code rate 1/24 is valid for info block length of 1-2 bits
** Other variants of agreed algorithms can be used for encoding and decoding (Complexity details should be illustrated)
*** Each of these info. block lengths shall be evaluated at at least one of the code rates. Other info. block lengths and code rates are not precluded. Similar info. and encoded block lengths should be used for the evaluation. Total coded bits = info. Block length/code rate. Note: these info. block length and code rate are only for initial performance evaluations. They are not interpreted as design targets or assumptions for complexity analysis.

- Companies are encouraged to provide information on complexity of their decoders, and on decoding latency.

Outer coding
R1-166374 Erasure coding and HARQ design Qualcomm Incorporated
R1-166375 Erasure coding evaluation methodology Qualcomm Incorporated
R1-166416 Discussion on outer codes for NR ZTE
R1-166898 Discussion on outer coding on eMBB data LG Electronics
R1-167913 Channel coding schemes for eMBB and URLLC Coexistence SHARP Corporation, MTI
Revision of R1-167617

R1-168120 WF on URLLC impact handling ZTE, ZTE Microelectronics, Qualcomm, Sharp, MTI, InterDigital, Sony, Verizon Wireless, CATR, MediaTek
Conclusion:
Await outcome of eMBB/URLLC multiplexing discussions.

R1-166369 LDPC HARQ Qualcomm Incorporated
R1-166371 Polar HARQ Qualcomm Incorporated
R1-166414 Discussion on LDPC codes for NR ZTE
R1-166415 Discussion on polar codes for NR ZTE
R1-166473 Low complexity decoding algorithm for Turbo codes CATT
R1-166474 Evaluation of dual-binary Turbo code for NR CATT
R1-166475 Evaluation of binary LDPC codes for NR CATT
R1-166476 Evaluation of non-binary LDPC codes for NR CATT
R1-166477 Evaluation of TBCC codes for NR CATT
R1-166558 Channel coding scheme for eMBB Intel Corporation
R1-166768 Summary of channel coding for NR Samsung
R1-166769 Discussion on length compatible Quasi-Cyclic LDPC codes Samsung
R1-166770 Discussion on rate compatible Quasi-Cyclic LDPC codes Samsung
R1-166772 Performance analysis on Polar codes Samsung
R1-166773 Discussion on flexible Polar codes Samsung

Petitioners' Exhibit 1003, p. 991
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166775 Discussion on throughput and latency of NR candidate FECs Samsung
R1-166891 Performance evaluation of LDPC codes LG Electronics
R1-166893 Discussion on polar code design LG Electronics
R1-166894 Polar code performance evaluation LG Electronics
R1-166895 TBCC design LG Electronics
R1-166896 TBCC performance evalution LG Electronics
R1-166897 Turbo code enhancement and performance evaluation LG Electronics
R1-166928 HARQ Schemes for NR Ericsson
R1-166929 LDPC Code Design for NR Ericsson
R1-166930 Turbo Code for NR Scenarios Ericsson
R1-166931 Impact of Shortening and Puncturing to LDPC Performance Ericsson
R1-166933 Latency Consideration of Channel Coding Candidates Ericsson
R1-166934 Flexibility Consideration of Channel Coding Candidates Ericsson
R1-167006 Performance comparison of channel coding schemes in the eMBB scenario Spreadtrum Communications
R1-167209 Polar code design and rate matching Huawei, HiSilicon
R1-167210 HARQ scheme for polar codes Huawei, HiSilicon
R1-167211 LDPC codes for eMBB Huawei, HiSilicon
R1-167214 Channel coding schemes for URLLC scenario Huawei, HiSilicon
R1-167215 Channel coding schemes for mMTC scenario Huawei, HiSilicon
R1-167240 On polar decoders Huawei, HiSilicon
R1-167271 Performance of mMTC and URLLC channel coding candidates Nokia, Alcatel-Lucent Shanghai Bell
R1-167273 LDPC design for eMBB Nokia, Alcatel-Lucent Shanghai Bell
R1-167274 IR HARQ schemes for LDPC Nokia, Alcatel-Lucent Shanghai Bell
R1-167275 Design and Performance of polar codes for eMBB Nokia, Alcatel-Lucent Shanghai Bell
R1-167276 Evaluation criteria for URLLC and mMTC coding schemes Nokia, Alcatel-Lucent Shanghai Bell
R1-167413 Enhanced Turbo Codes for NR: Implementation Details ORANGE
R1-167414 Enhanced Turbo Codes for NR: Performance Evaluation ORANGE
R1-167532 Discussion on LDPC Coding Scheme of Code Structure, Granularity and HARQ-IR MediaTek Inc.
R1-167544 Data sharing on NR Channel Coding Simulation Result MediaTek Inc.
R1-167565 Performance evaluation of channel coding for URLLC and mMTC InterDigital Communications
R1-167566 Performance evaluation of puncturing schemes for Polar Codes InterDigital Communications
R1-167567 Complexity comparison of channel coding candidates InterDigital Communications
R1-167568 Channel coding simulation data sharing InterDigital Communications
R1-167659 Double QC-LDPC codes with degree-3 for NR National Taiwan University
R1-167871 Examination of NR Coding Candidates for Low-Rate Applications MediaTek Inc.
R1-167884 Comparison of throughput and complexity for Turbo and LDPC codes LG Electronics
R1-167885 Consideration points for implementation of flexible channel decoder LG Electronics Inc.
R1-167889 Design of Flexible LDPC Codes Samsung
R1-167896 Complexity, throughput and latency analysis on channel coding candidates for NR ZTE
R1-167901 Consideration on channel coding for NR ZTE
R1-167921 Channel Coding for NR NTT DOCOMO, INC.
R1-168041 WF on Performance Verification of ME-LDPC Huawei, HiSilicon

8.1.4.2 Modulation

R1-168515 Chairman's notes of AI 8.1.4.2 on modulation for NR Ad-Hoc chair (Nokia)
The document was presented by Matthew Baker from Nokia.
Decision: The document is endorsed and incorporated as follows.

R1-166377 NR modulation requirements Qualcomm Incorporated
R1-167054 On modulation schemes for NR Ericsson
R1-166899 Discussion on modulation schemes and maximum supported modulation order in NR LG Electronics
R1-166776 Discussion on modulation for NR Samsung
R1-166777 Modulation scheme for MIMO Samsung
R1-166560 Power efficient modulation and waveform processing Intel Corporation
R1-166649 Performance of NU-QAM with Turbo codes for the NR Sony
R1-167569 Performance evaluation of Spatial Modulation for New Radio InterDigital Communications
R1-167570 Performance evaluation of Dual Carrier Modulation for New Radio InterDigital Communications
R1-167578 On Fractional N-ary Modulation for NR InterDigital Communications

R1-166099 Advanced modulation for NR Huawei, HiSilicon
R1-167278 Digital Modulation for 5G New Radio Nokia, Alcatel-Lucent Shanghai Bell

Petitioners' Exhibit 1003, p. 992
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166378 Evaluation assumptions for NR modulation schemes Qualcomm Incorporated
R1-168281 WF on Modulation for NR InterDigital, Qualcomm, Mediatek, Sony, Orange and Samsung
R1-168095 WF on modulation scheme for NR LGE, Nokia, ASB, Intel

8.1.5 Multi-antenna scheme for new radio interface

Discuss initial views on multi-antenna scheme including analog/digital/hybrid beam-forming

R1-167291 Digital subsystem with hybrid beamforming Nokia, Alcatel-Lucent Shanghai Bell, Verizon Wireless
The document was presented by Mihai Enescu from Nokia.

- Observation 1: Operating using hybrid transceiver architecture suffers from increased scheduling latency and system overhead compared to digital architectures. Especially UL control signaling is expensive with hybrid architecture.
- Observation 2: Widening the RX beams for UL control may be used in some situations but would be far from optimal solution.
- Observation 3: Full digital subsystem could be implemented in cost efficient manner along with hybrid architecture.
- Observation 4: Full digital subsystem has high potential to improve hybrid architecture operation significantly.
- Proposal 1: Define UL control signal and channel and RS structures in a way to allow optimizing BS hybrid implementation with full digital RX subsystem:
  - narrowband resource allocation structures with flexible allocation and scheduling possibility
  - signal design to enable high multiplexing capability for the control signals like scheduling request

Decision: The document is noted.

R1-166089 Beam Management Procedure for NR MIMO Huawei, HiSilicon
The document was presented by Leiming Zhang from Huawei.

- Proposal 1: The following beam refinement procedures should be studied in NR, including reliability performance, overhead and so on.
  - DL or UL based joint TRP and UE beam refinement
  - DL or UL based UE beam refinement only
  - DL or UL based TRP beam refinement only
- Proposal 2: Beam probing for best beam(s) and angle estimation should be considered in NR.
- Proposal 3: A mechanism and signaling for fast link recovery among TRPs should be supported in NR.
- Proposal 4: Control beam(s) derived from the data beam(s) and using the refinement beams for control signal transmission should be considered in NR
- Proposal 5: Beam management procedures taking LF assisted control signalling transmission for HF should be taken into considerations in the overall beam management.

Decision: The document is noted.

R1-167466 Key principles for beam management Ericsson
The document was presented by Mattias Frenne from Ericsson.

- Beam management is handled by L1/L2 procedures
- Strive to handle beam management within the CSI framework in NR (i.e. the framework used for link adaptation of data transmission).
- In the beam management procedures, one or multiple beam pair links (BPLs) are monitored by the network using uplink measurements by the TRPs and/or downlink measurements from the UE
- Support a sweep of BMRS in different TRP beams to allow for a measurement per TRP beam in the UE.
- Consider supporting a repetition of BMRS in the same TRP beam to allow for measurement of the TRP beam in different UE receive beams.

Decision: The document is noted.

R1-166379 Downlink MIMO transmission schemes Qualcomm Incorporated
The document was presented by … from Qualcomm.

- Proposal 1: The NR DL MIMO shall support CLSM using antenna ports with UE RSs.
- Proposal 2: For CLSM, the precoding granularity can be a single RE.
- Proposal 3: The NR MIMO shall support open-loop spatial multiplexing using antenna ports with UE RSs.
- Proposal 4: Study performance benefit of UE RS based open-loop spatial multiplexing with precoder cycling and small cyclic delay diversity.
- Proposal 5: Study performance benefit of UE RS based open-loop spatial multiplexing with implicit and explicit precoding.
- Proposal 6: The NR MIMO shall support transmit diversity using antenna ports with UE RSs.
- Proposal 7: Study performance benefit of UE RS based SFBC with transparent FSTD and non-transparent FSTD.
- Proposal 8: The NR MIMO shall support reciprocity based spatial multiplexing using antenna ports with UE RS.
- Proposal 9: For reciprocity based spatial multiplexing, the precoding granularity can be a single RE.

Petitioners' Exhibit 1003, p. 993
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Proposal 10: The NR MIMO may consider dynamic switching between close-loop and open-loop operations in addition to dynamic switching between spatial multiplexing and transmit diversity.

Decision: The document is noted.

WFs on Beam Management

R1-167951 WF on digital sub-system with hybrid beamforming Nokia, ASB

The document was presented by Mihai Enescu from Nokia.

- Support enhancing hybrid architecture operation using digital RX subsystem consisting of the same (or similar) amount of RxRUs as the number of antenna elements.
- UL Signal design and UL control channel design needs to follow the following principles:
  - Transmission bandwidth of the UL control signal and associated demodulation UL RS is significantly smaller than the system bandwidth, e.g. 10/20 MHz bandwidth.
  - UL Signal design to enable high multiplexing capability for the UL control signals like scheduling request.
  - Efficient joint operation of hybrid RX and digital RX, e.g. efficient utilization of UL data and UL control channels.

Discussion: Interference between narrowband and wideband should also be listed

Decision: The document is noted. Continue offline discussion until Tuesday – (Nokia)

R1-167962 WF on NR MIMO calibration ZTE Corporation, ZTE Microelectronics, Intel Corporation, Samsung

The document was presented by Ruyue Li from ZTE.

- RAN1 starts NR MIMO calibration to reach common ground for MIMO related evaluation:
- Link-level calibration
  - Support the subsequent link-level evaluation for candidate designs/approaches, e.g., reference signals;
  - Calibration assumptions and metrics are FFS;
- System-level calibration
  - Support the subsequent system-level evaluation for candidate designs/approaches, e.g., multi-beam sweeping/ selection/reporting;
  - Calibration assumptions and metrics are FFS;
- Approve the following scenario/channel model for link and system levels calibration:
- Link-level: CDL model with random angular offset, e.g.,
  - 3GPP TR38.900 CDL-A model (Delay spread = 10 ns)
  - 3GPP TR38.900 CDL-D model (Delay spread = 10 ns)
  - Mobility: 3km/h
  - Other details FFS
  - Notes: The angles should be wrapped around to be uniformly within 0-360 degrees in azimuth and clipped within 0-180 degrees in zenith angle via applying uniform-distribution translation angle in Section 7.7.5.1 in TR 38.900 accordingly.
- System-level: Indoor hotspot, urban macro, dense urban
  - Other details FFS

Discussion: Also supported by ASTRI, Xinwei, Mediatek

Decision: The document is noted. Continue offline discussion until Tuesday – (ZTE: R1-168273)

Thursday

R1-168487 WF on NR MIMO calibration ZTE Corporation, ZTE Microelectronics, Intel Corporation, Samsung, ASTRI, Xinwei, MediaTek, Nokia, ASB, Ericsson, NTT DOCOMO, Qualcomm, CATT

Revision of R1-168273

Agreements:

- For the purpose of calibration, companies are encouraged to provide baseline results for NR MIMO in the following meetings, including link-level and system level simulations
  - Discuss further on baseline simulation assumptions and metrics for calibration in email discussion after RAN1#86
  - Thereafter, email reflector is used to collect results (no online time for calibration discussions, similar to channel model calibration)
- Email discussion till Sept 8th - (ZTE)
  - Including detailed simulation parameters for UE movement, rotation and/or channel/beam blockage is FFS – (to be included in Ruyue's email discussion)

R1-167950 WF on beam management Intel Corporation, Ericsson

The document was presented by Yuan Zhu from Intel.

Petitioners' Exhibit 1003, p. 994
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Distinguish two beam related procedures:
  - **Procedure A** is used to support beam based mobility
    - Main purpose is to discover TRP TX beams and perform mobility related measurements
    - UE RX beam training support may also be considered
    - Searching and discovering TRP TX beams from neighbor TRPs which are non-synchronized is supported
      - Note: TRPs may still be synchronized but the UE shall not make such assumption
    - L3 reporting
  - **Procedure B** is used to support beam management
    - Purpose is to track TRP TX beams and support UE to select UE RX beams
    - RS (beams) to measure on are explicitly configured to the UE
      - Note: No search/discovery procedure is involved
    - L1/L2 reporting

Discussion: Samsung asked for more time, not a simple change.
Decision: The document is noted.

R1-167961 **WF on aperiodic beam sweeping and CSI reporting** **ZTE**
The document was presented by Ruyue Li from ZTE.

- Study the following aspects of aperiodic beam sweeping:
  - Three types of beam sweeping for both UL and DL:
    - TRP beam sweeping only, keeping a fixed UE beam
      - supporting measuring multiple TRP beams by the same UE beam
    - UE beam sweeping only, keeping a fixed TRP beam
      - supporting measuring the same TRP beam with multiple UE beams
        - E.g. by time domain replica waveform. TRP Tx using the same TRP beam and UE receives using one UE beam per replica
        - E.g. by multiple wider sub-carrier spacing based OFDM symbols. TRP Tx using the same TRP beam and UE receives each symbol with different UE beam
    - Joint TRP and UE beam sweeping
  - Indication of TX and/or RX beam on control/feedback signaling:
    - Indication is per beam or per beam group
  - Content of aperiodic CSI report e.g. RSRP, RI/PMI/CQI, beam ID
  - NOTE: support various mobility scenarios
  - Others are not precluded
- Study aperiodic CSI in conjunction with aperiodic RS transmission:
  - Dynamic indication of aperiodic reference signal and interference measurement resource including
    - Aperiodic reference signal for channel measurement for CSI feedback and beam selection/training
    - Aperiodic interference measurement resource for interference measurement, including using non-zero power reference signal
    - Resource pool sharing for aperiodic channel and interference measurement resources
  - DMRS based CSI feedback including CQI adjustment and beam refinement
    - Study the timing requirement among aperiodic CSI triggering, aperiodic RS transmission and CSI feedback.
      - Timing between CSI triggering and aperiodic RS transmission X
      - Timing between aperiodic RS transmission and CSI/beam feedback Y
  - Others are not precluded

Decision: The document is noted.

R1-167947 **WF on Beam Management** **Huawei, HiSilicon, Potevio**
The document was presented by Leimin Zhang from Huawei.

- Study on the following aspects for beam management
  - TRP(s) used to transmit beam management RS is transparent to UE
  - Beam management procedure based on L1 and L2 procedure
  - Beam management procedure based on LF assisted HF
  - Beam management includes the following two stages:
    - Coarse beam alignment, i.e., periodic beam sweeping without prior acquired beam(s) information
    - Fine beam alignment, i.e., periodic/aperiodic beam sweeping with prior acquired beam(s) information
      - Strive to handle this procedure within a unified CSI framework in NR
      - Fast link recovery procedure due to UE movement/rotation/blockage
        - » E.g., Monitoring multiple beam pairs for link recovery
      - Beam probing based beam refinement/tracking
        - » E.g., beam selection, or angle estimation
- RS design principle of Beam Management

Petitioners' Exhibit 1003, p. 995
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

  - DL beam management can be based on DL DMRS in addition to DL RS dedicated to CSI acquisition and beam management
  - UL beam management can be based on SRS, UL DMRS and energy-efficient UE-specific tracking signals

Decision: The document is noted.

R1-167966 **WF on Beam Management** **CATT, Samsung**

The document was presented by Rakesh Tamrakar from CATT.

- RAN1 should study beam management procedures under different channel reciprocity assumptions
  - At a TRP or UE, with TX and RX channel reciprocity (e.g., beam reciprocity), TX beam (or RX beam) can be obtained from RX beam (or TX beam) to reduce overhead and latency
  - Without TX and RX channel reciprocity, beam management procedure may require TX and RX beam sweeping in both DL and UL links
- RAN1 should study different methods of determining a beam pair for communication, e.g.,
  - Joint determination: Tx beam and Rx beam of the beam pair are determined jointly
  - Separate determination: Tx beam or Rx beam of the beam pair are determined sequentially
- Study beam management procedure with and without explicit indication of beam(s) used for data/control channel or reference signal transmission

Decision: The document is noted.

Continue offline discussion until Tuesday – (Intel, ZTE, CATT, Huawei)

R1-168119 WF on beam management Intel Corporation, Nokia, Alcatel-Lucent Shanghai Bell, Verizon

- The following two DL beam management procedures are supported:
  - Procedure A for beam selection without prior acquired beam(s) information (can be called as beam acquisition)
    - For initial beam acquisition and maintenance
    - UE RX beam training is also supported
    - [for TRPs not necessarily having common baseband/sync or having non-ideal backhaul.
    - option 1: Measurement reports on L3; option 2: Measurement reports can be L2/L1 and/or L3]
  - Procedure B for beam selection with prior acquired beam(s) information (can be called beam adjustment)
    - B-1: to support inter/intra-TRP Tx beam change within an NR cell for the same UE Rx beam
    - B-2: to support UE Rx beam change for the same TRP Tx beam
    - Intra-TRP and inter-TRP beam management follow the same procedure
      - Note: UE may or may not need to know the TRP has changed for inter-TRP Tx beam change
    - [option 1: L1/L2 procedure; option 2: L3 is involved as well]
    - Note: Procedures B-1&B-2 can be performed jointly
    - Note: Procedures B-1&B-2 can be performed multiple times to achieve e.g. TRP Tx/UE Rx beam change simultaneously
  - Support managing multiple Tx/Rx beam pairs for a UE for fast link recovery
  - Assistant information from another carrier (e.g., LF carrier) can be utilized in procedures A&B
    - E.g.. LF carrier is used to feedback the measurement for HF

Decision: The document is noted.

Possible agreements:

- The following two DL beam management procedures are supported:
  - Procedure A for initial beam acquisition without prior acquired beam(s) information (can be called as beam acquisition)
    - TRP TX beam and UE RX beam sweeping are supported
    - [Procedure A can be considered for mobility]
  - Procedure B for beam change with prior acquired beam(s) information (can be called beam adjustment)
    - B-1: to support inter/intra-TRP Tx beam change [within multiple TRPs] for the same UE Rx beam
    - B-2: to support UE Rx beam change for the same TRP Tx beam
    - Strive for the same procedure design for intra-TRP and inter-TRP beam management
      - Note: UE may not know the TRP has changed for inter-TRP Tx beam change
    - Note: Procedures B-1&B-2 can be performed jointly
    - Note: Procedures B-1&B-2 can be performed multiple times to achieve e.g. TRP Tx/UE Rx beam change simultaneously
    - [Procedure B can be considered for mobility]
  - Support managing multiple Tx/Rx beam pairs for a UE for fast link recovery
  - Assistant information from another carrier (e.g., LF carrier) can be utilized in procedures A&B
    - E.g., low frequency carrier is used to feedback the measurement for high frequency
  - [Procedure A can be used for beam maintenance]

Continue offline discussion until Wednesday – Yuan (Intel)

Thursday

Petitioners' Exhibit 1003, p. 996
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-168278 WF on DL beam management Intel Corporation, Huawei, HiSilicon, Ericsson, Nokia, Alcatel-Lucent Shanghai Bell, Verizon, MTK, LGE, NTT DoCoMo, Xinwei

Agreements:

- The following DL L1/L2 beam management procedures are supported within one or multiple TRPs:
  - P-1: is used to enable UE measurement on different TRP Tx beams to support selection of TRP Tx beams/UE Rx beam(s)
    - For beamforming at TRP, it typically includes a intra/inter-TRP Tx beam sweep from a set of different beams
    - For beamforming at UE, it typically includes a UE Rx beam sweep from a set of different beams
    - FFS: TRP Tx beam and UE Rx beam can be determined jointly or sequentially
  - P-2: is used to enable UE measurement on different TRP Tx beams to possibly change inter/intra-TRP Tx beam(s)
    - From a possibly smaller set of beams for beam refinement than in P-1
    - Note: P-2 can be a special case of P-1
  - P-3: is used to enable UE measurement on the same TRP Tx beam to change UE Rx beam in the case UE uses beamforming
  - Strive for the same procedure design for Intra-TRP and inter-TRP beam management
    - Note: UE may not know whether it is intra-TRP or inter TRP beam
  - Note: Procedures P-2&P-3 can be performed jointly and/or multiple times to achieve e.g. TRP Tx/UE Rx beam change simultaneously
  - Note: Procedures P-3 may or may not have physical layer procedure spec. impact
  - Support managing multiple Tx/Rx beam pairs for a UE
  - Note: Assistance information from another carrier can be studied in beam management procedures
  - Note that above procedure can be applied to any frequency band
  - Note that above procedure can be used in single/multiple beam(s) per TRP
  - Note: multi/single beam based initial access and mobility treated within a separate RAN1 agenda item

R1-168322 Definitions supporting beam related procedures Nokia, Qualcomm, CATT, Intel, NTT DoCoMo, Mediatek, Ericsson, ASB, Samsung, LG

The document was presented by Mihai Enescu from Nokia.

- **Beam management** = a set of procedures to acquire and maintain a set of TRP(s) and/or UE beams that can be used for DL and UL transmission/reception, which include at least following aspects:
  - **Beam selection**= for TRP(s) or UE to select of its own beam(s).
  - **Beam measurement** = for TRP(s) or UE to measure characteristics of received beamformed signals
  - **Beam reporting** = for UE to report a property/quality of beamformed signal(s) based on beam measurement
  - **Beam sweeping** = operation of covering a spatial area, with beams transmitted and/or received during a time interval in a predetermined way.

Discussion: Ericsson → can a note be added that these are not related to mobility?

Decision: The document is noted and agreed in:

R1-168468 Definitions supporting beam related procedures Nokia, Qualcomm, CATT, Intel, NTT DoCoMo, Mediatek, Ericsson, ASB, Samsung, LGE

R1-167965 WF on CSI measurement and reporting in NR Huawei, HiSilicon

The document was presented by Ming Lei from Huawei.

- A unified CSI acquisition framework should be studied in NR, which shall support
  - CSI measurement based on CSI-RS
  - Beam measurement based on RS for beam management
  - Implicit and explicit CSI feedback
  - Reciprocity based CSI acquisition
- The implicit CSI feedback methods should be studied in NR
  - Codebook design
  - Interference measurement results obtained from
    - ZP CSI-RS
    - NZP CSI-RS
    - DMRS
  - Beam measurement results
- The explicit CSI feedback methods should be studied in NR
  - Feedback of channel covariance matrix

Petitioners' Exhibit 1003, p. 997
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

        - E.g. based on Kronecker-product
    - Feedback of channel matrix or channel eigenvector
        - E.g. based on multi-beam combination
    - Both quantized and unquantized/analog feedback
- Multi-level CSI measurement and reporting with the following features should be supported in NR
    - Joint feedback of wideband/long-term and subband/short-term CSI
    - Based on hybrid non-precoded and beamformed CSI-RS
    - Joint feedback of explicit CSI and implicit CSI
- At least the following CSI measurement and reporting mechanisms should be studied by NR
    - Aperiodic CSI measurement and reporting
    - Semi-persistent CSI measurement and reporting
- Self-contained CSI triggering, measurement and reporting in a 'time interval X' should be studied in NR
    - Note: here the definition of 'time interval X' follows the agreements in RAN1#85 meeting

Decision: The document is noted. Continue offline discussion until Tuesday – (Huawei)

R1-168179 **WF on CSI measurement and reporting in NR Huawei, HiSilicon, Ericsson, China Telecom**

Decision: The document is noted and modified as follows:

Agreements:

- A simplified CSI acquisition framework should be studied in NR, which could support
    - CSI measurement based on CSI-RS (if supported)
    - Implicit and explicit CSI feedback
    - CSI acquisition based on different degree of reciprocity
    - Other features to be supported
- The implicit CSI feedback methods should be studied in NR
    - Codebook design
    - Interference measurement based on interference measurement resource which could be one or more of the following options
        - ZP CSI-RS (if supported)
        - NZP CSI-RS (if supported)
        - DMRS (if supported)
        - Other resources are not precluded
    - CSI feedback based on DMRS (if supported)
- The explicit CSI feedback_methods should be studied in NR
    - Feedback of channel covariance matrix
    - Feedback of channel matrix
    - Feedback of channel eigenvector
    - Both quantized and unquantized/analog feedback
    - Other methods are not precluded
- CSI measurement and reporting with the following components should be studied in NR
    - Wideband/long-term CSI
    - Subband/short-term CSI
    - Explicit CSI
    - Implicit CSI
    - Configuration of the above components individually or jointly is FFS

R1-167964 **WF on DL Transmission Scheme Huawei, HiSilicon, NEC**

- NR should support the multiplexing of different transmission schemes to different UEs at the same time-frequency resource (an example is shown by Figure 1)
- NR should support beam based transmit diversity
    - Beam based transmit diversity based on single-TRP transmission should be supported in NR
    - Beam based transmit diversity based on multi-TRP transmission should be supported in NR (an example is shown by Figure 2)
    - Beam based transmit diversity is based on DM-RS for demodulation
    - Beam based transmit diversity should be the fallback scheme of the multi-antenna based transmission mode
- The dynamic switching between different transmission schemes should be supported in a transmission mode

Decision: The document is noted.

R1-166788 **Discussion on DL MIMO transmission schemes and modes in NR Samsung**

- Study a unified MIMO transmission chain framework to support various transmission techniques (including DMRS based SM, TxD and RE-level precoder cycling), considering the following aspects:
    - Number of CWs

Petitioners' Exhibit 1003, p. 998
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Whether to reuse CW-to-layer mapping and precoding framework or to design a new framework
- DCI design alternatives – modular vs format-based

Decision: The document is noted.

Possible agreements:

- NR should support the multiplexing of different transmission schemes to different UEs at the same time-frequency resource (an example is shown by Figure 1)
- NR should support beam based transmit diversity
  - Beam based transmit diversity based on single-TRP transmission should be supported in NR
  - Beam based transmit diversity based on multi-TRP transmission should be supported in NR (an example is shown by Figure 2)
  - Beam based transmit diversity is based on DM-RS for demodulation
  - Beam based transmit diversity should be the fallback scheme of the multi-antenna based transmission mode
- The dynamic switching between different transmission schemes should be supported in a transmission mode

Continue offline discussion until Wednesday – (Huawei, Samsung)

Wednesday

R1-168271 WF on DL Transmission Scheme Huawei, HiSilicon, NEC, Intel

- RAN1 to study multiplexing of different transmission methods to different UEs at the same time-frequency resource
- RAN1 to study transmit diversity
  - SFBC
  - SFBC-FSTD
  - Other schemes are not precluded
  - Demodulation reference for transmit diversity is DM-RS
    - QCL with other types of RS should be studied
- Support dynamic switching between different transmission methods
  - One of the transmission methods shall be transmit diversity
- Note: the multiple antenna ports used for transmit diversity can be on different beams and/or on different TRPs and/or different polarizations

Decision: The document is noted.

R1-168394 WF on DL Transmission Scheme Huawei, HiSilicon, NEC , Intel, Samsung
R1-168476 WF on DL Transmission Scheme Huawei, HiSilicon, NEC , Intel, Samsung

Agreements:

- RAN1 to study transmit diversity for both data and control channels
  - Aspects to related to QCL (if any), # of ports, polarizations, etc.
- Demodulation reference signal for transmit diversity, if supported, could be
  - UE-specific RS (if supported by NR)
  - Shared (by two or more UEs)-RS (if supported by NR)
  - Other types of RS are not precluded

R1-168105 WF on Framework for NR MIMO Samsung, Ericsson

- Strive to design a unified CSI framework, avoiding introducing multiple classes/subclasses and unnecessary (equally performing) configurations, while still covering a wide variety of use cases
- Strive to remove tight coupling (e.g. fixed timing relationships, joint configuration) between the following modular functions
  - CSI-RS transmission
  - CSI measurement
  - CSI reporting
  - Multi-antenna transmission method
  - Downlink control signaling
- Consider supporting independent scheduling/configuration of CSI-RS, CSI report and data transmission
- At least for DL and except for non-spatial transmit diversity, per layer DMRS is supported
  - Note: the precoding is assumed to be the same for the layer and the associated DMRS
- At least 8 orthogonal DMRS ports is supported for SU-MIMO scheduling
  - Consider further the need for more than 8 orthogonal DMRS ports for MU-MIMO scheduling
- Support dynamic switching between transmission methods, e.g. between
  - Spatial transmit diversity (e.g. for control channels)
  - Spatial multiplexing

Petitioners' Exhibit 1003, p. 999
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Decision: The document is noted.

Agreements:

- Strive to design a unified CSI framework, avoiding introducing multiple classes/subclasses and redundant (equally performing) configurations, while still covering a wide variety of use cases and frequency bands
- Coupling/Decoupling (e.g. fixed timing relationships, joint configuration) between the following functions should be studied
  - RS transmission used for CSI acquisition (CSI-RS transmitted in DL and SRS transmitted in UL)
    - Use of other RS(s) is not precluded (e.g., DMRS)
    - Note that CSI-RS and SRS may or may not have the same physical signal design
    - Note that the reference signal naming can be revisited later
  - CSI measurement/reporting
  - Multi-antenna transmission method/scheme
  - Downlink control signaling
- Study flexible scheduling/configuration of CSI-RS, CSI report and transmission method/scheme for data and control
- DL DMRS and UL DMRS based spatial multiplexing (SU-MIMO/MU-MIMO) is supported
  - FFS: Necessity of sidelink spatial multiplexing
- At least 8 orthogonal DL DMRS ports is supported for SU-MIMO scheduling
- At least 8 orthogonal DL DMRS ports is supported for MU-MIMO scheduling
- Support dynamic switching between transmission methods/schemes, e.g. between
  - Transmit diversity
  - Spatial multiplexing

R1-168173 **WF on Frequency Selective Precoding for NR UL MIMO Samsung, Intel, NTT DOCOMO, Huawei**

- Frequency selective UL precoding (at least for digital beamforming) should be studied in NR
  - Study UL precoder signaling
    - Example 1: Signaling of multiple PMIs (subband) via single or two-level DCIs
    - Example 2: Signaling of multiple PMIs via Data channel
    - Example 3: For TDD, precoder calculation at the UE based on DL RS
      - For TDD and reciprocity calibrated UE, UE recommends candidates UL precoders to BS based on the DL RS measurement, BS determines the final precoder
  - Study the use of UL frequency selective precoding for both dynamic beamforming and semi-dynamic beamforming
  - Study UL subband size (i.e. UL precoding granularity) considering following aspects
    - Implicit (defined by spec.) or explicit (by eNB/UE decision) signaling support
    - Whether to Align with DL or not

Decision: The document is noted.

R1-168254 **WF on UL MIMO transmission Huawei, HiSilicon, China Unicom, Samsung, NTT DOCOMO**

The following aspects for UL MIMO transmission should be supported:

- Transmission schemes for both reciprocity calibrated UEs, reciprocity non-calibrated UEs, and non-reciprocity case
  - UE capability which indicates calibration accuracy for UL reciprocity based operation should be introduced
- Codebook based transmission
  - Frequency selective precoding should be considered for large system bandwidth
  - E.g., UE–aided and eNB-centric
- Non-codebook based transmission
  - E.g., reciprocity based (based on DL RS) transmission only for calibrated UEs
  - E.g., UE–aided and eNB-centric: UE recommends candidate UL precoders to eNB based on DL RS measurement , and BS determines the final precoder.

Decision: The document is noted.

Agreements:

The following aspects for UL MIMO transmission should be supported:

- Transmission schemes/methods for reciprocity calibrated UEs, reciprocity non-calibrated UEs, and non-reciprocity/partial reciprocity cases
  - If needed, signalling associated with UL reciprocity based operation is introduced, e.g. UE capability which indicates calibration accuracy
  - Whether to differentiate reciprocity non-calibrated UEs from non-reciprocity or not is to be studied

Petitioners' Exhibit 1003, p. 1000
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Note: the number of transmission schemes/methods can be further discussed
- At least one of the following candidate schemes/methods is to be supported
  - Candidate 1: Codebook based transmission
    - Frequency selective and frequency non-selective precoding in digital domain can be considered for large system bandwidth
      - The support for frequency selective precoding is conditioned on decision on NR waveform(s)
      - FFS: The values of the large system bandwidth
    - E.g., BS-centric mechanism analogous to LTE
    - E.g., UE–aided and BS-centric mechanism: UE recommends candidate UL precoders from a predefined codebook to BS based on DL RS measurement, and BS determines the final precoder taken from the codebook.
    - E.g., UE–centric and BS-aided mechanism: BS provides CSI (e.g. channel response, interference-related information) to the UE, and the UE determines the final precoder based on the information from the BS
  - Candidate 2: Non-codebook based transmission
    - Frequency selective and frequency non-selective precoding in digital domain can be considered for large system bandwidth
      - The support for frequency selective precoding is conditioned on decision on NR waveform(s)
      - FFS: The values of the large system bandwidth
    - E.g., reciprocity based (based on DL RS) transmission only for calibrated UEs
    - E.g., UE–aided and BS-centric mechanism: UE recommends candidate UL precoders to BS based on DL RS measurement, and BS determines the final precoder.
    - E.g., UE–centric and BS-aided mechanism: BS provides CSI (e.g. channel response, interference-related information) to the UE, and the UE determines the final precoder based on the information from the BS
  - Note: Other transmission schemes/methods are not precluded.

R1-168173 WF on Frequency Selective Precoding for NR UL MIMO Samsung, Intel, NTT DOCOMO, Huawei

- Frequency selective UL precoding (at least for digital beamforming) should be studied in NR
  - Study UL precoder signaling
    - Example 1: Signaling of multiple PMIs (subband) via single or two-level DCIs
    - Example 2: Signaling of multiple PMIs via Data channel
    - Example 3: For TDD, precoder calculation at the UE based on DL RS
      - For TDD and reciprocity calibrated UE, UE recommends candidates UL precoders to BS based on the DL RS measurement, BS determines the final precoder
  - Study the use of UL frequency selective precoding for both dynamic beamforming and semi-dynamic beamforming
  - Study UL subband size (i.e. UL precoding granularity) considering following aspects
    - Implicit (defined by spec.) or explicit (by eNB/UE decision) signaling support
    - Whether to Align with DL or not

Decision: The document is noted and modified as follows:

Agreements:

- Study UL precoder signaling for frequency selective/non-selective precoding
  - Example 1: Signaling of single or multiple PMIs via DL control and/or data channels
    - Multiple PMIs can be signaled via a single DCI or multi-level DCI (1st level DCI contains a location indication to the 2nd level DCI)
  - Example 2: For TDD, precoder calculation at the UE based on DL RS
  - Notes:
    - The feasibility of frequency selective precoding is conditioned RAN1 decision on, e.g. NR frame structure, waveform(s)
    - Impact on other system design aspects (e.g. DL control channel decoding performance/complexity) should be considered.
- Study the use of UL frequency selective precoding for precoded transmission including precoder cycling
- For frequency selective precoding, study UL precoding granularity (i.e. UL subband size) considering following aspects
  - Implicit (defined by spec.) or explicit (by eNB/UE decision) signaling support
  - Whether to align with DL or not
- Evaluation should include UL specific aspects such as CM analysis according to UL waveform, etc.
- Study of frequency non-selective precoding is of higher-priority

QCL

Petitioners' Exhibit 1003, p. 1001
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-167970 **WF on the antenna ports QCL in NR** **Intel, LGE, Ericsson, Samsung, InterDigital, Huawei/HiSilicon**
Decision: The document is noted.

Agreements:

- All physical channels and reference signals in NR are transmitted using antenna ports
- Agree as working assumption the following antenna port definition for NR (same as in LTE)
  - An antenna port is defined such that the channel over which a symbol on the antenna port is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed.
- ~~Working assumption:~~ Parameters for antenna port QCL in NR includes at least (if QCL is supported)
  - Average gain, average delay, delay spread, Doppler shift and Doppler spread (same as in LTE)
  - Additional parameters are FFS
- FFS whether the QCL or other means can be used for UE beamforming management
- The following QCL assumptions for DM-RS antenna ports in NR are for further study
  - QCL across DM-RS antenna ports
    - All the DMRS antenna ports are QCL-ed with each other
    - Not all the DMRS antenna ports are QCL-ed with each other
  - QCL across scheduled PRBs for DM-RS antenna port
  - QCL among DM-RS antenna port groups
  - QCL of DM-RS antenna ports with antenna ports of other reference signals (RS to be defined in NR)
  - Other assumptions are not precluded
- Note: The antenna ports of demodulation reference signal (DM-RS) in NR are used to transmit at least physical data and, possibly, control channels and used at the UE for demodulation.

R1-168272 **WF on QCL assumptions in NR** **Huawei, HiSilicon, China Telecom, DoCoMo, CATR, Intel**
Decision: The document is noted.

Possible agreements:

- No QCL by default in NR unless otherwise specified

Possible agreements:

- For the QCL assumptions and configurations, the following should be supported:
  - By default, no QCL assumptions in NR for the following cases unless otherwise indicated
    - FFS: between synchronization signals and CSI-RS (if supported)
    - between synchronization signals and DMRS (if supported)
  - By default, no QCL assumptions for antenna ports transmitted in different time occasions (e.g. different subframes or TTIs) in NR unless otherwise indicated
  - With explicit or implicit indications, NR should
    - support multiple QCL configurations
    - support flexible QCL configurations at least for the following cases:
      - FFS: Among CSI-RS ports (if supported)
      - Between different types of antenna ports
      - FFS: among other types of RS ports in addition to CSI-RS and DMRS (if supported)
    - Note: The definition of explicit indication is NR BS notifies the UE by the signaling about QCL configuration
  - Note: QCL configuration is defined as the different sets of large-scale channel properties and, in case of explicit signaling, the supporting signaling mechanism to notify the UE

Continue offline discussion until Thursday – Ming (Huawei)

R1-168360 **WF on QCL assumptions & configurations in NR** **Huawei, HiSilicon, China Telecom, DoCoMo, CATR, Intel**
R1-168436 **WF on QCL assumptions & configurations in NR** **Huawei, HiSilicon, China Telecom, DoCoMo, CATR, Intel**

Agreements:

- All QCL assumptions that a UE is allowed to make among antenna ports should be identified and explicitly specified
- QCL is defined as follows:
  - Two antenna ports are said to be quasi co-located if properties of the channel over which a symbol on one antenna port is conveyed can be inferred from the channel over which a symbol on the other antenna port is conveyed.
  - Future refinement on QCL definition is not precluded

R1-168388 **WF on beam management** **CATT, Samsung, National Instruments, ZTE**

Petitioners' Exhibit 1003, p. 1002
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Agreements:

- Consider different channel reciprocity assumptions in beam management procedures
  - At a TRP or UE, with TX and RX channel reciprocity (full or partial) (e.g., beam reciprocity), TX beam (or RX beam) can be obtained from RX beam (or TX beam) to reduce overhead and latency
  - Without TX and RX channel reciprocity, beam management procedure may require TX and RX beam sweeping in both DL and UL links
- RAN1 study different methods of determining Tx and Rx beam(s) for communication on one link direction (uplink or downlink), e.g.,
  - Joint determination: Tx beam and Rx beam are determined jointly
  - Separate determination: Tx beam or Rx beam are determined sequentially.
  - Multi-stage determination: for instance, coarse Tx-Rx beam determination followed by fine Tx-Rx beam determination
- Study beam management procedure with and without explicit signaling of beam(s) or beam group(s) used for transmission

Aperiodic CSI

R1-168386 WF on aperiodic CSI reporting ZTE Corporation, ZTE Microelectronics, ASTRI, Intel Corporation, Samsung, CATT

Agreements:

Study aperiodic CSI reporting in conjunction with aperiodic RS transmission:

- Dynamic indication of aperiodic RS and interference measurement resource including
  - Aperiodic RS for channel measurement for CSI reporting
  - Aperiodic interference measurement resource for interference measurement, including using non-zero/zero power RS, demodulation RS;
  - Resource pool sharing for aperiodic channel and interference measurement resources
- Study the timing requirement among aperiodic RS triggering, CSI reporting triggering, aperiodic RS transmission, and CSI reporting.
  - Timing between CSI triggering and aperiodic RS transmission X
  - Timing between aperiodic RS transmission and CSI reporting Y
  - Notes: Consider the single triggering for RS transmission and CSI reporting;
- Others are not precluded
- Note: aperiodic triggering doesn't preclude on-demand (using activate/release mechanism) triggering

Periodic CSI

R1-168186 WF on periodic and semi-persistent CSI for NR Samsung, Ericsson, Qualcomm

Agreements:

- Support at least one of the following schemes for CSI reporting:
  - Scheme 1: periodic CSI reporting analogous to LTE
  - Scheme 2: semi-persistent CSI reporting (e.g. activate/release mechanism analogous to LTE SPS)
  - Scheme 3: aperiodic CSI reporting
  - FFS: Possible signaling support
- Strive to design NR periodic, semi-persistent, and/or aperiodic CSI reporting, considering at least following aspects
  - UL coverage
  - Required RS
  - Reporting information type
  - Forward compatibility
  - Energy efficiency
  - RS and CSI reporting overhead
- Study whether to avoid specifying dependency between CSI reports in different reporting instances
  - Such dependencies, if any, can be different for periodic, semi-persistent, and/or aperiodic CSI reporting

CSI timing

R1-168135 WF on CSI timing relationship LG, InterDigital, Intel, Huawei

Agreements:

- Study flexible timings of RS indication/transmission for CSI measurement, CSI feedback triggering/reporting. Following aspects should be considered at least for periodic CSI (where appropriate)/aperiodic/semi-persistent CSI reporting
  - Linkage between each timing
    - Details FFS. Some non-exhaustive exemplary timing relationships include:

Petitioners' Exhibit 1003, p. 1003
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Ex1) RS indication and CSI feedback triggering
- Ex2) RS indication and RS transmission
- Ex3) RS indication, RS transmission, CSI feedback triggering and CSI reporting in the same [SF]

- Signaling method for timing, if needed (if so, details)
- Feasible time gap between RS transmission and CSI reporting taking CSI computation delay/complexity, propagation delay, channel coherence time, and UL timing advance into account
- Signaling overhead needs to be taken into account
- Note: the timing above refers to layer 1 control signaling, higher-layer signaling or a combination thereof
  - Note: RS indication can be RS triggering or RS activation/deactivation, and can include RS resource configuration.
- Note: This doesn't preclude a fixed timing based RS transmission for CSI measurement, CSI feedback reporting.

RS design

R1-168498 **WF on RS for CSI measurement in NR** **Huawei, HiSilicon**
Revision of R1-168176

Agreements:

- At least one of following RS configurations for CSI measurement are supported in NR
  - Aperiodic RS
  - Semi-persistent RS
  - Periodic RS
- Study RS pattern for CSI measurement in NR both for DL and UL
  - Study the density of RS
  - Study the position of RS in the [subframe]
  - Study the mapping of RS in one or several symbols

UE rotation

R1-168308 **WF on support of rotatable UE with beamforming in NR** **LG, Intel, KT, MediaTek, InterDigital, Samsung**

Agreements:

- Study impacts of UE movement, rotation and/or channel/beam blockage w.r.t. following aspects
  - UE/TRP beam change
  - CSI mismatch from CSI reporting instance to data transmission instance
- Study at least the following techniques under the consideration of UE movement, rotation and/or channel/beam blockage including
  - Beam management of UE/TRP Tx/Rx beams
  - Transmission/reception techniques to provide more robustness (e.g. semi-OL MIMO transmission, beam cycling, beam broadening)

R1-168389 **WF on the design of downlink control channel** **ZTE Corporation, ZTE Microelectronics, Qualcomm, ASTRI, Intel Corporation**
Revision of R1-168274

Agreements:

- Study the relationship of beam(s) used for L1 control channel and beam(s) used for data channel
  - E.g. Using different beamwidth for data and control
  - E.g. Using different beam directions for data and control
  - E.g. At least one beam is shared by data and control
  - E.g., same beam for data and control

R1-168486 **WF on number of antenna ports for CSI-RS** **Ericsson, Samsung, Verizon, Sprint, Deutsche Telekom**

Agreements:

- For NR, support DL CSI measurement with X antenna ports
  - Study the values of X = 1,2,4,8,12,16,20,24,28,32
  - Study whether additional values of X are needed, including X > 32 (e.g., 64)
  - Other values of X are not precluded

Petitioners' Exhibit 1003, p. 1004
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-168318 **Summary of Wednesday Offline Session on NR MIMO** **Samsung**
Decision: The document is noted.
R1-168448 **Summary of Thursday Offline Session on NR MIMO** **Samsung**

R1-168530 **WF on network coordination aspects** **Nokia, Samsung, Mediatek, Intel, ASB**

Agreements:

- Study to support various interference management schemes:
  - Interference management over different time scales:
    - Semi-static/preconfigured interference management
    - Dynamic interference management
  - Interference management where signals/channels from/to UE(s) is
    - Transmitted from/to multiple TRPs
    - Transmitted from/to single TRP
- The above study should consider:
  - Forward compatibility, e.g., for future introduction of additional interference management schemes (if any)
  - Low and high NR frequencies
  - Take into account backhaul/fronthaul latency constraints
  - Both TDD and FDD
  - Both data and control channels
  - Interference measurement/reporting
  - Taking into account interference management for advanced receivers
  - Taking into account various scenarios
  - Taking into account beam management, different antenna structures, etc.

R1-168536 **WF on RS design principle in NR** **Huawei, HiSilicon**

Agreements:

- NR support NR RS configured on a per UE basis
- FFS whether or not to support always-on non-UE-specific RS in NR
  - Including the details of always-on and non-UE-specific, if supported

R1-168529 **WF on scenario and channel model for NR MIMO link and system level calibration** **ZTE Corporation, ZTE Microelectronics**

R1-166109 Antenna structure: impact on MIMO transmission and remaining modeling issues Huawei, HiSilicon
R1-166211 Unified MIMO framework for NR above and below 6GHz ZTE Corporation, ZTE Microelectronics
R1-166212 Beam selection and CSI acquisition for NR MIMO ZTE Corporation, ZTE Microelectronics
R1-166213 Reference signal design for NR MIMO ZTE Corporation, ZTE Microelectronics
R1-166214 Beam management for NR MIMO ZTE Corporation, ZTE Microelectronics
R1-166215 Beamforming architecture for NR MIMO ZTE Corporation, ZTE Microelectronics
R1-166216 Views on transmission schemes for NR MIMO ZTE Corporation, ZTE Microelectronics
R1-166217 Discussion on Control Channel Design for NR MIMO ZTE Corporation, ZTE Microelectronics
R1-166218 Aperiodic CSI for NR MIMO ZTE Corporation, ZTE Microelectronics
R1-166219 NR beamforming with UE-group-specific beam sweeping ZTE Corporation, ZTE Microelectronics
R1-166220 Beamforming design considering channel charateristics of Above 6-GHz ZTE Corporation, ZTE Microelectronics
R1-166380 Uplink MIMO transmission schemes Qualcomm Incorporated
R1-166381 Reference Signals and Procedures for CSI Acquisition Qualcomm Incorporated
R1-166382 CSI feedback schemes Qualcomm Incorporated
R1-166383 QCL Considerations Qualcomm Incorporated
R1-166478 MIMO transmission schemes for NR CATT
R1-166479 CSI feedback for NR MIMO CATT
R1-166480 Discussion on beam training CATT
R1-166481 Reference signal design for NR MIMO CATT
R1-166482 Initial evaluation results for NR MIMO CATT
R1-166561 Beamforming for NR PDCCH Intel Corporation
R1-166563 On the need of new QCL parameters in NR Intel Corporation
R1-166564 Discussion on possible QCL and measurement assumptions for NR Intel Corporation

Petitioners' Exhibit 1003, p. 1005
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166565 Beam management without prior beam information Intel Corporation, Verizon Wireless
R1-166566 Beam management with prior beam information Intel Corporation, Verizon Wireless
R1-166567 UE beamforming impact on control channel design Intel Corporation
R1-166573 Maximum number of multiplexed layers for NR MIMO Mitsubishi Electric Co.
R1-166574 Nonlinear precoding schemes for NR MU-MIMO Mitsubishi Electric Co.
R1-166582 Application of compressive sensing based beam training for NR Beijing Xinwei Telecom Techn.
R1-166583 Considerations on Beam Management for NR Beijing Xinwei Telecom Techn.
R1-166584 Considerations on Multi-antenna Schemes for NR Control Channel Design Beijing Xinwei Telecom Techn.
R1-166585 Multi-antenna related considerations on Initial Access Beijing Xinwei Telecom Techn.
R1-166611 Discussion on analog beamforming for NR MIMO Guangdong OPPO Mobile Telecom.
R1-166612 DL PHY procedure issues for multi-beam based approaches Guangdong OPPO Mobile Telecom.
R1-166657 Views on beam management for NR Sony
R1-166677 Discussion on CSI Acquisition for Massive MIMO in NR Fujitsu
R1-166778 Discussions on CSI-RS design for NR MIMO Samsung
R1-166779 Discussions on CSI reporting for NR Samsung
R1-166780 Discussions on channel and interference measurements for NR Samsung
R1-166781 DL MIMO for NR Samsung
R1-166782 UL MIMO for NR Samsung
R1-166783 Advanced CSI feedback for NR Samsung
R1-166784 Simulation results for explicit CSI feedback for NR MIMO Samsung
R1-166785 Discussion on TRP beamforming and beam management Samsung
R1-166786 Discussion on CSI acquisition for multi-beam based approaches Samsung
R1-166787 Discussion on the antenna port and QCL assumption study in NR Samsung
R1-166789 Analog/digital/hybrid beamforming for massive MIMO Samsung
R1-166790 Discussion on paging in NR – Multi-beam aspects Samsung
R1-166791 Discussion on interference management based on advanced transceivers for NR Samsung
R1-166793 Discussion on interference coordination for NR Samsung
R1-166900 Views on NR MIMO design principle LG Electronics
R1-166901 Discussion on CSI-RS design and CSI procedure for NR LG Electronics
R1-166902 Discussion on reciprocity based transmission for NR MIMO LG Electronics
R1-166903 Discussion on transmit beam coordination and QCL for NR LG Electronics
R1-166904 Discussion on the impact of UE rotation LG Electronics
R1-166905 Discussion on Semi-OL MIMO for NR LG Electronics
R1-166906 Consideration on UL sounding signal design for NR LG Electronics
R1-166907 DMRS Design Issues in NR LG Electronics
R1-166908 Discussion on Performance Evaluation for NR DMRS LG Electronics
R1-166909 Discussion on Common Phase Error Compensation for above 6GHz LG Electronics
R1-166943 Discussion on CSI acquisition framework for NR ETRI
R1-167078 Massive MIMO: Channel State Information (CSI) Acquisition in Angular Domain Sony
R1-167111 CSI acquisition framework for NR MIMO CMCC
R1-167112 Initial System Level Evaluation for NR MIMO CMCC
R1-167128 Discussion on UL beam management in multi-beam operation Intel Corporation
R1-167129 Discussion on CSI feedback for NR Intel Corporation
R1-167130 Evaluation results of NR for above 6GHz Intel Corporation
R1-167197 CSI acquisition mechanism for NR DL MIMO Huawei, HiSilicon
R1-167198 Discussion on transmission schemes for NR DL MIMO Huawei, HiSilicon
R1-167199 Evaluation of the impact of QCL assumptions and discussion on potential QCL configurations Huawei, HiSilicon
R1-167208 Discussion on NR UL MIMO Huawei, HiSilicon
R1-167224 Principles for Reference Signal Design and QCL Assumptions for NR Huawei, HiSilicon
R1-167225 Interference Measurement Mechanism for Link Adaptation in NR Huawei, HiSilicon
R1-167226 Uplink Power Control Huawei, HiSilicon
R1-167279 On the UE beamforming in new radio Nokia, Alcatel-Lucent Shanghai Bell
R1-167280 Multi-Beam Common Control Plane Design Nokia, Alcatel-Lucent Shanghai Bell, Verizon Wireless
R1-167281 Scalability of MIMO operation across NR carrier frequencies Nokia, Alcatel-Lucent Shanghai Bell
R1-167282 Channel reciprocity support in NR Nokia, Alcatel-Lucent Shanghai Bell
R1-167283 Coverage Enhancement Opportunities at High Carrier Frequencies Nokia, Alcatel-Lucent Shanghai Bell, Verizon Wireless
R1-167284 CSI feedback mechanisms for multi antenna operation Nokia, Alcatel-Lucent Shanghai Bell
R1-167285 Unified MIMO transmission mode for 5G new radio interface Nokia, Alcatel-Lucent Shanghai Bell
R1-167286 Beam management procedures in beam based access Nokia, Alcatel-Lucent Shanghai Bell
R1-167287 On procedures for beam selection and feedback signalling Nokia, Alcatel-Lucent Shanghai Bell
R1-167288 On beam training based on periodic DL signals Nokia, Alcatel-Lucent Shanghai Bell

Petitioners' Exhibit 1003, p. 1006
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-167290 Reference symbols types in NR Nokia, Alcatel-Lucent Shanghai Bell
R1-167292 Power control for MIMO Nokia, Alcatel-Lucent Shanghai Bell
R1-167293 Downlink network coordination for New Radio Nokia, Alcatel-Lucent Shanghai Bell
R1-167332 Beam-based design framework for New Radio INTERDIGITAL COMMUNICATIONS
R1-167380 Multi-Antenna based Coverage Enhancement NTT DOCOMO, INC.
R1-167381 CSI acquisition schemes for NR NTT DOCOMO, INC.
R1-167382 RS structure for NR downlink transmission NTT DOCOMO, INC.
R1-167383 Simulation results for UE beamforming NTT DOCOMO, INC.
R1-167384 Initial Performance Investigation of Hybrid Beamforming NTT DOCOMO, INC.
R1-167385 TDD massive MIMO for NR NTT DOCOMO, INC.
R1-167386 Discussion on CSI acquisition scheme for Uplink MIMO transmission NTT DOCOMO, INC.
R1-167460 Overview of CSI framework for NR Ericsson
R1-167461 Dynamic CSI framework Ericsson
R1-167462 Unified CSI reporting framework Ericsson
R1-167463 Pooling of RS resources for CSI reporting Ericsson
R1-167464 General aspects of spatial multiplexing for NR Ericsson
R1-167465 Multi antenna transmisssion principles for data channels in NR Ericsson
R1-167467 Reference signals and reports to support beam management Ericsson
R1-167468 On DL RS for CSI measurements Ericsson
R1-167469 On UL RS for CSI measurements Ericsson
R1-167470 Multi-antenna aspects for DMRS design Ericsson
R1-167471 Discussion of multi-antenna and highly directional beam-forming for unlicensed operation Ericsson
R1-167519 Discussion on hybrid beamforming Lenovo
R1-167520 Comparison of beam-selection and PMI-based schemes for NR MIMO Lenovo
R1-167525 Beam Sweeping Design Issues in NR MediaTek Inc.
R1-167543 Beam Management Considerations for above 6GHz NR MediaTek Inc.
R1-167548 Discussion on NR beam identification information design ITRI
R1-167571 On UL channel reciprocity for NR InterDigital Communications
R1-167572 On CSI feedback for NR InterDigital Communications
R1-167573 Considerations on Reference Signal Design for NR InterDigital Communications
R1-167585 Over the Air Reciprocity Calibration and Compensation in NR MIMO National Instruments Corp.
R1-167756 UL power control in multi-beam based approaches ASUSTEK COMPUTER (SHANGHAI)
R1-167822 On multi-antenna schemes for New Radio CEWiT
R1-167827 Considerations on multi-antenna scheme design for NR China Unicom
R1-167887 Discussion on spatial multiplexing for NR Samsung
R1-167888 Study of phase noise tracking Intel Corporation
R1-167903 Evaluation methodology and assumptions for NR MIMO ZTE Corporation, ZTE Microelectronics
R1-167948 WF on RS for CSI acquisition and demodulation in NR Huawei, HiSilicon
R1-167952 WF on network coordination aspects Nokia
R1-167997 WF on frequency selective precoding for NR UL MIMO Samsung, Intel
R1-168175 WF on RS for beam management Huawei
R1-168185 WF on aperiodic beam sweeping and CSI reporting ZTE
R1-168467 WF on digital sub-system with hybrid beamforming Nokia, Alcatel-Lucent Shanghai Bell

8.1.6 Aspects related to initial access and mobility

Discuss PHY layer aspects related to initial access and mobility, considering beamforming aspects, for standalone and non-standalone operation

R1-167055 Overview on initial access and mobility Ericsson
The document was presented by Asbjorn Grovlen from Ericsson.

- Proposal 1: The initial time synchronization is provided by the Synchronization Signal(synchronization signal) where identical synchronization signal can be transmitted by multiple transmission points.
- Proposal 2: Target 100 ms periodicity for the synchronization signal and system information to limit the always-on signals for forward compatibility and lower energy consumption.
- Proposal 3: Idle-mode mobility measurements are based on the synchronization signals used for initial access.
- Proposal 4: Connected mode mobility measurements are based on specific reference signal unrelated to the synchronization signals used for initial access and idle mode mobility.
- Proposal 5: The reference signals for connected mode mobility can be configured that can be configured on a per-need basis

Decision: The document is noted.

R1-167294 Basic Principles for Initial Access and Mobility Nokia, Alcatel-Lucent Shanghai Bell, Verizon Wireless
The document was presented by Mihai Enescu from Nokia.

Petitioners' Exhibit 1003, p. 1007
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Proposal 1: Periodic synchronization signal(s) are needed for initial search and synchronization.
- Proposal 2: Signal structure used for initial search signal should be common both in single-beam and multi-beam operation.
- Proposal 3: Default numerology is used for synchronization signals (per frequency band).
- Observation 1: Tens to hundreds of beams per cell which needs to be uniquely identifiable by the UEs.
- Observation 2: Hierarchical beam identification structure is needed.
- Observation 3: Synchronization signal needed for beam synchronization.
- Observation 4: Synchronization signal can convey ID that is used as basis to derive beam reference signal for the cell.
- Proposal 4: Physical broadcast channel needs to be defined to deliver essential system information.
- Proposal 5: PBCH should support both single-beam and multi-beam operation.
- Proposal 6: Random access procedure should support both single-beam and multi-beam operation.
- Proposal 7: Default numerology applied for the signals and channels in random access procedure.
- Proposal 8: Periodical downlink beam reference signals are basis for downlink based mobility.
- Proposal 9: Define a periodical discovery signal comprising synchronization signal(s), beam reference signals and physical broadcast channel transmitted by a cell.
- Observation 6: UL signal for UL based mobility may be used triggering downlink mobility measurements.
- Observation 7: UL based mobility likely more feasible at lower carrier frequencies than higher carrier frequencies where UE uses directional transmissions instead of omni-directional.

Decision: The document is noted.

R1-167912 Discussion on initial access and mobility for NR NTT DOCOMO, INC.

The document was presented by Hiroki Harada from NTT DOCOMO.

- Proposal 1: RAN1 should study synchronization signal (SS) design for eMBB/URLLC.
  - Different design of SS for mMTC can be considered and introduced (if necessary) later.
- Proposal 2: NR should support multiple SS numerologies for different frequency bands and different synchronization accuracy requirements.
- Proposal 3: NR should support both single-beam based and multi-beam based approaches for SS transmission.
  - Target number of beams for SS transmission and corresponding resource mapping design should be studied.
- Observation 1: SS transmission periodicity for standalone NR carrier should be short (e.g., 5 or 10 ms) while SS transmission periodicity for non-standalone NR carrier can be longer (including possibility of no transmission) by using assistance from other NR or LTE carrier.
- Proposal 4: Only essential system information required for standalone initial access is transmitted in MIB (and SIB) as always-on signal and other system information can be provided on-demand after random access.
- Proposal 5: Design of identity parameter used for SS generation and MIB decoding should not limit NR deployment flexibility.
- Proposal 6: DL-based measurement should be assumed as baseline for UE controlled mobility.

Decision: The document is noted.

R1-167944 WF on NR initial access NTT DOCOMO, Nokia, ASB, Ericsson

The document was presented by Hiroki Harada from NTT DOCOMO.

- RAN1 should strive for a common framework, including for example structure of synchronization signals, for initial access
- More specifically, especially within a given frequency range, RAN1 should strive for a common framework covering
  - Single beam based and multi-beam based deployments
  - TDD and FDD operations
  - Different/mixed numerologies
  - Standalone and non-standalone operations
  - Licensed band and unlicensed band operations
- RAN1 should take following requirements into account to design synchronization signal(s) and essential system information for initial access
  - Providing at least following functionalities
    - Detection of NR cell and its ID
    - Initial time/frequency synchronization to the cell
    - Providing necessary information for random access
  - Providing sufficient number of identity parameters to allow deployment flexibility

Decision: The document is noted and modified as follows:

Agreements:

- RAN1 should strive for a common framework, including for example structure of synchronization signals, for initial access
- More specifically, especially within a group of frequency bands in the frequency range, RAN1 should strive for an unified framework covering

Petitioners' Exhibit 1003, p. 1008
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Single beam based and multi-beam based deployments
- TDD and FDD operations
- Different/mixed numerologies
- Standalone and non-standalone operations
- Licensed band and unlicensed band operations
- FFS: mMTC use case

- RAN1 should take at least following requirements into account to design initial access
  - Providing at least following functionalities
    - Detection of NR cell and its ID
      - Note: In this context, NR cell corresponds one or multiple TRP(s)
    - Initial time/frequency synchronization to the cell
    - Providing necessary information for random access
  - Providing sufficient number of the identity values to allow deployment flexibility
  - FFS: supporting efficient mobility
  - FFS: supporting efficient inter-RAT measurement
  - Reducing the frequency hypothesis UE needs to search for compared to LTE
  - FFS: detecting beam ID(s)

R1-167957 WF on evaluation assumptions for initial access in NR Intel Corporation
The document was presented by Gregory Morozov from Intel.
Discussion: Huawei requested more time for detailed review.
Decision: The document is noted. Continue offline discussion until Tuesday – (Intel)
Tuesday: Evaluation assumptions have been revised in R1-168107 and agreed in R1-168162.
Continue offline discussion until Wednesday – (Intel)
Wednesday: Evaluation assumptions have been revised in R1-168239 , all brackets removed and agreed in R1-168255 by adding the following note in PHY abstraction: "Proponents are allowed to provide PHY abstraction details if used"
Note that R1-168255 superseeds the previously agreed R1-168162.
Thursday
R1-168481 WF on evaluation assumptions for initial access in NR Intel
Agreed in R1-168493 with following updates in channel model

- CDL-C for 4 and 30GHz, CDL-D for 70 GHz (other CDL models are not precluded),

RACH procedure
R1-168124 WF on RACH procedure for NR NTT DOCOMO, Ericsson, Nokia, Alcatel-Lucent Shanghai Bell
The document was presented by Kazuaki Takeda from NTT DOCOMO.

- RACH procedure including RACH preamble (Msg. 1), random access response (Msg. 2), message 3, and message 4 is at least assumed for NR from RAN1 perspective
- Simplified RACH procedure, e.g., Msg. 1 (UL) and Msg. 2 (DL), should be further studied
  - Details on Msg. 1 and Msg. 2 are FFS
- The design of the random access procedure should take into account the possible use of multi-beam DL and multi-beam UL as well as multi-beam DL and single-beam UL
- In case that beam-forming is applied to DL broadcast channels/signals for initial access, association between DL broadcast channels/signals detected by UE for initial access and RACH resource is considered.
  - FFS: Details on association in the context of multi-beam DL - multi-beam UL and multi-beam DL - single-beam UL
- Multiple occasions for RACH preamble transmission in a given time interval is supported
  - FFS: Details on time interval
- Allow for RACH reception/RAR transmission in TRPs other than the one transmitting synchronization signals

Decision: The document is noted. Continue offline discussion until Wednesday – (NTT DOCOMO)

R1-168104 WF on NR multi beam initial access ZTE
The document was presented by Patrick Svedman from ZTE.

- RAN1 should study multi-beam based approaches to enable beamforming gain in each initial access step, considering:
  - Non Rx/Tx reciprocity at BS or UE
  - Full or partial Rx/Tx reciprocity at BS or UE
- RAN1 should strive for a unified initial access framework for different reciprocity cases.

Discussion: Also supported by InterDigital.
Decision: The document is noted. Continue offline discussion until Wednesday – (ZTE)

R1-168260 WF on RACH procedure for NR NTT DOCOMO, ZTE, CATT, Samsung

Petitioners' Exhibit 1003, p. 1009
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Decision: The document is noted.

Agreements:

- RACH procedure including RACH preamble (Msg. 1), random access response (Msg. 2), message 3, and message 4 is at least assumed for NR from RAN1 perspective
- Simplified RACH procedure, e.g., Msg. 1 (UL) and Msg. 2 (DL), should be further studied
  - Details on Msg. 1 and Msg. 2 are FFS
  - Study should include comparison with the above procedure (first bullet)
- The design of the random access procedure should take into account the possible use of single-beam and multiple beam operations, including
  - Non Rx/Tx reciprocity at BS or UE
  - Full or partial Rx/Tx reciprocity at BS or UE
- In case that multiple beam-forming is applied to DL broadcast channels/signals for initial access,
  - RACH resource is obtained by UE from detected DL broadcast channels/signals
    - FFS: Details on association
  - Other mechanism w/o association is also considered
- Multiple occasions for RACH preamble transmission in a given time interval are considered
  - Details are FFS
  - Other mechanism is not precluded
- Study further RACH reception/RAR transmission in TRPs/beams other than the one transmitting synchronization signals

About RACH, continue offline discussion until Thursday focusing on evaluation assumptions and signal design – Patrick (ZTE), Kazuaki, (DOCOMO), Seunghee (Intel), Hyunseok (Samsung)

Thursday

R1-168390 **WF on Link Level Evaluation Assumptions for RACH Preamble NTT DOCOMO**

Agreed in R1-168492 with following updates in channel model

- CDL-C for 4 and 30GHz, CDL-D for 70 GHz (other CDL models are not precluded),

R1-168127 **WF on RRM measurement in NR LG Electronics, NTT DoCoMo**

- For RRM measurement in NR, DL measurement is supported at least for idle mode UE with the consideration on
  - Both single-beam based operation and multi-beam operation
- FFS: Definition of RRM measurement for multi-beam based operation
- FFS: DL signal for RRM measurement in idle mode

Decision: The document is noted.

R1-166393 High speed mobility performance evaluations Qualcomm Incorporated

- Observation 1: For RRC inactive state, in mobility challenging scenario, DL based mobility can have high paging miss probability
- Observation 2: For RRC inactive state, in mobility challenging scenario, paging missing probability for DL based mobility can be improved at the expense of UE power consumption increase, e.g. more frequent and longer cell-search
- Observation 3: For RRC inactive state, in mobility challenging scenario, UL based mobility can still provide reliable paging because of fast closed-loop L1 handshake at each DRX wakeup (i.e., UE transmitting a reference signal and Network sending back a response signal)
- Observation 4: For RRC inactive state, in mobility challenging scenario, UL based mobility can provide better paging reliability and UE power consumption tradeoff, compared to DL based mobility
- Our proposals are as follows
- Proposal 1: NR shall support UL-based mobility in which UE transmits reference signals and RAN determines a mobility event based on measurements of reference signals of UE's.
- Proposal 2: NR shall consider supporting hybrid/dynamic DL-based and UL-based mobility
- Proposal 3: Evaluate mobility performance. Following are the proposed KPIs.
  - RRC inactive state (similar to LTE_IDLE)
    - Paging-miss rate
    - Call-setup delay (i.e., number of consecutive Network paging miss before UE establishes a connection)
    - Network paging resource utilization (e.g., number of TRPs involved in paging a UE)
    - UE (intra-frequency) cell-search rate (relates to UE power consumption.)
    - Comparative UE power consumption analysis
  - RRC connected state (similar to LTE RRC_CONNECTED)
    - Handover-failure rate
    - Mobility interruption time
    - User experience during the HO

Decision: The document is noted.

Petitioners' Exhibit 1003, p. 1010
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Agreements (made on Wednesday further to offline discussions refining R1-168127):

- For RRM measurement in NR, at least DL measurement is supported with the consideration on
  - Both single-beam based operation and multi-beam based operation
- FFS: Definition of RRM measurement for multi-beam based operation
- FFS: DL signal for RRM measurement
- FFS: When DL measurement is applied
- Note that there is no conclusion that DL measurement is a complete solution for RRM measurement in NR for now

R1-168137 WF on RRM Measurement and Mobility Huawei, HiSilicon, Qualcomm

- For RRM measurement and mobility in NR, the following should be supported:
  - UL measurement can be used for:
    - L1/L2 based intra NR cell TRP mobility
    - L3 based inter NR cell mobility
  - UL signals used for UL measurement includes:
    - At least an energy-efficient UE-specific UL tracking signals
  - DL measurement can be used for
    - intra NR cell TRP mobility and DL beam management
    - NR cell reselection

  Note: In this context, NR cell corresponds to one or multiple TRP(s)

Decision: The document is noted.

Conclusions:

- For RRM measurement and mobility in NR, RAN1 needs to study DL and UL based measurements considering following RAN2 study
  - RRC driven at 'cell' level
  - Zero/Minimum RRC involvement (e.g. at MAC /PHY)
  - FFS what is the definition of a cell

Continue offline discussion about the detailed evaluation assumptions until Wednesday – (Huawei, Qualcomm)

Wednesday

R1-168464 Evaluation Scenarios and Assumptions for DL and UL Mobility Qualcomm, Huawei

R1-168488 Evaluation Scenarios and Assumptions for DL and UL Mobility Qualcomm Incorporated, Huawei, Intel

R1-166795 Discussion on numerology aspects of NR synchronization signal Samsung

Decision: The document is noted. Continue offline discussion about SS numerology – Samsung

R1-168277 WF on numerology for synchronization signals in NR Samsung, ETRI, CATT, NTT DOCOMO, Ericsson

Agreements:

- For subcarrier spacing of each synchronization signal (e.g. NR PSS,SSS) in a NR carrier, the following alternatives should be studied
  - Alt 1: Subcarrier spacing is predefined in the specification for a given frequency range
    - Ex: 15kHz for sub-6GHz, 60kHz for over-6GHz
    - Note that there are more than one frequency ranges
  - Alt 2: Subcarrier spacing is selected by NR BS
    - FFS: Details on the set of possible numerologies
    - Note: Blind detection of multiple numerologies can be considered
  - Alt 3: Single subcarrier spacing is predefined in the specification for all frequency ranges
  - Other alternatives are not precluded
- NR synchronization signal is based on CP-OFDM
  - Note that DFT-spread-OFDM based design is not precluded

R1-166387 Uplink based mobility physical channels Qualcomm Incorporated

Decision: The document is noted.

R1-167059 On the random access procedure Ericsson

The document was presented by Asbjorn Grovlen from Ericsson.

- Proposal 1: NR should support a four message random access procedure in order to support larger distances between UE and TRP

Petitioners' Exhibit 1003, p. 1011
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Proposal 2: Study additional two step random access procedure to reduce the delay of accessing the network
- Proposal 3: If synchronization signals are beamformed, an association between SS and PRACH preambles should be supported.

Decision: The document is noted.

R1-167378 **RACH procedures for NR NTT DOCOMO, INC.**

The document was presented by Hiroki Harada from NTT DOCOMO.

- Proposal 1: The RACH procedure involving a transmission/reception of RACH preamble, RAR, message 3 and message 4 is at least supported for NR.
- Proposal 2: The simplified RACH procedure including only RACH preamble (and UL control channel/data) and RAR should be further considered.
- Proposal 3: Association between RACH resource and beam index should be considered to support efficient multi-beam operation for RACH procedure.

Decision: The document is noted.

R1-166799 **Random access in NR considering flexible UE channel bandwidth Samsung**

The document was presented by … from Samsung.

- Requirements to support different UE bandwidths on the same NR carrier
  - In order to support UEs with different bandwidth capabilities on the same NR carrier, PRACH bandwidth should be larger than or equal to minimum supported UE bandwidth.
  - The NR-PDCCH for RAR and RAR should be transmitted by NR-BS over bandwidth less than or equal to channel bandwidth of UE.
  - The NR-PDCCH for MSG3 retransmission should be transmitted by NR-BS over bandwidth less than or equal to channel bandwidth of UE. Resources for MSG3 transmission should be allocated to UE over bandwidth less than or equal to channel bandwidth of UE.
  - The NR-PDCCH for MSG4 (re)transmissions should be transmitted by NR-BS over bandwidth less than or equal to channel bandwidth of UE. Resources for MSG4 transmission should be allocated to UE over bandwidth less than or equal to channel bandwidth of UE.
- Proposal: The RACH-related signals and channels should be designed to take a benefit from various bandwidth values that NR UEs may support.

Decision: The document is noted.

R1-168091 **WF on carrier bandwidth for initial access in NR Mediatek**

- The synchronization channel and at least some essential system information are restricted within a certain specified bandwidth.
  - The specified bandwidth may depend on the range of the frequency bands.
  - The specified bandwidth is not larger than the minimum system bandwidth to be supported in the corresponding frequency bands
  - e.g., the specified bandwidth can be 5MHz, 20Mhz, 80Mhz depending on the range of frequency bands.
- FFS: mMTC case
- FFS: uplink bandwidth for RACH.

Decision: The document is noted. Continue offline discussion within Wednesday

Wednesday

R1-168299 **WF on carrier bandwidth for initial access in NR MediaTek, SierraWirless**

- The synchronization channel and at least some essential system information are restricted within a set of specified frequency resources.
- A set of specified frequency resources may depend on the range of the frequency bands and the numerology.
  - FFS: a set of frequency resources
- FFS: whether the used frequency resource is blindly detected by UE from a set of specified frequency resources or set by default according to the frequency bands.

Discussion: FFS: uplink bandwidth for RACH.

Decision: The document is noted. Continue offline discussion until Thursday

Thursday

R1-168397 **WF on carrier bandwidth for initial access in NR MediaTek**

R1-168483 **WF on carrier bandwidth for initial access in NR MediaTek, Intel**

Agreements:

- At least one transmission bandwidth within a carrier bandwidth can be specified for transmission of each synchronization signal and at least some essential system information.
  - The transmission bandwidth may be specified either differently according to the frequency range or the same across the frequency ranges

Petitioners' Exhibit 1003, p. 1012
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- FFS: transmission bandwidths for each synchronization signal and at least some system information are same or not
- FFS: the transmission bandwidth and the corresponding numerology
- FFS: whether the used transmission bandwidth is blindly detected by UE from specified bandwidths according to the frequency bands

R1-168463 Way forward on initial access for NR LG Electronics, NTT DOCOMO
Also supported by Mitsubishi, ZTE
R1-168512 Way forward on initial access for NR LG Electronics, NTT DOCOMO, Panasonic, ETRI

Agreements:

- In order for the transmission of the information required for the initial access (e.g. configuration of random access resource), at least following options are to be studied:
  - Note: the above information can consist of multiple parts, and different option below can be applied for the transmission of each part
  - Opt 1: the transmission is scheduled by dynamic signaling (e.g. control channel)
  - Opt 2: the transmission is scheduled by semi-static signaling (e.g. via the previous part)
  - Opt 3: the transmission is done alone without associated signaling (e.g. predefined in spec)
- In the above study, at least following aspects should be considered:
  - Resource flexibility (e.g. in terms of ensuring forward compatibility, dynamic TDD operation)
  - Resource overhead
  - UE complexity (e.g. involved with decoding of the information)

R1-168494 WF on sync and carrier rasters Huawei, HiSilicon, Qualcomm, Nokia, Alcatel-Lucent Shanghai Bell, NTT Docomo, Ericsson, ETRI, InterDigital

Email approval until Sept 1st to inform RAN2 on the current RAN1 agreements and WA

R1-166088 Access mechanism for beam based approach Huawei, HiSilicon
R1-166107 Synchronization and initial access mechanism in NR Huawei, HiSilicon
R1-166114 Low frequency assisted high frequency operation Huawei, HiSilicon
R1-166222 Evaluation and analysis on coverage issue of initial access for NR above 6GHz ZTE Corporation, ZTE Microelectronics
R1-166228 Beam control operation for common channels/signals in NR Mitsubishi Electric Co.
R1-166384 Initial access consideration for mmW Qualcomm Incorporated
R1-166385 Initial access consideration for NR sub6GHz Qualcomm Incorporated
R1-166386 DL and UL based mobility procedures Qualcomm Incorporated
R1-166387 Uplink based mobility physical channels Qualcomm Incorporated
R1-166389 Beam management for NR Qualcomm Incorporated
R1-166417 Overview of NR initial access ZTE
R1-166418 Design considerations for DL sweeping time interval in NR ZTE
R1-166419 Beamformed random access in NR ZTE
R1-166420 Performance analysis of cell search in NR ZTE
R1-166421 Multi-TRP aspects of random access ZTE
R1-166422 Unified synchronization structure ZTE
R1-166483 NR Initial Access and Mobility Management CATT
R1-166586 Considerations on Initial Access Design Beijing Xinwei Telecom Techn.
R1-166639 Discussion on initial access and mobility for NR standalone cell NEC
R1-166653 Consideration on synchronization for NR Sony
R1-166658 On RRM measurement for NR Sony
R1-166678 Discussion on initial access in NR Fujitsu
R1-166794 Network topology and system operation for NR Samsung
R1-166796 Overview on issues for NR initial access Samsung
R1-166797 Coverage enhancement of broadcasting channels/signals Samsung
R1-166798 PHY initial access procedure for multi-/single-beam based approaches Samsung
R1-166910 Discussion on DL Synchronization in NR LG Electronics
R1-166911 Discussion on PRACH preamble design and RACH procedure for NR LG Electronics
R1-166912 Discussion on Coverage Enhancement with Multi-beam LG Electronics
R1-166913 RRM measurement and beam procedure in NR LG Electronics

Petitioners' Exhibit 1003, p. 1013
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166944 Band-agnostic initial access for NR ETRI
R1-166945 Aspects related to RRM measurements ETRI
R1-166946 Aspects related to system informations ETRI
R1-166947 Beam sweeping for initial access ETRI
R1-166948 Transmission of synchronization signal on demand ETRI
R1-166949 Band-agnostic synchronization and cell search ETRI
R1-167028 Sync and beam acquisition procedure in multi-beam based approach KT Corp.
R1-167056 Idle mode operation and initial access Ericsson
R1-167057 Connected mode mobility Ericsson
R1-167058 On PRACH preamble design Ericsson
R1-167060 On NR random-access response design Ericsson
R1-167113 Link level evaluation for single-beam based and multi-beam based initial access CMCC
R1-167114 Gradual UE-Specific (GUS) initial access and multi-beam-based mobility management CMCC
R1-167115 Discussion on beam sweeping for Initial Access CMCC
R1-167200 RRM Measurement for NR Huawei, HiSilicon
R1-167205 UE-cell-center-like design principles and tracking signal design Huawei, HiSilicon
R1-167217 A common synchronization signal for a NR carrier supporting different numerologies Huawei, HiSilicon
R1-167222 Discussion on Multiple Access and Channel Multiplexing for High Frequency Huawei, HiSilicon
R1-167295 Radio resource management in NR Nokia, Alcatel-Lucent Shanghai Bell
R1-167296 Random access principles for New Radio Nokia, Alcatel-Lucent Shanghai Bell
R1-167333 Random access aspects for beam-based NR initial access INTERDIGITAL COMMUNICATIONS
R1-167377 Design for RACH preamble for NR NTT DOCOMO, INC.
R1-167526 Considerations for Synchronization Signals Design in NR Beamformed Initial Access MediaTek Inc.
R1-167542 Discussion on initial access for NR MediaTek Inc.
R1-167574 On beam-based initial access for NR InterDigital Communications
R1-167631 Cell detection and mobility measurement in NR Motorola Mobility
R1-167672 Synchronization in NR considering beam sweeping ASUSTEK COMPUTER (SHANGHAI)
R1-167704 On NR Initial Access and Mobility Intel Corporation
R1-167705 Design on NR DL Synchronization Intel Corporation
R1-167706 Simulation assumptions and scenarios for NR initial access Intel Corporation
R1-167707 Initial performance evaluation of different beamforming options for NR synchronization signals Intel Corporation
R1-167741 Discussion on System Information Acquisition III
R1-167772 Localization-Assisted Mobility Support for NR Vehicular Communication National Taiwan University
R1-167801 Discussion on reference signal design for HF-NR National Taiwan University
R1-167840 Discussion on Beamforming Initial Access Operations Convida Wireless LLC
R1-167847 Discussion on Sync Signals Supporting Different Numerologies Convida Wireless LLC

8.1.7 Remaining details on evaluation and scenarios for new radio interface

Focus on general evaluation assumptions and scenarios including newly introduced scenarios, e.g., satellite, air-to-ground communications. Discuss other evaluation assumptions related to each technique under each A.I.

R1-168419 Chairman's notes of AI 8.1.7 on remaining details on evaluation and scenarios for NR Ad-Hoc chair (Qualcomm)
The document was presented by Wanshi Chen from Qualcomm.
Decision: The document is endorsed and incorporated as follows.

R1-166112 Simulation assumptions on URLLC Huawei, HiSilicon
R1-166398 URLLC system level simulation assumptions Qualcomm Incorporated
R1-166484 Discussions on KPI and evaluation configuration for URLLC CATT
R1-167298 Remaining details on URLLC assumptions Nokia, Alcatel-Lucent Shanghai Bell

R1-166394 mMTC system level simulation assumptions Qualcomm Incorporated
R1-167539 Discussion on the channel model for mMTC SLS evaluation MediaTek Inc.

R1-166396 Extreme long range evaluation assumptions and methodologies Qualcomm Incorporated
R1-166599 Measurements of Extreme Rural Scenarios Telstra Corporation Limited

R1-166915 High level view on the study for eV2X LG Electronics
R1-166916 Remaining issues on the evaluation assumptions for eV2X LG Electronics
R1-167942 WF on coexistence between NR sidelink and LTE sidelink LG Electronics, Huawei, HiSilicon, Deutsche Telekom

Petitioners' Exhibit 1003, p. 1014
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Conclusion:
- This topic as in R1-167942 is to be revisited next meeting (after V2V WI, expected to be finished this meeting)

R1-167943 WF on remaining evaluation assumptions for eV2X LG Electronics, Deutsche Telekom, Huawei, HiSilicon

Proposal:
- The performance metric agreed in the email discussion [85-15] is captured in TR38.802
- The specific numbers of traffic model, inter-RSU distance, and UE distribution are by the agreed values in the TR 38.913. These values can be further updated modified, after SA1 input.
- Following the agreement in the SLS evaluation assumptions of rural and urban macro, [TBD for TDD] is removed in BS Tx power part for SLS evaluation assumptions of eV2X
- For the in-band emission modeling, RAN1 needs to study the impact of in-band emission and proper modeling for it for NR sidelink operations.
- For the LLS evaluation assumptions for eV2X, those in LTE V2X described in TR38.885 could be reused as start point, and updated if NR study has new proposals
  - Target frequency can be revisited

Further discussion offline

R1-167931 WF on performance metric for V2X NR Ericsson, LGE

Agreement:
- For the two alternatives as part of the RAN1#85 email discussion [85-15], the following is agreed:
  - Alt. 2: (1-Y) is the packet reception ratio calculated on a subset of UEs:
    - For one Tx packet, 1-Y is calculated by S/Z, where Z is the number of UEs in the intended set of receivers, and S is the number of UE with successful reception among Z.
      - Unicast is the special case where Z includes a single UE, where the PRR is average of packets of the unicast link

R1-167932 WF on system level simulations for V2X NR Ericsson

Proposal:
- Add 63GHz carrier frequency with 1GHz bandwidth (63-64GHz) for UE-UE and for UE-RSU [1]
- FFS UE-UE and UE-RSU channel models at 63GHz
- 40dBm e.i.r.p. Tx power limitation at 63GHz
- Revise the assumptions on RSU antenna pattern.
  - 4 antenna arrays with 2 elements each
  - The arrays point to the 4 streets in the intersection
  - Each antenna element irradiates with halfspherical uniform distribution over a 90deg azimuth angle
  - Antenna gain = 9dBi
- Slide 5 of R1-167932

Discuss further offline

R1-166110 On building material distribution modeling and indoor user ratio modeling Huawei, HiSilicon
R1-167387 Remaining details of the dense urban scenario NTT DOCOMO, INC.

Proposal: Regarding TRP dropping:
- Option 1 in Table II of R1-167387 is used for 4GHz case.
- Option 3 in Table II of R1-167387 is used for 30GHz case.
- Modelling of coverage enhancement schemes, e.g., using the multi-beam based transmission shall be considered, at least for 30 GHz case, in order to perform the macro-layer/micro-layer cell association.

Further discussion offline

R1-167553 On max EIRP values Ericsson

Agreement:
- Remove the brackets for urban macro scenario to set the EIRP limit to 78 dBm
- In dense urban scenario, set the EIRP limit to 73 dBm and 68 dBm for the macro and micro layers respectively
- In indoor open office scenarios, set the EIRP limit to 58 dBm

R1-167576 UE Transceiver Architecture and Noise Figure Assumptions for NR with Frequencies Above 6 GHz Straight Path Communications, Qorvo

R1-167876 High speed train scenario for RRH and relay at 30GHz: scenario and CDL-D descriptions Mitsubishi Electric

Petitioners' Exhibit 1003, p. 1015
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Revision of R1-166937

R1-167792 **Battery Assumptions for NR** **u-blox AG, Sony**
R1-166885 **Evaluation assumptions for flexible duplex operation** **LG Electronics**

R1-168125 **Offline discussion summary** **NTT DoCoMo**
Conclusion:
- The green parts in R1-168125 are endorsed
- Table A.2.1-1, 2, 3, cell E11, is endorsed with the following updates:
  - NOTE1: See Appendix for the derivation of maximum allowed EIRP (R1-164383, R1-167553).

R1-168121 **Way Forward on O2I Penetration Loss Model Mix for NR Evaluation** **Straight Path, Ericsson, Samsung, Nokia, ASB, LGE, Huawei**

Agreements:
- The following mix of O2I penetration loss models should be evaluated for high frequency for NR:
  - For Urban Micro and Urban Macro
    - Option1
      - Low loss model – 80%
      - High-loss model – 20%
    - Option2
      - Low loss model – 50%
      - High-loss model – 50%
    - Other mix ratio(s) is not precluded.

R1-168053 **WF on scenarios and evaluation assumptions for flexible duplex** **LG Electronics, Huawei, HiSilicon**

Agreement:
- The WF in R1-168053 is agreed, with the following updates:
  - Channel model:
    - Current entries are used as a starting point
    - Can further discussion whether or not to update the channel model
  - Traffic model
    - Add optional DL/UL ratio of 1:1
    - Add one more packet size of 2Mbtyes
    - Add "other FTP model is not precluded"
  - UE receive noise figure:
    - Update according to last meeting's agreements on the noise figures (i.e., 10dB vs. 13dB)
  - Layout
    - Add: FFS other cluster dropping models for dense Urban

R1-168391 **Offline dicussion updated sumary of evaluation assumptions for NR NTT DOCOMO, INC.**

Agreement: The green entries in the attached spreadsheet in R1-168391 are agreed

R1-168371 **WF on URLLC evaluation parameter and LLS method** **Huawei, HiSilicon, CATR**

Agreements:
- Slide 3 and slide 4 in R1-168371 are agreed
- Slide 5 in R1-168371 is agreed, with the following updates:
  - From "Companies report delay assumption, e.g., processing delay, transmission delay, re-transmission delay."
  - To "Companies report delay assumptions according to Table 1 in R1-166485". For calibration purpose only, the entries 1.1 and 1.4 of the Table 1 are assumed to be zero. In addition, each company reports the max number of HARQ re-transmissions.

R1-168441 **WF on URLLC Evaluation Scenarios** **Intel, Ericsson, Qualcomm Inc.**

Agreements:
- From RAN1 perspective, the following scenarios are used as a starting point for initial URLLC evaluations
  - Indoor Hotspot scenario

Petitioners' Exhibit 1003, p. 1016
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Urban Macro scenario

R1-168343 **Extreme Long Range KPI Evaluation** **Qualcomm Incorporated, Ericsson, Huawei**

R1-168174 **WF on CDL-D model for high speed train scenario at 30GHz for RRH and relay** **Mitsubishi Electric, ETRI, Ericsson**

Agreement: Slide 3 in R1-168174 is agreed

R1-168398 **WF on URLLC System Capacity Definition Clarification** **Intel, Qualcomm Inc.**

Agreements:

- System level evaluation method is used for URLLC system capacity study to analyze impact from inter-cell interference, queueing and scheduling latency, multiplexing with other services
- URLLC system capacity is calculated as follows:
  - C(L, R) is the maximum offered cell load under which Y% of UEs in a cell operate with target link reliability *R* under *L* latency bound
  - X = (100 – Y) % is the percentage of UEs in outage
  - A UE in outage is defined as the UE can not meet latency L and link reliability R bound
  - Companies report their assumption on X
- Note: definition of latency L and target link reliability *R* is provided in R1-168371

R1-168372 **WF on channel model issues for flexible duplex evaluation** **Huawei, HiSilicon, Intel**

Agreement:

- Slide 2 in R1-168372 is agreed with the following update:
  - The following assumption is used as starting point for flexible duplex evaluation, and further update might be made ~~after more measurements are available~~.

R1-168373 **WF on penetration issues for flexible duplex evaluation** **Huawei, HiSilicon, LG Electronics**

Agreement:

- R1-168373 is agreed with the following update:
  - The following assumption is used as starting point for flexible duplex evaluation, and further update might be made ~~after more measurements are available~~.

R1-168370 **WF on Modeling Line-of-Sight Blockage for V2V** **Huawei, HiSilicon, Volkswagen, Ericsson, General Motors, Vodafone**
Continue discussion next meeting

R1-168547 **Offline dicussion further updated sumary of evaluation assumptions for NR NTT DOCOMO**

Agreement: The green entries and F14 in the spreadsheet attached in R1-168547 are agreed.

R1-168510 **WF on SLS evaluation methodologies for MA** **LG Electronics, ZTE, ZTE Microelectronics**

Agreements: Slide 4 and slide 5 are agreed except the cell "packet size" and "Target packet drop rate"

Email discussion on the two options of the packet size and clarification on Target packet drop rate as listed in R1-168510 until 9/1 – (NTT DOCOMO)

R1-168485 **Battery Lifetime Model for NR** **Sony, u-blox, Sierra Wireless**
Email discussion on battery lifetime model in R1-168485 until next meeting – (SONY)
Traffic model for urban coverage for massive connection (UL) (column I and row 21 in the excel sheet) was also discussed based on the draft papers. However, no consensus has been reached on.
Email discussion on traffic model for urban coverage for massive connection (UL) (until 9/15) – (Huawei)

R1-168517 **WF on Battery Life Evaluation Methodology for mMTC** **Qualcomm Inc.**
Discuss discussion next meeting

Petitioners' Exhibit 1003, p. 1017
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-168543 **Pathloss calibration between companies Qualcomm Inc.**
Email discussion for path loss calibration for 3D UMa at carrier frequency of 700 MHz until 9/9 – (Qualcomm)

R1-168473 **WF on evaluation assumptions related to outdoor micro cell TRP ZTE Corporation, ZTE Microelectronics, Intel Corporation, Samsung, NTT DOCOMO**

R1-168537 **WF on Dense Urban Scenarios Samsung, Ericsson, Intel, Nokia, ASB, AT&T, CMCC, Softbank, Verizon, KT, Vodafone, Deutsche Telecom**

- Include the 30GHz band in the macro layer for the carrier frequency of dense urban scenario in Table A.2.1-1 in TR38.802.

Decision: The document is noted. Continue discussion next meeting

R1-168421 **WF on Indoor TRP Configuration NTT DOCOMO, CATT, Ericsson, Intel**
Email discussion on R1-168421 till 9/2 – (NTT DOCOMO)

R1-166485 **Discussions on evaluation methodology for URLLC CATT**
R1-166802 **Dense urban evaluation assumption and results Samsung**

R1-166113	On scenarios and evaluation method of eV2X	Huawei, HiSilicon
R1-166390	Updated sub6 DL full-buffer KPI evaluation for eMBB	Qualcomm Incorporated
R1-166391	Updated sub6 UL full-buffer KPI evaluation for eMBB	Qualcomm Incorporated
R1-166395	URLLC system capacity and URLLC-eMBB multiplexing efficiency analysis	Qualcomm Incorporated
R1-166397	Sub6 DL bursty traffic evaluation for eMBB	Qualcomm Incorporated
R1-166423	Evaluation assumptions for URLLC	ZTE
R1-166568	Comparison of different TRP antenna option for indoor deployment	Intel Corporation
R1-166569	Remaining issues of evaluation assumptions for URLLC	Intel Corporation
R1-166681	Traffic Model assumptions for mMTC Battery Life and Latency Evaluation	Sierra Wireless, S.A.
R1-166800	Remaining issues for URLLC evaluation assumptions	Samsung
R1-166801	TRP density and antenna modeling for indoor hotspot	Samsung
R1-166803	Evaluation results of dense urban on 30GHz frequency band	Samsung
R1-166914	Remaining details of evaluation assumptions for URLLC	LG Electronics
R1-166917	Evaluation results on mobility enhancement for eV2X	LG Electronics
R1-167116	Quantitative metric for network energy efficiency	CMCC
R1-167194	Evaluation result of NR for below 6GHz	Intel Corporation
R1-167219	Modeling the Evolution of Line-of-Sight Blockage for V2V Channels	Huawei, HiSilicon, Volkswagen
R1-167297	[85-18] PA assumptions for NR; Email discussion summary	Nokia, Alcatel-Lucent Shanghai Bell
R1-167447	On KPIs for mMTC	Ericsson
R1-167448	On evaluation assumptions for mMTC	Ericsson
R1-167449	On battery lifetime evaluation for mMTC	Ericsson
R1-167451	Channel model of extreme rural scenario	Ericsson, Telstra
R1-167452	Path loss model of extreme rural scenario	Ericsson, Telstra
R1-167453	User and traffic distribution for extreme rural scenario	Ericsson, Telstra
R1-167454	Link budget for extreme rural scenario	Ericsson, Telstra
R1-167455	On URLLC reliability evaluation	Ericsson
R1-167457	Remaining issues on the indoor office scenario	Ericsson
R1-167458	Antenna model for outdoor TRP for micro in dense urban	Ericsson
R1-167459	On the use of 30 GHz in macro on all layers in dense urban scenario	Ericsson
R1-167540	Remaining Issues on NR System Evaluation for mMTC	MediaTek Inc.
R1-167575	URLLC KPI and evaluation assumptions	InterDigital Communications
R1-167603	Discussion on URLLC evaluation	CATR
R1-167702	Discussion on channel modeling for UE-UE and BS-BS links	Intel Corporation
R1-167904	Remaining issues on assumptions related to outdoor micro cell TRP	ZTE Corporation, ZTE Microelectronics
R1-168128	WF on Traffic and Battery Models for mMTC NR	Sony
R1-168129	WF on URLLC System Outage Evaluation	Intel Corporation
R1-168130	WF on URLLC Evaluation Metric	Intel Corporation
R1-168131	WF on URLLC Evaluation Scenario	Intel Corporation
R1-168387	WF on micro TRP	ZTE
R1-168453	WF on URLLC evaluation parameter and LLS method	Huawei
R1-168518	WF on Battery Life Evaluation Methodology for mMTC	Qualcomm

8.1.8 Other

R1-167067 **Observations on 150 ohm and way forward Ericsson**

Petitioners' Exhibit 1003, p. 1018
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The document was presented by Stefan Parkvall and was intended introducing fun to RAN1 heavy NR session and the famous dammsugare (Swedish cookie), sweet almond chocolate gourmet.

R1-166489 NR and LTE co-existence AT&T GNS Belgium SPRL
Decision: The document is noted.
R1-166570 URLLC capacity evaluation Intel Corporation
Decision: The document is noted.
R1-167207 Sidelink Support & Enhancements for NR Huawei, HiSilicon
Decision: The document is noted.

R1-166115 Support for flexible backhauling for NR Huawei, HiSilicon
R1-166116 Support for energy efficient NR Huawei, HiSilicon
R1-166118 Support for vehicular communications in NR Huawei, HiSilicon
R1-166804 Discussion on co-existence of LTE and NR Samsung
R1-166805 Design aspects of mMTC for NR Samsung
R1-166806 Aggregation of NR Carriers Samsung
R1-166807 Shared spectrum support for NR Samsung
R1-166918 Structure of control and data multiplexing for NR LG Electronics
R1-166919 Consideration on DL control channel design for NR LG Electronics
R1-166920 Consideration on common control signaling for NR LG Electronics
R1-166921 Consideration on UL control channel design for NR LG Electronics
R1-166922 Consideration on UL power control procedure for NR LG Electronics
R1-166923 Consideration on support of CA operation for NR LG Electronics
R1-166924 On coexistence of NR and LTE LG Electronics
R1-166925 Overall discussion on mMTC LG Electronics
R1-166990 On URLLC service characteristics Ericsson LM
R1-166991 On URLLC design Ericsson LM
R1-167061 On URLLC design principles Ericsson
R1-167062 On URLLC characteristics Ericsson
R1-167063 On channel access mechanisms for NR in unlicensed spectrum Ericsson
R1-167064 On physical Layer Design Policies for Unlicensed Operation of NR Ericsson
R1-167065 Technology components for unlicensed operation Ericsson
R1-167066 On autonomous UL transmissions for NR in unlicensed spectrum Ericsson
R1-167068 Aggregation of carriers in NR Ericsson
R1-167202 Discussion on unified duplex for unpaired spectrum - dynamic TDD Huawei, HiSilicon
R1-167221 Discussion on unified duplex for paired spectrum - flexible duplex Huawei, HiSilicon
R1-167231 Work plan for unified duplex Huawei, HiSilicon
R1-167300 Adaptive-length redundancy matching for HARQ transmission Nokia, Alcatel-Lucent Shanghai Bell
R1-167301 HARQ enhancements for large transport block transmission Nokia, Alcatel-Lucent Shanghai Bell
R1-167302 Early Hybrid ARQ Feedback for the 5G New Radio Nokia, Alcatel-Lucent Shanghai Bell
R1-167303 HARQ Pooling for Carrier Aggregation in NR Nokia, Alcatel-Lucent Shanghai Bell
R1-167304 On the utilization of Advanced Receivers in NR Nokia, Alcatel-Lucent Shanghai Bell
R1-167305 On the cross-link interference mitigation Nokia, Alcatel-Lucent Shanghai Bell
R1-167306 On network energy efficiency requirement and evaluation for the 5G new radio Nokia, Alcatel-Lucent Shanghai Bell
R1-167307 Uplink power control for 5G New Radio Nokia, Alcatel-Lucent Shanghai Bell
R1-167308 Punctured Scheduling for Low Latency Transmissions Nokia, Alcatel-Lucent Shanghai Bell
R1-167309 Semi-persistent scheduling for 5G New Radio URLLC Nokia, Alcatel-Lucent Shanghai Bell
R1-167341 In-band full duplexing in NR HTC Corporation
R1-167388 TRP placement for the indoor scenario NTT DOCOMO, INC.
R1-167389 Draft CR on ZoD offset for UMa NLOS in TR 38.900 NTT DOCOMO, INC.
R1-167390 Use case and operational aspects for eV2X NTT DOCOMO, INC.
R1-167391 On co-existence of eMBB and URLLC NTT DOCOMO, INC.
R1-167396 Views on NR dynamic TDD NTT DOCOMO, INC.
R1-167545 mm wave RFFE technology for NR Skyworks Solutions Inc.
R1-167546 mm wave power amplifier AM/AM and AM/PM measurements Skyworks Solutions Inc.
R1-167708 Discussion on multiplexing of eMBB and URLLC Intel Corporation
R1-167771 Discussion on Beam-forming Support in NR Multicast National Taiwan University
R1-167799 Discussion on wireless relay backhauling in HF-NR National Taiwan University
R1-168484 WF on sidelink based UE cooperation in NR Huawei

Petitioners' Exhibit 1003, p. 1019
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

8.2 Other

Including channel model for frequency spectrum above 6 GHz

R1-168420 Chairman's notes of AI 8.2 Ad-Hoc chair (Nokia)
The document was presented by Matthew Baker from Nokia.
Decision: The document is endorsed and content is incorporated as follows.

Channel model TR38.900

Section 3
R1-167927 Definitions, symbols and abbreviations in Section 3 of TR38.900 Huawei, HiSilicon (R1-167228)
Decision: Revised in R1-168001 with only the changes for sections 3.2 and 3.3.
MCC: post-meeting it is noted that both CR revision number and SI code are wrong – correction will be made before submission to plenary – CR0002r2 to 38.900 is the agreed CR with SI code FS_6GHz_CH_model

Section 4
R1-168000 Applicability of TR38.900 Huawei, HiSilicon (R1-167860)
1st bullet: Add "For system level simulations"
4th bullet: Add "For the stochastic model"
Remove the changes-on-changes
Decision: CR0038r2 to 38.900 is agreed in R1-168159 with the above changes.

Section 6
R1-167806 TR38.900_CR_Section_6 Fraunhofer HHI
Decision: CR0014r1 to 38.900 is agreed in R1-168003 as Cat-F.

Section 7.1
R1-167809 TR38.900_CR_Section_7.1 Fraunhofer HHI
Decision: CR0015r1 to 38.900 is agreed in R1-168004 as Cat-F, with comment removed.

Section 7.2
R1-167811 TR38.900_CR_Section_7.2 Fraunhofer HHI
Decision: CR0016 to 38.900 is agreed.

Section 7.3
R1-167812 TR38.900_CR_Section_7.3 Fraunhofer HHI
Decision: CR0017r1 to 38.900 is agreed in R1-168005 as Cat-F with correct change-tracking in the table.

Section 7.4
R1-167818 TR38.900_CR_Section_7.4 Fraunhofer HHI
Decision: CR0027 to 38.900 is agreed.
R1-167229 Editorial correction to path loss equations in Section 7.4 of TR38.900 Huawei, HiSilicon
Decision: Covered by R1-167818

Section 7.5
R1-168109 TR38.900_CR_Section_7.5 Fraunhofer HHI (R1-167819)
Decision: Merged into R1-168023.

R1-167223 CR for cluster DS of indoor office in TR 38.900 Huawei, HiSilicon
Decision: Discuss offline what should be the right values - revision in R1-168007.
Decision: **R1-168007** is withdrawn. Revisit the topic at RAN1#86bis.

R1-167230 Clarifications and corrections to fast fading model in Section 7.5 of TR38.900 Huawei, HiSilicon
Double-check offline the numbers below Table 7.5-7.
Remove unspecified scenarios from step 1.
Check offline with Samsung regarding the other changes to steps 1-5 and other comments.
Decision: Revision in R1-168008.
Decision: Agreed in principle. Add section 7.6 on the cover sheet. Consider whether any merging with other CRs is needed.
CR0004r2 to 38.900 is agreed in R1-168023.

R1-167476 Correction for mean ZOA Ericsson
Decision: CR0024 to 38.900 is agreed.
R1-167232 Correction on average ZOA for indoor UTs in TR 38.900 Huawei, HiSilicon

Petitioners' Exhibit 1003, p. 1020
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Decision: Covered by R1-167476.

R1-167478 Correction for RMa shadow fading Ericsson
Decision: Revised and agreed as CR0022r1 to 38.900 in R1-168021.

R1-167481 Correction to UMi O2I delay spread Ericsson
Decision: CR0019 to 38.900 is agreed.
R1-167482 Correction for ZOA scaling factor Ericsson
Decision: To be taken into account in revision of R1-167819.

R1-167234 Correction on the phase difference between antenna panels without calibration Huawei, HiSilicon
Decision: CR is not pursued. May discuss separately in NR evaluation assumptions.

Section 7.6.1
R1-166486 Draft CR on oxygen absorption CATT
Decision: Agreed in R1-168009 as CR0041 to 38.900, with addition of apostrophe in "clusters" below table 7.6.1-1.

Section 7.6.2.1
R1-167824 TR38.900_CR_Section_7.6.2.1 Fraunhofer HHI, Huawei, HiSilicon
R1-166809 Correction on large antenna array support in TR38.900 Samsung
Decision: Discuss offline how to merge R1-167824 and R1-166809. Prepare revision in R1-168010.
Decision: CR0029r1 to 38.900 is agreed in R1-168010.

Section 7.6.2.2
R1-167920 TR38.900_CR_Section_7.6.2.2 Fraunhofer HHI, Huawei, HiSilicon (R1-167825)
Decision: CR0030r1 to 38.900 is agreed.
R1-166640 Draft CR on reference table to correlation distance for large bandwidth/antenna array NEC
Decision: Covered by R1-167920.

Section 7.6.3
R1-168110 TR38.900_CR_Section_7.6.3 Fraunhofer HHI(R1-167826)
Decision: Agreed in principle, but to be revisited after merging any other changes from revision of R1-167236 -> CR0031r2 to 38.900 is agreed in R1-168012.

Section 7.6.3.1
R1-166808 Draft CR on spatially consistent random variable clarification in TR38.900 Samsung
Decision: Move to an earlier section of the TR - prepare a revision offline.
Decision: CR0042 is agreed in R1-168478.

R1-167236 Correction to the spatial consistency Section 7.6.3 of TR38.900 Huawei, HiSilicon
Discuss offline with Samsung which changes are agreeable.
Note typos in "maybe 2D processes with Uniformely distributed (delays and angles) or Normaly"
Put references in correct section.
Merge any agreeable changes into R1-168012.

Section 7.6.3.3
R1-167472 Clarification and correction of the soft LOS state model in TR 38.900 Ericsson
R1-167479 Correction to soft LOS state Ericsson, Intel
Already included in R1-168010.

R1-167480 Correction for spatial consistency of indoor distance Ericsson
Decision: CR0020 to 38.900 is agreed.
R1-167623 Corrections on spatial consistency across floors in TR 38.900 ZTE Corporation, ZTE Microelectronics
Decision: Agreed in R1-168013 as CR0040.

Section 7.6.4
R1-168151 Correction of blockage modeling Intel Corporation, Nokia, Alcatel-Lucent Shanghai Bell, Huawei, HiSilicon, InterDigital, Qualcomm, Samsung (R1-166572)
R1-167918 TR38.900_CR_Section_7.6.4 Fraunhofer HHI(R1-167829)
Includes R1-168151. Discuss offline.
Decision: Revised and agreed as CR0032r2 in R1-168329.

Section 7.6.6

Petitioners' Exhibit 1003, p. 1021
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-166571 **Correction of time varying Doppler definition** **Intel Corporation, Samsung, InterDigital**
R1-168113 **TR38.900_CR_Section_7.6.6** **Fraunhofer HHI** (R1-167836)
Discuss offline - revisit on Friday.
Decision: Revised and agreed as CR0037r2 in R1-168330.

Section 7.7.1, 7.7.2
R1-167237 **Correction to the TDL-E and CDL-E** **Huawei, HiSilicon**
Decision: CR0009 to 38.900 is agreed.

Section 7.7.2
R1-167474 **Correction for Doppler spectrum of TDLsEricsson**
Revise in R1-168014 with definition of fD and changing "frequency" to "shift".
Decision: Revised and agreed as CR0026r1 in R1-168014.

R1-167477 **Correction to MIMO extension of TDLs** **Ericsson**
Decision: CR0023 to 38.900 is agreed.

Section 7.7.3
R1-166810 **Draft CR on delay scaling parameters in LLS channel model in TR38.900** **Samsung**
Discuss offline which values to use, and show the deleted table.
Decision: Revised and agreed as CR0043 in R1-168479.

R1-167830 **TR38.900_CR_Section_7.7.3** **Fraunhofer HHI**
Decision: CR0033 to 38.900 is agreed.

Section 7.7.4
R1-168111 **TR38.900_CR_Section_7.7.4** **Fraunhofer HHI** (R1-167831)
Decision: Revised and agreed as CR0034r2 in R1-168016 with correct figure number references and delete the problem description text.

R1-167238 Correction of angular scaling parameters of CDL models in TR38.900 Huawei, HiSilicon
Decision: Superseded by R1-168016. CR is not pursued.

Section 7.7.5
R1-166811 **Draft CR on CDL channel models in TR38.900** **Samsung**
Decision: Covered by R1-167919.
R1-167919 **TR38.900_CR_Section_7.7.5** **Fraunhofer HHI** (R1-167832)
Decision: CR0035r1 to 38.900 is agreed.

Section 7.7.6
R1-167473 **Identified errors in K-factor scaling for TDL-D/E in TR 38.900** **Ericsson**
R1-167475 **Correction for K-factor scaling of TDL models** **Ericsson**
Decision: Agreed in principle; discuss offline the correct terminology for K_{1sttap} -> Revised and agreed as CR0025r1 in R1-168017.
Note that a further modification may be considered at RAN1#86bis to show how the formulae in the last table depend on the figures in the previous table.

R1-167242 **Correction to K factor scaling in Table 7.7.6-2** **Huawei, HiSilicon**
Decision: Covered by R1-167475.

Section 7.7.5.1
R1-167233 **Correction on the translation equation for scaling of angles in TR 38.900** **Huawei, HiSilicon**
Decision: Covered by R1-167919.

Section 7.8
R1-168138 **Correction on Calibration Simulation Assumption in TR38.900** **Samsung, Intel**
Decision: Revised and agreed as CR0044 in R1-168480

Section 7.8.1 & 7.8.2
R1-167579 CR for TR38.900 to capture large and full scale calibration Samsung
Decision: CR0012 to 38.900 is agreed.

Section 7.6.2.1, 7.8.2, 7.8.3
R1-167580 **Draft CR for TR38.900 for editorials and minor corrections** **Samsung**

Petitioners' Exhibit 1003, p. 1022
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Changes in only sections 7.8.2 and 7.8.3 are agreed. Other changes are already covered elsewhere.
Decision: Revised and agreed as CR0013r1 in R1-168477.

Section 8.4
R1-168112 TR38.900_CR_Section_8.4 Fraunhofer HHI (R1-167833)
Discuss offline how to handle the dependencies with section 7.5 -> R1-168019 - revisit on Friday.
Decision: Revised and agreed as CR0036r3 in R1-168022.

Miscellaneous
R1-167227 General discussion on the TR38.900 Huawei, HiSilicon
Discuss offline any remaining issues and prepare CRs for any remaining corrections that seem agreeable.
2 remaining issues:
1. 2D vs 3D pathloss
2. Multi-frequency simulation clarifications

Decision: Prepare a CR for consideration at RAN1#86bis.

R1-168153 TR38.900_CR_Consistent_Equation_Numbering Fraunhofer HHI, CATT, Huawei, HiSilicon, Ericsson
Decision: CR0039 to 38.900 is agreed.

R1-167117 Full calibration for channel model above 6GHz CMCC
R1-168020 E-mail discussion summary on additional feature calibrations Samsung (R1-167581)
Decision: Email discussion until September 30th to collect calibration data for additional features.

Other
R1-167310 Sidelink design for NR Qualcomm Incorporated

9 Closing of the meeting

Mr Chair thanked all for really appreciated hard work during the week. Special thanks to V2V team who closed Thursday session very late (23:55).
V2V rapporteur (LGE) asked for taking the floor and thanked Shailesh Patil (Qualcomm) for his work – the best to Shailesh in his future position out of RAN1.
Thanks also to the European Friends of 3GPP for hosting and organizing meeting room facilities for such big meeting.
Mr Chair thanked Vice chairs and all the chair persons who help managing the number of parallel sessions during the course of the week.
Question was raised clarifying the NR scheduling for upcoming meetings
Mr Chair confirmed that Way Forward (especially on multiple access schemes) are welcome to next meeting. Any contribution submission is welcome but RAN1 chair warned the group that RAN1 had only 3 meetings left before the completion of the NR SI, including January ad-hoc additional meeting. Agenda to next upcoming meetings shall take into account this constraint.
ZTE commented that online discussions do not preclude offline/email discussions to progress further
Ericsson still believe that RAN1 should strive reaching progress online
Meeting was closed at 17:00.
See you all in Lisbon.

Petitioners' Exhibit 1003, p. 1023
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Annex A: List of Tdocs at RAN1 #86

Please see excel file attached to this report

Petitioners' Exhibit 1003, p. 1024
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Annex B: List of CRs agreed at RAN1 #86

TS	CR	Rev	Rel	Title	Cat	Vsn	@ Mtg	TD#	Source to WG	Work Item
25.211	323	-1	Rel-12	On adding the TS 25.321 to the list of references of TS 25.211, which used in the definition of "UL DPCH 10ms Mode"	D	12.1.0	R1#86	R1-168035	Ericsson	UTRA_DCHenh-Core
25.211	324	-1	Rel-13	On adding the TS 25.321 to the list of references of TS 25.211, which used in the definition of "UL DPCH 10ms Mode"	A	13.0.0	R1#86	R1-168036	Ericsson	UTRA_DCHenh-Core
25.214	749	-	Rel-12	Clarifications on UL Discontinuous Transmission with DCH enhancements	F	12.4.0	R1#86	R1-166495	Qualcomm Europe Inc.(France)	UTRA_DCHenh-Core
25.214	750	-	Rel-13	Clarifications on UL Discontinuous Transmission with DCH enhancements (Rel. 13)	A	13.3.0	R1#86	R1-166496	Qualcomm Europe Inc.(France)	UTRA_DCHenh-Core
25.214	751	1	Rel-13	Correction of DCH enhancements	A	13.3.1	R1#86	R1-168032	Huawei, HiSilicon	UTRA_DCHenh-Core
25.214	752	1	Rel-12	Correction of DCH enhancements	F	12.4.0	R1#86	R1-168033	Huawei, HiSilicon	UTRA_DCHenh-Core
25.214	753	1	Rel-13	Correction of Dual Carrier HSUPA enhancements for UTRAN CS	F	13.3.1	R1#86	R1-168031	Huawei, HiSilicon, Ericsson	DC_HSUPA_CS-Core
25.214	754	-	Rel-12	Editorial clarification on the definitions of "UL DPCH 10ms Mode" and "UL DPCH 20ms Mode" of DCH enhancements for UMTS	D	12.4.0	R1#86	R1-167760	Ericsson	UTRA_DCHenh-Core
25.214	755	-	Rel-13	Editorial clarification on the definitions of "UL DPCH 10ms Mode" and "UL DPCH 20ms Mode" of DCH enhancements for UMTS	A	13.3.1	R1#86	R1-167761	Ericsson	UTRA_DCHenh-Core
36.211	253	-	Rel-13	Correction on DMRS for NB-IoT in TS 36.211	F	13.2.0	R1#86	R1-166180	Huawei, HiSilicon	NB_IOT-Core
36.211	254	1	Rel-13	Correction on NPRACH in TS 36.211	F	13.2.0	R1#86	R1-168364	Huawei, HiSilicon	NB_IOT-Core
36.211	255	-	Rel-13	Correction on SC-FDMA signal generation for NB-IoT in TS 36.211	F	13.2.0	R1#86	R1-166182	Huawei, HiSilicon	NB_IOT-Core
36.211	256	-	Rel-13	Corrections to RRC parameter names for NB-IoT in TS 36.211	F	13.2.0	R1#86	R1-166195	Huawei, HiSilicon	NB_IOT-Core
36.211	259	-	Rel-13	MPDCCH search-space with Temporary C-RNTI	F	13.2.0	R1#86	R1-166621	Sequans Communications	LTE_MTCe2_L1-Core
36.211	260	-	Rel-13	Correction on NPBCH in TS 36.211	F	13.2.0	R1#86	R1-167166	Huawei, HiSilicon	NB_IOT-Core
36.211	261	1	Rel-13	Correction on UL collisions in TS 36.211	F	13.2.0	R1#86	R1-167991	Huawei, HiSilicon	NB_IOT-Core
36.211	262	1	Rel-13	Correction on NPSS mapping in TS 36.211	F	13.2.0	R1#86	R1-168293	Huawei, HiSilicon, Rohde & Schwarz	NB_IOT-Core
36.211	263	1	Rel-13	Corrections on the presence of NRS for standalone and guard band operation mode in TS 36.211	F	13.2.0	R1#86	R1-168444	Huawei, HiSilicon	NB_IOT-Core
36.211	264	-	Rel-13	Correction on the determination of EPDCCH starting position	F	13.2.0	R1#86	R1-167402	ITRI	LTE_LAA-Core
36.211	265	-	Rel-13	Corrections on NPDCCH scrambling in TS 36.211	F	13.2.0	R1#86	R1-167419	Huawei, HiSilicon, Intel, Neul, Qualcomm	NB_IOT-Core
36.211	272	1	Rel-13	Frequency hopping for SI and paging messages for BL/CE UE	F	13.2.0	R1#86	R1-167953	Ericsson, Qualcomm	LTE_MTCe2_L1-Core
36.211	275	-	Rel-13	Scrambling of DL DMRS for BL/CE UE	F	13.2.0	R1#86	R1-167852	Ericsson	LTE_MTCe2_L1-Core

Petitioners' Exhibit 1003, p. 1025
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

TS	CR	Rev	Rel	Title	Cat	Vsn	@ Mtg	TD#	Source to WG	Work Item
36.211	276	-	Rel-13	Enable cross-subframe channel estimation for BL/CE UE	F	13.2.0	R1#86	R1-167861	Ericsson	LTE_MTCe2_L1-Core
36.211	278	-	Rel-13	Frequency hopping interval for MPDCCH during random access for BL/CE UE	F	13.2.0	R1#86	R1-167909	Ericsson	LTE_MTCe2_L1-Core
36.211	279	-	Rel-13	CR on the correction from SC-FDFMA to SC-FDMA	F	13.2.0	R1#86	R1-167933	Panasonic	LTE_D2D_Prox-Core
36.211	280	-	Rel-13	Correction for PHICH resource reservation on the LAA cell in 36.211 for Rel-13 LAA	F	13.2.0	R1#86	R1-167935	Huawei, HiSilicon	LTE_LAA-Core
36.211	281	-	Rel-13	Correction on MPDCCH transmission without repetition in special subframes	F	13.2.0	R1#86	R1-168155	Huawei, HiSilicon	LTE_MTCe2_L1-Core
36.211	282	1	Rel-13	Introduction of a reserved range of NPRACH sub-carriers for contention based access	F	13.2.0	R1#86	R1-168495	Ericsson, ZTE, Qualcomm	NB_IOT-Core
36.211	283	-	Rel-13	Clarification of valid subframe in eMTC	F	13.2.0	R1#86	R1-168234	Panasonic	LTE_MTCe2_L1-Core
36.211	284	-	Rel-13	Correction of NB-IoT antenna port mapping	F	13.2.0	R1#86	R1-168236	Panasonic, Huawei, HiSilicon, NEC, MediaTek	NB_IOT-Core
36.211	285	-	Rel-13	Clarification on PRACH system frame number	F	13.2.0	R1#86	R1-168508	Qualcomm Incorporated	LTE_MTCe2_L1-Core
36.211	286	-	Rel-13	PUCCH retuning with puncturing for BL/CE UE	F	13.2.0	R1#86	R1-168549	Ericsson, Qualcomm, NEC, NTT DoCoMo	LTE_MTCe2_L1-Core
36.211	287	1	Rel-13	Phase difference between NRS and CRS	F	13.2.0	R1#86	1- 168219	Qualcomm Incorporated	NB_IOT-Core
36.212	211	-	Rel-13	Correction on BCH rate matching in TS 36.212	F	13.2.0	R1#86	R1-167183	Huawei, HiSilicon	NB_IOT-Core
36.212	213	1	Rel-13	Correction on bitwidth of CLASS A codebook	F	13.2.0	R1#86	R1-167938	Intel Corporation	LTE_EBF_FDMIMO-Core
36.212	214	1	Rel-13	Corrections on CRI bit width in 36.212	F	13.2.0	R1#86	R1-167939	Huawei, Hisilicon	LTE_EBF_FDMIMO-Core
36.212	215	-	Rel-13	Subband CQI report and TM6	F	13.2.0	R1#86	1- 168287	Qualcomm Incorporated	LTE_MTCe2_L1-Core
36.212	216	1	Rel-13	CR for clarification of DCI sizes for format 6-1A (TM6 and TM9) in TS 36.212	F	13.2.0	R1#86	R1-168212	Virtuosys Ltd.	LTE_MTCe2_L1-Core
36.213	689	1	Rel-13	Correction on random access procedure for NB-IoT on TS 36.213	F	13.2.0	R1#86	R1-167989	Huawei, HiSilicon	NB_IOT-Core
36.213	690	-	Rel-13	Correction on NPDCCH related procedure on TS 36.213	F	13.2.0	R1#86	R1-166184	Huawei, HiSilicon	NB_IOT-Core
36.213	691	-	Rel-13	Corrections to RRC parameter names for NB-IoT in TS 36.213	F	13.2.0	R1#86	R1-166196	Huawei, HiSilicon	NB_IOT-Core
36.213	692	1	Rel-13	Corrections on NPDSCH related procedure in TS 36.213	F	13.2.0	R1#86	R1-167990	Huawei, HiSilicon	NB_IOT-Core
36.213	693	-	Rel-13	Correction on FD-MIMO codebook in 36.213	F	13.2.0	R1#86	R1-166337	Nokia, Alcatel-Lucent Shanghai Bell, Samsung	LTE_EBF_FDMIMO-Core
36.213	694	-	Rel-13	Correction on RRC paremeters for SRS enhancement in 36.213	F	13.2.0	R1#86	R1-166338	Nokia, Alcatel-Lucent Shanghai Bell	LTE_EBF_FDMIMO-Core
36.213	695	-	Rel-13	Transport block size determination for Msg2	F	13.1.2	R1#86	R1-166623	Sequans Communications	LTE_MTCe2_L1-Core

Petitioners' Exhibit 1003, p. 1026
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

TS	CR	Rev	Rel	Title	Cat	Vsn	@ Mtg	TD#	Source to WG	Work Item
36.213	696	-	Rel-13	Correction on NPUSCH related procedure on TS 36.213	F	13.2.0	R1#86	R1-167172	Huawei, HiSilicon	NB_IOT-Core
36.213	698	-	Rel-13	Correction on the reference of narrowband definition in TS 36.213	F	13.2.0	R1#86	R1-167184	Huawei, HiSilicon	LTE_MTCe2_L1-Core
36.213	699	-	Rel-13	Correction on the relationship between IMCS and ITBS for DCI format 6-1A in TS 36.213	F	13.2.0	R1#86	R1-167185	Huawei, HiSilicon	LTE_MTCe2_L1-Core
36.213	700	1	Rel-13	Correction on the scrambling initialization for SIB1-BR and SI for eMTC in TS 36.213	F	13.2.0	R1#86	R1-168157	Huawei, HiSilicon, Qualcomm Incorporated	LTE_MTCe2_L1-Core
36.213	701	-	Rel-13	Corrections on NPDCCH search space for random access in connected mode in TS 36.213	F	13.2.0	R1#86	R1-167188	Huawei, HiSilicon	NB_IOT-Core
36.213	704	1	Rel-11	Correction on storing soft channel bits for different UE categories	F	11.11.0	R1#86	R1-168313	Huawei, HiSilicon, NTT DOCOMO, SoftBank	TEI11
36.213	705	1	Rel-12	Correction on storing soft channel bits for different UE categories in Rel-12	A	12.10.0	R1#86	R1-168314	Huawei, HiSilicon, NTT DOCOMO, SoftBank	TEI11
36.213	706	1	Rel-13	Correction on storing soft channel bits for different UE categories in Rel-13	A	13.2.0	R1#86	R1-168315	Huawei, HiSilicon, NTT DOCOMO, SoftBank	TEI11
36.213	708	-	Rel-13	Correction on the citation of table indexs for mapping of ICRI to MCRI	F	13.2.0	R1#86	R1-167404	ITRI	LTE_EBF_FDMIMO-Core
36.213	710	-	Rel-13	Corrections on Codebooks in 36.213	F	13.2.0	R1#86	R1-167678	Huawei, Hisilicon	LTE_EBF_FDMIMO-Core
36.213	711	-	Rel-13	Default max number of PUSCH repetitions for Msg3 for BL/CE UE	F	13.2.0	R1#86	R1-167853	Ericsson	LTE_MTCe2_L1-Core
36.213	714	1	Rel-13	PDSCH start subframe in TDD for BL/CE UE	F	13.2.0	R1#86	R1-168462	Ericsson	LTE_MTCe2_L1-Core
36.213	715	-	Rel-13	Repetition with aperiodic CSI for BL/CE UE	F	13.2.0	R1#86	R1-167857	Ericsson	LTE_MTCe2_L1-Core
36.213	718	-	Rel-13	Correction on "special subframe" for frame structure type 3 in 36.213 for Rel-13 LAA	F	13.2.0	R1#86	R1-167934	Huawei, HiSilicon	LTE_LAA-core
36.213	719	-	Rel-13	36.213 CR Clarification on HARQ-ACK transmission	F	13.2.0	R1#86	R1-167936	CATT	LTE_CA_enh_b5c
36.213	720	1	Rel-13	Correction for UL grant size in RAR	F	13.2.0	R1#86	R1-168513	Ericsson, Sequans Communications	LTE_MTCe2_L1-Core
36.213	721	2	Rel-13	MBSFN subframes and SIB2 decoding	F	13.2.0	R1#86	R1-168437	Qualcomm Incorporated	LTE_MTCe2_L1-Core
36.213	722	1	Rel-13	Overriding of invalid subframe for msg3 PUSCH when R=1	F	13.2.0	R1#86	R1-168424	Nokia, Alcatel-Lucent Shanghai Bell	LTE_MTCe2_L1-Core
36.213	723	-	Rel-13	On the mapping of TPC command field to power correction values in TS 36.213	F	13.2.0	R1#86	R1-168156	Huawei, HiSilicon	LTE_MTCe2_L1-Core
36.213	724	-	Rel-13	Correction on the MPDCCH scheduling Paging in special subframe in TS 36.213	F	13.2.0	R1#86	R1-168158	Huawei, HiSilicon	LTE_MTCe2_L1-Core
36.213	725	1	Rel-13	Clarification of valid subframe in eMTC	F	13.2.0	R1#86	R1-168213	Panasonic	LTE_MTCe2_L1-Core
36.213	726	-	Rel-13	Quasi-colocation of NB-IoT antenna ports	F	13.2.0	R1#86	R1-168237	Panasonic, Huawei, HiSilicon	NB_IOT-Core

Petitioners' Exhibit 1003, p. 1027
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

TS	CR	Rev	Rel	Title	Cat	Vsn	@ Mtg	TD#	Source to WG	Work Item
36.213	728	1	Rel-13	PUCCH resource allocation	F	13.2.0	R1#86	R1-168519	Qualcomm Incorporated	LTE_MTCe2_L1-Core
36.213	729	1	Rel-13	RV version for PDSCH carrying paging	F	13.2.0	R1#86	R1-168399	Nokia, Alcatel-Lucent Shanghai Bell	LTE_MTCe2_L1-Core
36.213	730	-	Rel-13	Missing definition of higher layer parameter eutra-CRS-SequenceInfo	F	13.2.0	R1#86	R1-168374	NEC, Ericsson	NB_IoT-Core
36.213	731	-	Rel-13	PUSCH timing delay for NB-IoT	F	13.2.0	R1#86	R1-168375	Qualcomm Incorporated	NB_IOT-Core
36.213	732	-	Rel-13	Draft CR on RV Cycling for PUSCH and PDSCH	F	13.2.0	R1#86	R1-168450	Samsung	LTE_MTCe2_L1-Core
36.213	734	-	Rel-13	Clarification of scheduling delay	F	13.2.0	R1#86	R1-168496	ZTE	NB_IoT-Core
36.213	736	-	Rel-13	Clarification on MPDCCH monitoring on SFN rollover and search space overlap	F	13.2.0	R1#86	R1-168509	Qualcomm Incorporated	LTE_MTCe2_L1-Core
36.213	737	-	Rel-13	PUCCH transmission and invalid subframes	F	13.2.0	R1#86	R1-168521	Qualcomm Incorporated	LTE_MTCe2_L1-Core
36.213	738	-	Rel-13	SRS bit in DCI	F	13.2.0	R1#86	R1-168535	Qualcomm Incorporated	LTE_MTCe2_L1-Core
36.213	739	-	Rel-13	Clarification of NB-IoT DL subframe configuration	F	13.2.0	R1#86	R1-168539	Huawei, HiSilicon	NB_IOT-Core
36.213	740	1	Rel-13	Correction on FD-MIMO codebooks	F	13.2.0	R1#86	R1-168544	Qualcomm Incoporated	LTE_EBF_FDMIMO-Core
36.213	741	-	Rel-13	CR on LAA post transmission backoff	F	13.2.0	R1#86	R1-168555	Broadcom Limited	LTE_LAA-Core
36.214	34	-	Rel-12	Correction to the Beacon RSSI definition	F	12.2.0	R1#86	R1-167547	Nokia, Intel, Alcatel-Lucent Shanghai Bell, Qualcomm Incorporated, Ericsson	UTRA_LTE_WLAN_interw-Core
36.214	35	-	Rel-13	Correction to the WLAN RSSI definition	F	13.2.0	R1#86	R1-167549	Nokia, Intel, Alcatel-Lucent Shanghai Bell, Qualcomm Incorporated, Ericsson	LTE_WLAN_radio-Core
36.214	36	-	Rel-13	Correction on NRS port number mapping	F	13.2.0	R1#86	R1-168199	Huawei, HiSilicon, Pansonic, Samsung	NB_IOT-Core
36.214	37	-	Rel-13	Correction on NRSRQ applicability	F	13.2.0	R1#86	R1-168296	Huawei, HiSilicon	NB_IOT-Core

TS	CR	Rev	Rel	Title	Cat	Vsn	@ Mtg	TD#	Source to WG	Work Item
38.900	2	1	Rel-14	Definitions, symbols and abbreviations in section 3 of TR38.900	F	14.0.0	R1#86	R1-168001	Huawei, HiSilicon, Fraunhofer HHI, Ericsson, Samsung	FS_6GHz_CH_model
38.900	4	2	Rel-14	Clarifications and corrections to fast fading model in Sections 7.5 and 7.6 of TR38.900	F	14.0.0	R1#86	R1-168023	Huawei, HiSilicon, Fraunhofer HHI, Ericsson, Samsung, Intel Corporation	FS_6GHz_CH_model
38.900	9	-	Rel-14	Correction to the TDL-E and CDL-E	F	14.0.0	R1#86	R1-167237	Huawei, HiSilicon	FS_6GHz_CH_model
38.900	12	-	Rel-14	CR for capturing large-scale and full-scale calibration results	F	14.0.0	R1#86	R1-167579	Samsung	FS_6GHz_CH_model

Petitioners' Exhibit 1003, p. 1028
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

TS	CR	Rev	Rel	Title	Cat	Vsn	@ Mtg	TD#	Source to WG	Work Item
38.900	13	1	Rel-14	CR for TR38.900 for editorials and minor corrections	F	14.0.0	R1#86	R1-168477	Samsung	FS_6GHz_CH_model
38.900	14	1	Rel-14	TR38.900_CR_Section_6	F	14.0.0	R1#86	R1-168003	Fraunhofer HHI	FS_6GHz_CH_model
38.900	15	1	Rel-14	TR38.900_CR_Section_7.1	F	14.0.0	R1#86	R1-168004	Fraunhofer HHI	FS_6GHz_CH_model
38.900	16	-	Rel-14	TR38.900_CR_Section_7.2	F	14.0.0	R1#86	R1-167811	Fraunhofer HHI	FS_6GHz_CH_model
38.900	17	1	Rel-14	TR38.900_CR_Section_7.3	F	14.0.0	R1#86	R1-168005	Fraunhofer HHI	FS_6GHz_CH_model
38.900	19	-	Rel-14	Correction to UMi O2I delay spread	F	14.0.0	R1#86	R1-167481	Ericsson	FS_6GHz_CH_model
38.900	20	-	Rel-14	Correction for spatial consistency of indoor distance	F	14.0.0	R1#86	R1-167480	Ericsson	FS_6GHz_CH_model
38.900	22	1	Rel-14	Correction for RMa shadow fading	F	14.0.0	R1#86	R1-168021	Ericsson, Fraunhofer HHI	FS_6GHz_CH_model
38.900	23	-	Rel-14	Correction to MIMO extension of TDLs	F	14.0.0	R1#86	R1-167477	Ericsson	FS_6GHz_CH_model
38.900	24	-	Rel-14	Correction for mean ZOA	F	14.0.0	R1#86	R1-167476	Ericsson	FS_6GHz_CH_model
38.900	25	1	Rel-14	Correction for K-factor scaling of TDL models	F	14.0.0	R1#86	R1-168017	Ericsson, Huawei	FS_6GHz_CH_model
38.900	26	1	Rel-14	Correction for Doppler spectrum of TDLs	F	14.0.0	R1#86	R1-168014	Ericsson,Fraunhofer HHI, Huawei	FS_6GHz_CH_model
38.900	27	-	Rel-14	TR38.900_CR_Section_7.4	F	14.0.0	R1#86	R1-167818	Fraunhofer HHI	FS_6GHz_CH_model
38.900	29	1	Rel-14	TR38.900_CR_Section_7.6.2.1	F	14.0.0	R1#86	R1-168010	Fraunhofer HHI, Huawei, HiSilicon, Samsung, Ericsson, Intel Corporation	FS_6GHz_CH_model
38.900	30	1	Rel-14	TR38.900_CR_Section_7.6.2.2	F	14.0.0	R1#86	R1-167920	Fraunhofer HHI, Huawei, HiSilicon, NEC	FS_6GHz_CH_model
38.900	31	2	Rel-14	TR38.900_CR_Section_7.6.3	F	14.0.0	R1#86	R1-168012	Fraunhofer HHI, Ericsson, Huawei, HiSilicon, Samsung, Intel Corporation	FS_6GHz_CH_model
38.900	32	2	Rel-14	TR38.900_CR_Section_7.6.4	F	14.0.0	R1#86	R1-168329	Intel Corporation, Fraunhofer HHI, Ericsson, Samsung, Qualcomm, Nokia, Alcatel-Lucent Shanghai Bell, Huawei, HiSilicon, InterDigital	FS_6GHz_CH_model
38.900	33	-	Rel-14	TR38.900_CR_Section_7.7.3	D	14.0.0	R1#86	R1-167830	Fraunhofer HHI	FS_6GHz_CH_model
38.900	34	2	Rel-14	TR38.900_CR_Section_7.7.4	F	14.0.0	R1#86	R1-168016	Fraunhofer HHI, Ericsson	FS_6GHz_CH_model
38.900	35	1	Rel-14	TR38.900_CR_Section_7.7.5	F	14.0.0	R1#86	R1-167919	Fraunhofer HHI	FS_6GHz_CH_model
38.900	36	3	Rel-14	TR38.900_CR_Section_8.4	F	14.0.0	R1#86	R1-168022	Fraunhofer HHI, Ericsson, ZTE Corp, ZTE Microelectronics	FS_6GHz_CH_model

Petitioners' Exhibit 1003, p. 1029
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

TS	CR	Rev	Rel	Title	Cat	Vsn	@ Mtg	TD#	Source to WG	Work Item
38.900	37	2	Rel-14	TR38.900_CR_Section_7.6.6	F	14.0.0	R1#86	R1-168330	Intel Corporation, Fraunhofer HHI, Ericsson, Samsung	FS_6GHz_CH_model
38.900	38	2	Rel-14	Applicability of TR38.900	F	14.0.0	R1#86	R1-168159	Huawei, HiSilicon, Ericsson, Telecom Italia, Fraunhofer HHI	FS_6GHz_CH_model
38.900	39	-	Rel-14	TR38.900_CR_Consistent_Equation_Numbering	D	14.0.0	R1#86	R1-168153	Fraunhofer HHI, CATT, Huawei, HiSilicon, Ericsson	FS_6GHz_CH_model
38.900	40		Rel-14	Corrections on spatial consistency across floors in TR 38.900	F	14.0.0	R1#86	R1-168013	ZTE Corporation, ZTE Microelectronics	FS_6GHz_CH_model
38.900	41		Rel-14	CR on Oxygen Absorption	F	14.0.0	R1#86	R1-168009	CATT, Fraunhofer HHI, Huawei, HiSilicon, Ericsson	FS_6GHz_CH_model
38.900	42	-	Rel-14	CR on spatially consistent random variable clarification in TR38.900	F	14.0.0	R1#86	R1-168478	Samsung	FS_6GHz_CH_model
38.900	43	-	Rel-14	CR on delay scaling parameters in LLS channel model in TR38.900	F	14.0.0	R1#86	R1-168479	Samsung	FS_6GHz_CH_model
38.900	44	-	Rel-14	Correction on Calibration Simulation Assumption in TR38.900	F	14.0.0	R1#86	R1-168480	Samsung	FS_6GHz_CH_model

Petitioners' Exhibit 1003, p. 1030
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Annex C-1: List of Outgoing LSs from RAN1 #86

TDoc #	Title	Source	Release	Related WIs	Reply to	To	Cc	Original LS	Reply in
R1-167914	Reply LS for clarification on MIMO capability	RAN1, Huawei	Rel-10	TEI10	R1-166073	RAN2			
R1-167916	Reply LS on Network Assistance for Network Synchronization in LTE	RAN1, Huawei	Rel-14	FS_LTE_NW_SYNC	R1-166085	RAN3, RAN	RAN4		
R1-167917	LS on Parameters for WP5D sharing and compatibility studies	RAN1, NTT DOCOMO	Rel-14	FS_NR_newRAT		RAN4			
R1-168026	LS on RAN1 agreements for LTE-based V2X	RAN1, LGE	Rel-14	LTE_V2X-Core		RAN2, RAN3, SA2			
R1-168030	LS on Updates on HS-SCCH DRx Feature in Cell Fach	RAN1, Qualcomm	Rel-14	FACH_DTXDRX-Core		RAN2			
R1-168037	LS to RAN2/3 on RAN1 progress on MC enhancements	RAN1, Huawei	Rel-14	UTRA_MCe		RAN2, RAN3			
R1-168214	LS on RAN1 agreements for NR initial access and mobility	RAN1, Ericsson	Rel-14	FS_NR_newRAT		RAN2			
R1-168250	LS on Timing Offset Indication for V2V	RAN1, Ericsson	Rel-14	LTE_SL_V2V-Core		RAN2	RAN4		
R1-168251	LS on RAN1 agreements in sidelink-based V2V	RAN1, LGE	Rel-14	LTE_SL_V2V-Core		RAN2, RAN3, RAN4			
R1-168252	LS on L1 parameters for sidelink-based V2V	RAN1, LGE	Rel-14	LTE_SL_V2V-Core		RAN2			
R1-168256	Reply LS on VoLTE and video quality related enhancements	RAN1, CMCC	Rel-14	FS_LTE_eVoLTE	R1-166075	RAN2			
R1-168258	LS on NR waveform	RAN1, Huawei	Rel-14	FS_NR_newRAT		RAN4			
R1-168300	LS regarding agreements for FeMTC	RAN1, Qualcomm, Huawei	Rel-14	LTE_feMTC-Core		RAN4, RAN2			
R1-168346	LS on further RRC Parameters for Enhanced LAA for LTE	RAN1, Huawei	Rel-14	LTE_eLAA-Core		RAN2			
R1-168377	LS on introducing 1.2Gbps and 1.6Gbps UE categories in Rel-13	RAN1, Huawei	Rel-13	TEI13		RAN, RAN2			
R1-168425	LS to RAN2 regarding valid MBSFN subframes for eMTC	Qualcomm Incorporated	Rel-13	LTE_MTCe2_L1-Core		RAN2			
R1-168459	LS on introduction of new UL categories in Rel-13	RAN1, Qualcomm	Rel-13	TEI13		RAN2, RAN			
R1-168460	LS on introduction of new UL categories in Rel-14	RAN1, Qualcomm	Rel-14	LTE_UL_CAP_enh-Core		RAN2, RAN			
R1-168497	LS on nrs-Power signaling for NB-IoT non-anchor carrier	RAN1, ZTE	Rel-13	NB_IOT-Core		RAN2	RAN4		
R1-168528	Reply LS on RAN2 Agreements on Skipping Uplink Transmission	RAN1, Nokia	Rel-14	LTE_LATRED_L2-Core		RAN2			
R1-168553	LS on NB-IoT positioning	RAN1, Huawei	Rel-14	NB_IOTenh-Core		RAN	RAN2, RAN3, RAN4		

Petitioners' Exhibit 1003, p. 1031
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

TDoc #	Title	Source	Release	Related WIs	Reply to	To	Cc	Original LS	Reply in
R1-168554	LS regarding agreement on paging for NB-IoT	RAN1, Qualcomm	Rel-14	NB_IOTenh-Core		RAN2			
R1-168556	LS on SRS Carrier-Based Switching	RAN1, Huawei	Rel-14	LTE_SRS_switch-Core		RAN2, RAN4			
R1-168557	LS on PRS sequence generation per TP	RAN1, Huawei	Rel-14	UTRA_LTE_iPos_enh2-Core		RAN2, RAN3			
R1-168558	LS on PRS-based Terrestrial Beacon System (TBS)	RAN1, Qualcomm	Rel-14	UTRA_LTE_iPos_enh2-Core		RAN2, RAN3	RAN4		
R1-168559	LS on introducing a new special subframe configuration	RAN1, CMCC	Rel-14	LTE_UL_CAP_enh-Core		RAN2, RAN3			

Petitioners' Exhibit 1003, p. 1032
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Annex C-2: List of Incoming LSs from RAN1 #86

TDoc #	Title	Source	Release	Related WIs	Reply to	To	Cc	Original LS	Reply in
R1-166058	Updated characteristics of terrestrial IMT systems for frequency sharing / interference analysis in the frequency range between 24.25 GHz and 86 GHz	ITU-R WP5D	Rel-14	FS_NR_newRAT		RAN1, RAN4, RAN		LS_EOs_5D_234_temp_112R1	
R1-166059	MODELLING AND SIMULATION OF IMT NETWORKS FOR USE IN SHARING AND COMPATIBILITY STUDIES	ITU-R WP5D	Rel-14	-		RAN1, RAN4, RAN		LS_EOs_5D_234_temp_125R1	
R1-166060	LS to RAN1 on RAN2 agreements related to V2X	RAN2, LGE	Rel-14	FS_LTE_V2X		RAN1		R2-164373	
R1-166061	Reply LS on questions on NB-IOT	CT1, Nokia	Rel-13	NB_IOT-Core, CIoT-CT	R3-161032	RAN3, RAN2, SA2	RAN1, CT4	C1-162926	
R1-166062	LS to RAN1 on SPS	RAN2, LGE	Rel-14	LTE_SL_V2V-Core		RAN1		R2-164359	
R1-166063	LS on V2V transmission path selection	RAN2, Huawei	Rel-14	LTE_SL_V2V-Core		SA2, RAN1, RAN3		R2-164356	
R1-166064	INCREASING LEVELS OF RF NOISE IN THE ENVIRONMENT AND CONSEQUENT INTERFERENCE TO RADIOCOMMUNICATION SERVICES	ITU-R WP 1A	-	-		RAN1, RAN4		ITU-R WP 1A/TEMP/26 (14 June 2016)	
R1-166065	LS on 5G millimeter wave channel simulator	NYU WIRELESS	Rel-14	-		RAN1	RAN	LS_from_NYU_Wireless on NYUSIM (3)	
R1-166066	Long Term Evolution in Operation in Unlicensed Spectrum Must Not Interfere with Wi-Fi	City of Madison (Office of the Mayor of)	Rel-13	LTE_LAA-Core		RAN, RAN1	FCC Office of Engineering & Technologies, FCC Wireless Telecommunications Bureau, WiFi Alliance, IEEE 802, Councel of the Mayor of NYC	NYC LTE-U Letter	
R1-166067	LS on RAN2 aspects on MC enhancements	RAN2, Huawei	Rel-14	FS_UTRA_MCe		RAN1	RAN3	R2-164352	
R1-166068	Reply LS on EPC procedures for providing eNB with V2X authorization information	RAN2, LGE	Rel-14	FS_LTE_V2X	S2-162248	SA2	RAN1, RAN3, SA1	R2-164498	
R1-166069	LS on HARQ process selection for UL asynchronous HARQ	RAN2, Huawei	Rel-13	LTE_MTCe2_L1-Core, LTE_eLAA-Core		RAN1		R2-164538	

Petitioners' Exhibit 1003, p. 1033
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

TDoc #	Title	Source	Release	Related WIs	Reply to	To	Cc	Original LS	Reply in
R1-166070	LS to RAN1 on WLAN RSSI	RAN2, Nokia	Rel-13	LTE_WLAN_radio-Core		RAN1	RAN4	R2-164548	
R1-166071	LS to RAN1 on RAN2 agreements on skipping Uplink transmission	RAN2, Nokia	Rel-14	LTE_LATRED_L2-Core		RAN1		R2-164554	
R1-166072	LS to RAN1 on agreed TPs	RAN2, LGE	Rel-14	FS_LTE_V2X		RAN1		R2-164558	
R1-166073	LS to RAN1 on clarification on MIMO capability	RAN2, Huawei	Rel-10	TEI10		RAN1		R2-164559	R1-167906
R1-166074	LS on the evaluation of simultaneous transmission and reception	RAN2, ZTE	Rel-14	LTE_eMob-Core		RAN1, RAN4		R2-164565	
R1-166075	LS on VoLTE and video quality related enhancements	RAN2, Ericsson	Rel-14	FS_LTE_eVoLTE		RAN1		R2-164566	
R1-166076	LS on Multi-carrier enhancements	RAN3, Huawei	Rel-14	FS_UTRA_MCe		RAN1	RAN2	R3-161516	
R1-166077	Reply LS on Formation of IEEE 1914 Next Generation Fronthaul Interface Working Group	RAN3, Intel	Rel-14	FS_NR_newRAT	201604 LS IEEE1914 to 3GPP	IEEE 1914	RAN1, RAN2, RAN	R3-161538	
R1-166078	Response LS on the feasibility of mobility enhancement solutions	RAN3, ZTE	Rel-14	LTE_eMob-Core	R2-163135	RAN2	RAN1, RAN4	R3-161542	
R1-166079	LS on Characteristics of terrestrial IMT systems for frequency sharing/interference analysis in the frequency range between 24.25 GHz and 86 GHz	RAN4, Nokia	Rel-14	FS_NR_newRAT		RAN	RAN1	R4-164527	
R1-166080	Reply LS on the feasibility of mobility enhancement solutions	RAN4, ZTE	Rel-14	LTE_eMob-Core	R2-163135	RAN2	RAN1, RAN3	R4-164906	
R1-166081	LS on continuous uplink transmission in eMTC	RAN4, Intel	Rel-13	LTE_MTCe2_L1-Core		RAN1, RAN2		R4-164928	
R1-166082	Reply LS on V2V multicarrier configuration	RAN4, LGE, Ericsson	Rel-14	LTE_SL_V2V-Core	R1-163746	RAN1, RAN2		R4-164930	
R1-166083	Response to Wi-Fi Alliance comments on "Way forward on coexistence tests for LAA"	RAN4, Qualcomm, Ericsson	Rel-13	LTE_LAA-Core		Wi-Fi Alliance	RAN, RAN1	R4-164972	
R1-166084	Reply LS on SRS carrier switching interruption time	RAN4, Huawei	Rel-14	LTE_SRS_switch-Core	R1-163453	RAN1		R4-164974	
R1-166085	LS on Network Assistance for Network Synchronization in LTE	RAN, Huawei	Rel-14	FS_LTE_NW_SYNC		RAN4, RAN1	RAN3	RP-161262	
R1-166086	LS on 256QAM support for UE Category 9/10 from Rel-12	RAN, Intel	Rel-12	LTE_SC_enh_L1-Core		RAN1, RAN2		RP-161327	
R1-166087	LS on 5G NR study – mMTC use case	RAN, MediaTek	Rel-14	FS_NR_newRAT		RAN1		RP-161333	
R1-167878	LS on V2V Authorization	RAN3, Huawei	Rel-14	LTE_SL_V2V-Core		SA2, CT4	RAN2, RAN1, SA1	R3-161540	
R1-167879	Reply LS to ITU-R WP5D/TEMP/39(Rev.2) = RP-	RAN, Nokia	Rel-14	FS_NR_newRAT	R1-163390	ITU-R WP5D	RAN1, RAN4	RP-161056	

Petitioners' Exhibit 1003, p. 1034
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

TDoc #	Title	Source	Release	Related WIs	Reply to	To	Cc	Original LS	Reply in
	160508 on Characteristics of terrestrial IMT systems for frequency sharing/interference analysis in the frequency range between 24.25 GHz and 86 GHz								
R1-167880	Reply LS on Rel-13 LAA specifications	RAN, Qualcomm, NTT DOCOMO	Rel-13	LTE_LAA-Core	R1-165449	IEEE 802 LMSC	RAN1, RAN4, IEEE 802 19 Coexistence WG	RP-161228	
R1-167881	Response to Liaison Statement on coexistence simulation results for DL only LAA	Wi-Fi Alliance	Rel-13	LTE_LAA-Core	R1-161396	RAN1		20160811 Response to 3GPP LS on coexistence simulation results for DL only	
R1-167882	Proposal for Improved RMa model and upgraded open source channel simulator	NYU Wireless	Rel-14	FS_NR_newRAT		RAN1	RAN	LS_from_NYU_Wireless on Proposed Improved Rma model	
R1-167908	Review of 3GPP LAA Specification Rel. 13	IEEE 802 LMSC	Rel-13	LTE_LAA-Core		RAN1	RAN	802 to 3GPP 01AUG2016 liaison	
R1-167928	LS on CSI measurement ambiguity in LAA	RAN4, LGE	Rel-13	LTE_LAA-Perf		RAN1		R4-165659	
R1-168089	LS on Multi-Carrier enhancements	RAN2, Huawei	Rel-14	UTRA_MCe		RAN1		R2-165744	
R1-168126	Response LS to Priority for V2V	RAN2, LGE	Rel-14	LTE_SL_V2V-Core	R1-165814	RAN1	SA2	R2-165765	
R1-168340	LS on applicability of NRSRQ measurement	RAN4, Huawei	Rel-13	NB_IOT-Perf		RAN1	RAN2	R4-166696	
R1-168520	LS on Support of CAT 9/10 and CAT 13	RAN2, Intel	Rel-12	TEI12		RAN1			

Petitioners' Exhibit 1003, p. 1035
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Annex D: List of Approved updated WIDs

None

Petitioners' Exhibit 1003, p. 1036
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Annex E: List of draft TSs/TRs agreed at RAN1 #86

Tdoc Number	Title	Source	Conclusion/Decision
R1-168526	TR 38.802 V0.1.0 Study on New Radio (NR) Access Technology - Physical Layer Aspects	NTT DOCOMO, INC.	Endorsed

Petitioners' Exhibit 1003, p. 1037
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Annex F: List of actions

- **Outgoing LS.**

[86-21] Asbjorn (Ericsson)
LS to RAN2 about NE initial access and mobility
Email approval until 1st September to tell the current RAN1 agreements and WA to RAN2
Done: Final LS is agreed in R1-168214 as per Mr Chair's decision posted on Sept 2nd.

- **CR approval**

[86-01] Bob (Motorola Mobility)
R1-167507 Addition of LTE_LATRED_L2-Core Ericsson LM
CR0709 of 36.213 is for email approval until Sept 12th.
Done: CR0709r2 to 36.213 is in R1-168228 as per Mr Chair's decision posted on Sept 13th.

[86-02] Suzuki (Panasonic)
R1-167434 Clarification of valid subframe in eMTC Panasonic Corporation
Email discussion/approval until Sep. 1st
Done: CR0725r1 to 36.213 is agreed in R1-168213 as per Mr Chair's decision posted on Sept 2nd.

[86-03] Johan (Ericsson)
R1-168549 PUCCH retuning with puncturing for BL/CE UE Ericsson, Qualcomm, NEC, NTT DoCoMo
Email approval until Sept 2nd
Done: CR0286 to 36.211 is agreed per Mr Chair's decision posted on Sept 3rd.

[86-04] Editors
Editors will provide updated eLAA CRs including the agreements and WA until Sept 6th , for email approval until Sept 12th
Rapporteur will provide agreement lists until August 29th.
Done: Agreements list was provided as R1-168210 by rapporteur (Ericsson). The set of agreed CRs are listed below:

R1-168220	**Introduction of eLAA (PHY layer aspects) in 36.213**	**Motorola Mobility**	**Rel-14**	**36.213**	**13.2.0**	**LTE_eLAA-Core**	**CR0742**	**B**	
R1-168221	**Introduction of eLAA (UL Channel Access Procedure) in 36.213**	**Motorola Mobility**	**Rel-14**	**36.213**	**13.2.0**	**LTE_eLAA-Core**	**CR0743**	**B**	
R1-168222	**Introduction of eLAA**	**Ericsson**	**Rel-14**	**36.211**	**13.2.0**	**LTE_eLAA-Core**	**CR0266r2**	**B**	
R1-168225	**Introduction of eLAA into 36.212**	**HuaWei Technologies Co., Ltd**	**Rel-14**	**36.212**	**13.2.0**	**LTE_eLAA-Core**	**CR0218**	**B**	**RP-161571**
R1-168457	**Introduction of eLAA into 36.201**	**Nokia**	**Rel-14**	**36.201**	**13.2.0**	**LTE_eLAA-Core**	**CR0015**	**B**	**RP-161571**

Petitioners' Exhibit 1003, p. 1038
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

R1-168560 Introduction of eLAA (UL Channel Access Procedure) in 36.213 Motorola Mobility Rel-14 36.213 13.2.0 LTE_eLAA-Core CR0743r1 B

[86-05] Editors
Editors will provide updated V2V CRs including the agreements and WA until Sept 6th , for email approval until Sept 12th
Rapporteur will provide agreement lists until August 29th.
Done: Agreements list was provided as R1-168217 by rapporteur (LGE). The set of agreed CRs are listed below:

R1-168201	**Introduction of V2V**	**Nokia**	**Rel-14**	**36.201**	**13.2.0**	**LTE_SL_V2V-Core**	**CR0016r1**	**B**
R1-168223	**Introduction of V2V support**	**Ericsson**	**Rel-14**	**36.211**	**13.2.0**	**LTE_SL_V2V-Core**	**CR0267r2**	**B**
R1-168224	**Introduction of V2V into TS36.212**	**HuaWei Technologies Co., Ltd**	**Rel-14**	**36.212**	**13.2.0**	**LTE_SL_V2V-Core**	**CR0217**	**B**
R1-168226	**Introduction of V2V into TS36.213**	**Motorola Mobility**	**Rel-14**	**36.213**	**13.2.0**	**LTE_SL_V2V-Core**	**CR0744**	**B**
R1-168227	**Introduction of V2V support**	**Ericsson**	**Rel-14**	**36.214**	**13.2.0**	**LTE_SL_V2V-Core**	**CR0038r1**	**B**

[86-40] Harish (Qualcomm)
R1-167814 Introduction of HS-SCCH Order for HS-SCCH DRx feature in enhanced Cell Fach Qualcomm Europe Inc.(France)
R1-167815 UE Procedures for HS-SCCH DRx feature in enhanced Cell Fach Qualcomm Europe Inc.(France)
Email discussion until Sept 9th. on Qualcomm CRs.
Done: Clean versions of both CRs (revision of CR0343 to 25.212 and revision of CR0756 to 25.214) were agreed, according to Mr Chair's email posted on Sept 12th. It was also agreed by all companies that these CRs could wait until the end of the WI - December 2016 acc. to the draft SR to RAN#73. Therefore the approval of these CRs is postponed to RAN#74.

- **Text proposal for TS and TR**

None

- **Miscellaneous**

[86-06] Philippe (Huawei)
Following the agreements on step 2 of resource (re)-selection, the threshold values in brackets (-128 dBm, 0 dBm and 2 dB) need to be finalized for V2V.
Email discussion until Sept. 2nd on the numbers in the brackets
Done: As per Mr Chair's decision posted on Sept 3rd, the following is agreed

- **The threshold per subcarrier is in a range (-136…-38) dBm/15kHz with 2dB steps**
- **The threshold configuration is 6bits coded**

[86-07] Hanbyul (LGE)
Energy measurement in each sub-channel for V2V
Email discussion until 2nd September

Petitioners' Exhibit 1003, p. 1039
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Done: As per Mr Chair's decision posted on Sept 3rd, the following is agreed for S-RSSI definition:

- **Sidelink RSSI (S-RSSI) is defined as the linear average of the total received power (in [W]) per SC-FDMA symbol observed only in the configured sub-channel in the SC-FDMA symbols #1, #2, …, #12 by the UE.**
- **The reference point for the S-RSSI shall be the antenna connector of the UE.**
- **If receiver diversity is in use by the UE, the reported value shall not be lower than the corresponding S-RSSI of any of the individual diversity branches.**

[86-08] Stefano (Ericsson)
R1-168348 **WF on CBR measurement – Ericsson**
Email discussion until Sept 2nd
Done: As per Mr Chair's decision posted on Sept 3rd, there is no consensus to define a CBR measurement. Revisit at next meeting.

[86-09] Stefano (Ericsson)
R1-168080 **WF on V2V congestion control - Ericsson**
Email discussion until Sept 2nd
Done: As per Mr Chair's decision posted on Sept 3rd, there is no consensus to define details of the congestion control framework of V2V. Revisit at next meeting, if needed.

[86-10] Hanbyul (LGE)
Candidate size for V2V for email discussion until Sept 2nd
Done: As per Mr Chair's decision posted on Sept 3rd, the following is agreed:

- **The candidate size of a sub-channel is {4,5,6,8,9,10,12,15,16,18,20,30,48,72,96} for SA-data non-adjacent case.**

[86-11] Shailesh (Qualcomm)
DCI for V2V for email discussion to finalize the square-bracketed figure and FFS until Sept 2nd
Done: As per Mr Chair's decision posted on Sept 3rd, the following is agreed:
DCI X for all BW
Let k be the number of sub-channels configured on the resource pool of a sub-carrier

- **CIF : 3 bits**
- **Lowest index of sub-channel allocation ceil(log2(k)) = 0 to 5 bits**
- **Time gap between tx and retx 4 bits**
- **Frequency resource of initial and last tx ceil(log2(k*(k+1)/2) = 0 to 8 bits**

If the number of information bits in V2V DCI format mapped onto a given search space is less than the payload size of format 0 mapped onto the same search space, zeros shall be appended to V2V DCI format until the payload size equals that of format 0 including any padding bits appended to format 0.

[86-12] Philippe (Huawei)

Petitioners' Exhibit 1003, p. 1040
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

SCI contents for V2V
Email discussion until Sept 2nd to confirm the working assumption and square-bracketed figures, and the details of joint encoding of frequency location of the other transmission and number of subchannels
Done: As per Mr Chair's decision posted on Sept 7th, the following is agreed:

- **Fixed size of 48 for the SCI**
- **For frequency RA, copy the frequency RA field from DCI and pad it to 8 bits.**
- **All other aspects (e.g., DMRS randomization) FFS to be addressed at next meeting including how to set the padding bits in frequency RA.**

[86-13] Hanbyul (LGE)
PSD offset for V2V for email approval until Sept.1st
Done: According to Mr Chair's email dated on Sept 2nd, the PSD offset is fixed to [3] dB in specifications.
Note that exact fixed value can be discussed in the next meeting by seeing more evaluation results and analysis.

[86-14] Mark (Ericsson)
Antenna Port Layouts for FD-MIMO for email discussion until the next meeting
Done: Status to be checked at RAN1#86bis.

[86-15] Yi (Huawei)
SLS baseline for NR MA for email discussion on any other potential parameters until Sept.2nd
Done: According to Mr Chair's email dated on Sept 3rd, the following clarifications are agreed:

Attributes	**Agreed** values or assumptions	**Further clarifications**
Waveform	CP-OFDM as the UL waveform • UL DMRS overhead, 1 OFDM symbol out of 7 OFDM symbols	**Summary**: no change to the existing agreements.
Resource allocation	A UE selects a MA physical resource randomly from a pool of orthogonal MA physical resources • There is no partial overlapping between the MA physical resources selected by more than one UE • All orthogonal MA physical resources are of same size	Total allocated bandwidth: 6RB, 4RB (optional) for calibration purpose only, • Companies are encouraged to provide calibration results for both values, • Either value can be used for later evaluation of the proposed MA scheme
		Bandwidth per user per transmission: 1 RB
Receiver	MMSE, assuming realistic channel estimation • No blind decoding assumed	MMSE-IRC, assuming ideal channel estimation for calibration purpose only • 2Rx • No blind decoding assumed
MCS	Same for all Ues • MCS is reported by each company	Same for all UEs, • Derived by the bandwidth per user of 1 RB and TB size of 160 bits per transmission • QPSK is assumed
Power control	Open loop power control • Alpha=1, P0= -90 dBm	**Summary**: no change to the existing agreements. A few companies share different views. This power control setting for evaluation can be discussed later.
Packet size	Fixed by 20 bytes	TB size with CRC included

Petitioners' Exhibit 1003, p. 1041
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

HARQ retransmission		No. of transmission is 1 (i.e., no repetition or retransmission)
Traffic model		FTP 3 with fixed TB size
Average no. of users per sector		20 assuming 3 sectors/cell, total 57 sectors
Channel code		LTE Turbo
Any other potential parameters		**Summary**: how to present the results for calibration/comparison can be discussed later.

[86-16] Yi (Huawei)
Templates for NR MA
Huawei will provide the initial template for preliminary simulation results summary by 9th Sept, and email discussion about this template by 16th Sep
Done: According to Mr Chair's email dated on Sept 20th , clean versions of the proposed templates (for UL & DL NR MA preliminary LLS results – for UL & DL NR MA preliminary SLS results) are agreed.

[86-17] Yi (Huawei)
SLS calibration for NR MA for email discussion until Sept 16th.
Done: Status to be checked at RAN1#86bis.

[86-18] Yifei (ZTE)
Categorization for NR MA schemes for email discussion until the next meeting
Done: Status to be checked at RAN1#86bis.

[86-19] Joseph (Qualcomm)
Use cases discussion for time domain structure for NR for email discussion Sept 15th.
Done: Summary to be submitted at RAN1#86bis.

[86-20] Ruyue (ZTE)
MIMO calibration for NR for email discussion until Sept 8th.
Done: Summary to be submitted at RAN1#86bis.

[86-22] Kazuaki (NTT DOCOMO)
Target packet drop rate for NR
Email discussion on the two options of the packet size and clarification on Target packet drop rate
as listed in R1-168510 until Sept. 1st
Done: According to Mr Chair's email dated on Sept 3rd, the following clarifications are agreed:

- **Packet size**
  - **Observation : There is no consensus on which option to use. Each company would need to report the option used,. but are encouraged to evaluate both options. Decide on which option(s) is used to draw the conclusion of MA at RAN1#86bis meeting**

Petitioners' Exhibit 1003, p. 1042
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

  - **Proposal 1**
    - **Option 1: Follow TR45.820**
    - **Option 2: Fix 40 Bytes**
- **Target packet drop rate**
  - **Proposal 2: Packet drop rate = (Number of packet in outage) / (number of generated packets), where a packet is in outage if this packet failed to be successfully received by destination receiver beyond "Packet dropping timer"**
  - **Proposal 3: Companies report HARQ/retransmission assumption.**
  - **Proposal 4: Companies are encouraged to provide CDF of packet drop rate per UE.**

[86-23] Martin (Sony)
Battery lifetime model for NR for email discussion on battery lifetime model in R1-168485 until the next meeting
Not Done: According to Mr Chair's email dated on Sept 28th, further to RAN#73 last plenary decision, mMTC related discussion is postponed until next March 2017, and therefore this email discussion is suspended.

[86-24] Wu Yong (Huawei)
Traffic model for NR for email discussion on traffic model for urban coverage for massive connection (UL) (until Sept 15th)
Done: According to Mr Chair's email dated on Sept 29th, the following traffic model assumption is agreed for connection density evaluation, and not for coverage nor battery life evaluation.

- **Packet size**
  - **Follow proposal1 of [86-22] (proposal on packet size). Companies report which option(s) is used.**
- **Packet arrival rate**
  - **Poisson packet arrival for each device, with arrival rate l.**
  - **Proponents are encouraged to report**
    - **What packet arrival rate (l) could be supported to achieve the connection density target, when packet arrival rate is assumed to be larger than what is assumed in TR45.820.**
    - **What connection density can be supported, when packet arrival rate is assumed the same as in TR45.820.**

[86-25] Haitong (Qualcomm)
Path loss calibration for NR
Email discussion for path loss calibration for 3D UMa at carrier frequency of 700 MHz until Sept 9th.
Done: According to Mr Chair's email dated on Sept 12th, the pathloss calibration results will be compiled and presented as input to next meeting.

[86-26] Young-Han (Samsung)
R1-168537 **WF on Dense Urban scenarios** **Samsung, Ericsson, Intel, Nokia, ASB, AT&T, CMCC, Softbank, Verizon, KT, Vodafone, Deutsche Telecom**

- Include the 30GHz band in the macro layer for the carrier frequency of dense urban scenario in Table A.2.1-1 in TR38.802

Email approval until Sept 8th

Petitioners' Exhibit 1003, p. 1043
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Done: According to Mr Chair's email dated on Sept 12th, R1-168537 is agreed.

[86-27] Na (NTT DOCOMO)
R1-168421 **WF on Indoor TRP Configuration NTT DOCOMO, CATT, Ericsson, Intel**
Email discussion until Sept 2nd
Done: According to Mr Chair's email dated on Sept 13th, the following is agreed:

- **Adopt deployment ceiling mounted TRP:**
  - **Option 1 (baseline at least for calibration): Boresight direction is perpendicular to the ceiling. Antenna model is taken from alternative 3 in R1-165850 (90 degree HPBW in Azimuth and zenith).**
    - **The number of sites is 3 and 12. Placement of 12 sites is the same as TR 38.900. Placement of 3 sites is according to Figure 1.**
    - **Antenna array baseline configuration:**
      - **(M,N,P,Mg,Ng) = (4, 4, 2, 1, 1) , d_H = d_V = 0.5 lambda for 4GHz**
      - **(M,N,P,Mg,Ng) = (4, 8, 2, 1, 1) , d_H = d_V = 0.5 lambda for 30GHz**
      - **(M,N,P,Mg,Ng) = (8, 16, 2, 1, 1), d_H = d_V = 0.5 lambda for 70 GHz**

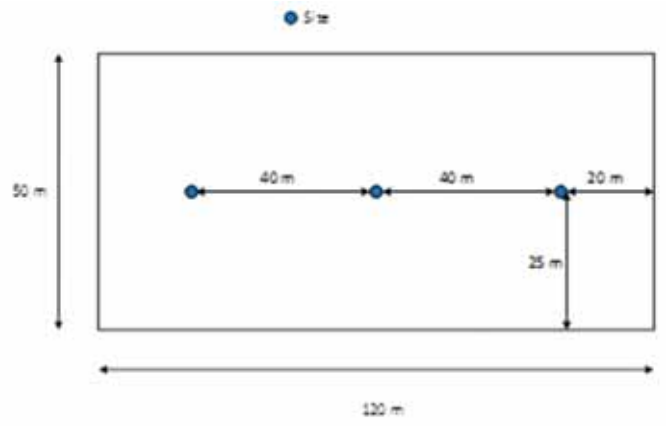


Figure 1: 3-site deployment of indoor TRPs.

  - **Option 2: Three sectors (example below). Antenna model is taken from alternative 2 in R1-165850 (65 degree HPBW in Azimuth and zenith).**

Petitioners' Exhibit 1003, p. 1044
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121



- **Used antenna tilt should be reported by each company.**
- **The number of sites is 3 and 12. Placement of 12 sites is the same as TR 38.900. Placement of 3 sites is according to Figure 1.**
- **Antenna array baseline configuration:**
  - **Same as Option 1**
- **Boresight direction is according to TR 38.900**

- **Option 3 : Boresight direction is perpendicular to the ceiling. Omni antenna model is applied for 4 GHz.**
  - **The number of sites is 3 and 12. Placement of 12 sites is the same as TR 38.900. Placement of 3 sites is according to Figure 1.**
  - **Antenna array baseline configuration:**
    - **(M,N,P,Mg,Ng) = (1, 1, 2, 1, 1) for 4GHz.**
- **Indoor TRP transmission power and various interference management schemes can be further studied when TRP density is high, e.g., 12 or 36.**

[86-28] Young-Han (Samsung)
Additional feature calibration for channel model
Email discussion until 30th September to collect calibration data for additional features
Done: Summary to be submitted at RAN1#86bis.

Petitioners' Exhibit 1003, p. 1045
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Annex G: List of participants at RAN1 #86

Please see excel file attached to this report

Petitioners' Exhibit 1003, p. 1046
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Annex H: **TSG RAN WG1 meetings in 2016 – 2017**

TITLE	TYPE	DATES	LOCATION	CTRY
3GPPRAN1#86bis	WG	10 – 14 Oct 2016	Lisbon	Portugal
3GPPRAN1#87	WG	14 – 18 Nov 2016	Reno	US
3GPPRAN1-NR	AH	16 – 20 Jan 2017	TBD	US
3GPPRAN1#88	WG	13 – 17 Feb 2017	Athens	Greece
3GPPRAN1#88bis	WG	03 – 07 Apr 2017	TBD	US
3GPPRAN1#89	WG	15 – 19 May 2017	TBD	China
3GPPRAN1-NR	AH	27 – 30 Jun 2017	TBD	TBD
3GPPRAN1#90	WG	21 – 25 Aug 2017	Prague (TBC)	Rep Czech
3GPPRAN1#90bis	WG	09 – 13 Oct 2017	Prague (TBC)	Rep Czech
3GPPRAN1#91	WG	27 Nov – 01 Dec 2017	TBD	US

MEETING TYPES	
AH = Ad Hoc	CM = Chairmen's meeting
JM = Joint	OR = Ordinary
PM = Preparatory Meeting	RG = Rapporteurs Group
RM = Resolution Meeting	SG = Steering Group
ST = Startup Meeting	TG = Task Group
WG = Working Group	XO = Extraordinary

End of document

Petitioners' Exhibit 1003, p. 1047
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

APPENDIX 5

3GPP TSG-RAN WG2 Meeting #93bis **R2-162366**
Dubrovnik, Croatia, 11 - 15 April 2016

Agenda item: **9.6**

Source: **Nokia, Alcatel-Lucent Shanghai Bell**

Title: **Beam Forming Impacts**

SID: **FS_NR_newRAT - Release 14**

Document for: **Discussion and Decision**

1 Introduction

A new study item was agreed at RAN#71 that aims to develop a New Radio Access Technology (NR) [1]. In the study item document, key requirements were listed and it was proposed that NR system should be able to use frequency bands up to 100 GHz. To compensate the increased path loss of higher frequency bands, the need for beam forming was identified. In this contribution we propose to include the study of potential impacts of common channel beam forming on Layer 2 protocols and procedures design.

2 Discussion

The effect of higher frequencies on coverage and the compensation of path loss by using multiple narrow beams for downlink common channels are illustrated on Figure 1. In lower frequency bands (e.g. current LTE bands < 6GHz) the required cell coverage may be provided by forming a wide sector beam for transmitting downlink common channels. However, utilizing wide sector beam on higher frequencies (>> 6GHz) the cell coverage is reduced with same antenna gain. Thus, in order provide required cell coverage on higher frequency bands, higher antenna gain is needed to compensate the increased path loss. To increase the antenna gain over a wide sector beam, larger antenna arrays (number of antenna elements ranging from tens to hundreds) are used to form high gain beams.

As a consequence the high gain beams are narrow compared to a wide sector beam so multiple beams for transmitting downlink common channels are needed to cover the required cell area. The number of concurrent high gain beams that access point is able to form may be limited by the cost and complexity of the utilized transceiver architecture. In practice, on higher frequencies, the number of concurrent high gain beams is much less than the total number of beams required to cover the cell area. In other words, the access point is able to cover only part of the cell area by using a subset of beams at any given time.

Petitioners' Exhibit 1003, p. 1049
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

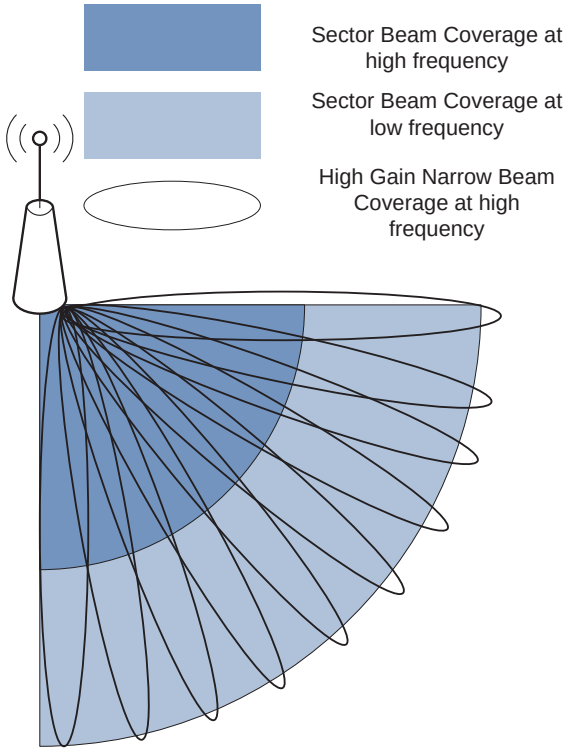


Figure 1. Illustration of providing cell coverage with sector beams and multiple high gain narrow beams

In DL, common channels including synchronization signals, system information and paging will be sweeping across beams to cover the entire cell area. In UL, reception of random access channel (RACH) will also be impacted by the presence of beams. Thus, RAN2 should study the impact of beamforming when designing and defining NR L2 protocols and procedures.

Proposal 1: RAN2 should study the potential impact of beam formed common control plane and beam forming in general on NR Layer 2 procedures and protocol design

Beam formed common control plane may also have an impact to UE mobility. Due to the need for potentially multiple narrow beams to cover a cell area UE may move from coverage area of one beam to another beam inside the cell *the impact of so-called beam level mobility* and its visibility to Layer 2 and Layer 3 should be studied. Furthermore it should be also studied how the beam forming affects inter-cell mobility procedures

Proposal 2: RAN2 should study the potential impact of beam formed common control plane and beam forming in general on the NR mobility and its visibility to Layer 2

3 Conclusion

Proposal 1: RAN2 should study the potential impact of beam formed common control plane and beam forming in general on NR Layer 2 procedures and protocol design

Proposal 2: RAN2 should study the potential impact of beam formed common control plane and beam forming in general on the NR mobility and its visibility to Layer 2

References

[1] RP-160671, New SID Proposal: Study on New Radio Access Technology, NTT DOCOMO

[2] 3GPP TR 38.913, Study on Scenarios and Requirements for Next Generation Access Technologies

APPENDIX 6

3GPP TSG RAN WG1 Meeting #86 **R1-166519**
Gothenburg, Sweden, 22 - 26 Aug 2016

Source: **Intel Corporation**
Title: **Performance comparison of CDM-4 and CDM-8 for CSI-RS**
Agenda item: **7.2.4.1.1**
Document for: **Discussion and Decision**

1 Introduction

In the RAN#71 meeting a Rel-14 work item on Enhancements on Full-Dimension MIMO for LTE was approved [1]. One of the objectives defined in the work item is to specify enhancements for the NZP CSI-RS reference signals to support up to 32 antenna ports. In the RAN # 85, it was concluded to further study the benefits of OCC8 for Rel-14 CSI-RS.

Conclusion:

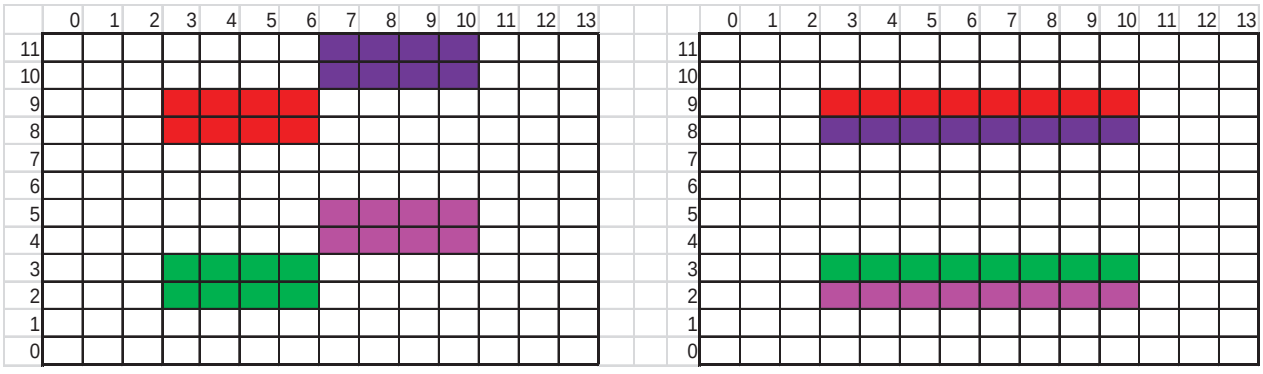
- Further discussion till RAN1#86, especially regarding evaluating different alternatives, e.g., using OCC 2/4/8, high reuse of CSI-RS, etc.

In this contribution we provide comparison of CSI-RS with OCC-4 and OCC-8 and provide views on the possible support of OCC-8 in DL subframes.

2 Discussion

2.1 Support of higher order OCC

In Rel-13 the OCC-4 was introduced to support full power utilization for CSI-RS transmission. The OCC-4 spreading is applied to 4 CSI-RS antenna ports within the same CSI-RS resource. For Rel-14 NZP CSI-RS resource the issue of the full power utilization should be also considered by extending the existing OCC-4 spreading to OCC-8. Comparing to Rel-13 NZP CSI-RS design, to avoid the power boosting above 6dB, the OCC-8 spreading should be applied across the two or more aggregated CSI-RS resources to provide CSI-RS antenna port transmission at least across 4 OFDM symbols. Figure 1 shows an example of the OCC mapping within a sub-frame, where one colour corresponds to the 8 multiplexed CSI-RS antenna ports using OCC-8 codes. In Figure 1a, the OCC spreading is applied across 4 OFDM symbols and 2 adjacent subcarriers, while in Figure 1b across 8 OFDM symbols. Note that the CSI-RS resources used in the Figure-1 are not compatible with the legacy UE's CSI-RS resources.



(a) (b)

Figure 1: Examples of OCC-8 mapping across 2 or 4 CSI-RS resources

Petitioners' Exhibit 1003, p. 1053
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

In Figure-2, we show another example of multiplexing 8 ports using OCC-8, where the OCC spreading is applied across 4 OFDM symbols and 2 adjacent subcarriers. One colour corresponds to the 8 multiplexed CSI-RS antenna ports using OCC-8 codes. The resources used in the Figure-2 are compatible with the legacy UE's CSI-RS resources.

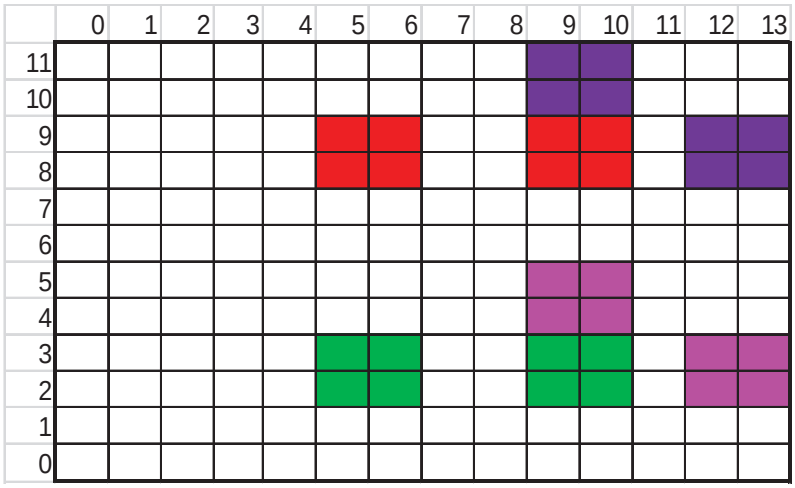


Figure 2: Example of OCC-8 mapping across 2 sub-carriers and 4 OFDM symbols, that is compatible with the Rel-13 CSI-RS resource elements.

To evaluate the performance benefits of OCC-8 the link-level evaluations were carried out for PDSCH throughput. The realistic channel measurement on NZP CSI-RS with 32 antenna ports, using the CSI-RS configuration of Figure-2, was used for CSI feedback. The maximum power boosting for NZP CSI-RS was set to 6dB which gives 3dB power advantage for CSI-RS with OCC-8 comparing to OCC-4. The PDSCH throughput performance vs SNR is provided in Figure 2. It can be seen the performance advantage of OCC-8 can be observed for MCS corresponding to 16QAM R = 1/2 and below, while limited gains has been observed for the higher MCS value (16QAM R=3/4). The higher performance gains for low MCS can be explained by the limited channel accuracy provided by OCC-4 processing.

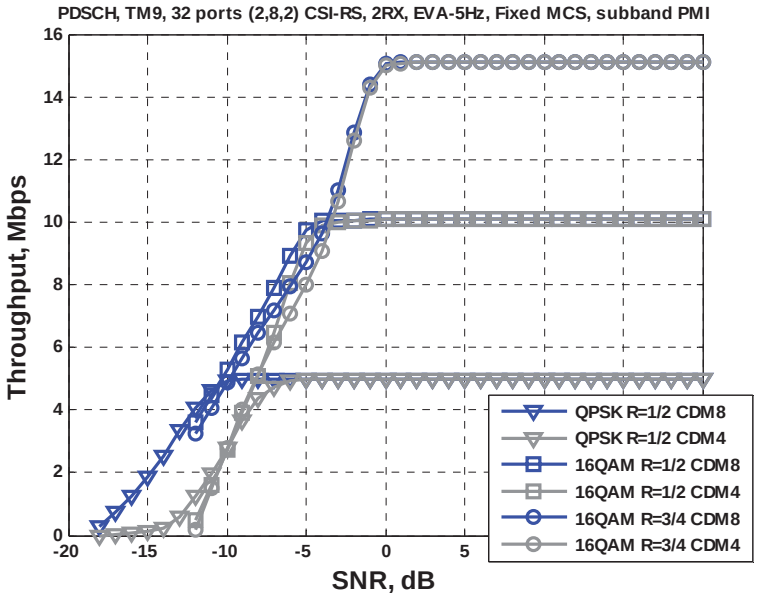


Figure 2: Performance comparison of PDSCH throughput relying on CSI feedback calculated on NZP CSI-RS with OCC-8 and OCC-4

Petitioners' Exhibit 1003, p. 1054
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Summarizing the discussion above the following proposal can be made:

Proposal:

- *To achieve full power utilization consider OCC-8 for Rel-14 NZP CSI-RS resource with up to 32 antenna ports. The OCC-8 spreading can be applied in the time domain only or in both time and frequency domains.*
- *The legacy UE's CSI-RS resources can be used to support OCC-8 for up to 32 ports, where the OCC spreading is applied across 4 OFDM symbols and 2 adjacent subcarriers.*

2.4 Additional CSI-RS resource elements

In Rel-10 CSI-RS signals were designed in such way to avoid possible collision with other reference signals such as CRS. More specifically the OFDM symbols used for CSI-RS are different from the OFDM symbols used for CRS transmission. Such design assumption for CSI-RS perfectly avoids the collision with CRS for any CRS shift. For Rel-14 timeframe, it is expected that most of the devices would be already capable of DM-RS support for at least TM9. Therefore, the CRS transmission in every downlink subframe would not be critical from the system perspective. Under given assumption and to reduce the overhead associated with simultaneous CRS and DM-RS transmission, the CRS-free subframes (e.g. MBSFN subframes) should be also considered as realistic assumption for the networks supporting Rel-14 FD-MIMO. For such subframes, the additional resource elements of the downlink subframe can be released for CSI-RS transmission to increase the number of CSI-RS configurations. More specifically, the OFDM symbol 3,4 and 7,8 may be considered as possible candidate symbols for Rel-14 NZP CSI-RS transmission (see Figure 5). Introduction of the additional REs for NZP CSI-RS would provide easier way to support OCC-8 and therefore should be considered for specification.

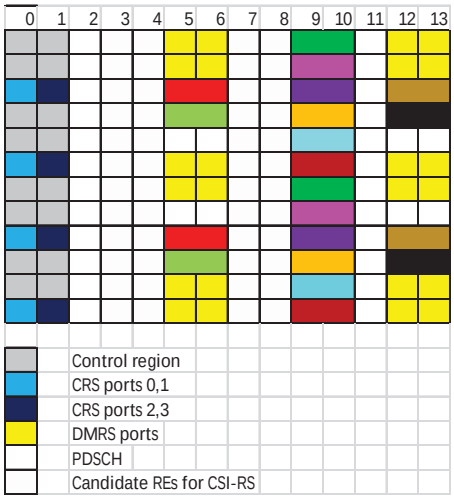


Figure 5: Candidate CSI-RS resource elements for Rel-14 specification

Proposal:

For Rel-14 NZP CSI-RS, consider additional resource elements for CSI-RS transmission assuming CRS-less subframes (e.g. MBSFN subframes)

Petitioners' Exhibit 1003, p. 1055
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Summary

In this contribution we have provided comparison of CSI-RS with OCC-4 and OCC-8 and provide views on the possible support of OCC-8 in the DL subframes. The following proposals were made:

Proposals:

- *To achieve power utilization consider OCC-8 for Rel-14 NZP CSI-RS resource with up to 32 antenna ports. The OCC-8 spreading can be applied in the time domain only or in both time and frequency domains.*
- *The legacy UE's CSI-RS resources can be used to support OCC-8 for up to 32 ports, where the OCC spreading is applied across 4 OFDM symbols and 2 adjacent subcarriers.*
- *For Rel-14 NZP CSI-RS, consider additional resource elements for CSI-RS transmission assuming CRS-less subframes (e.g. MBSFN subframes)*

References

[1] RP-160623, "New WID Proposal: Enhancements on Full-Dimension (FD) MIMO for LTE," Samsung, 3GPP TSG RAN Meeting #71, Göteborg, Sweden, March 7 - 10, 2016.

[2] Chairman's notes, RAN1#85, 3GPP TSG RAN WG1 Meeting #85, Nanjing, China 23rd - 27th May 2016.

Petitioners' Exhibit 1003, p. 1056
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

APPENDIX 7

3GPP TSG RAN WG1 Meeting #86 **R1-166439**
Gothenburg, Sweden, August 22nd-26th, 2016

Source: **CATT**
Title: **CSI-RS design for {20,24,28,32} ports**
Agenda Item: **7.2.4.1.1**
Document for: **Discussion and Decision**

---

1. Introduction

In RAN#71, the work item on further full-dimension MIMO (FD-MIMO) enhancement has been approved [1]. The objective of reference signal enhancement for non-precoded CSI-RS is:

- *Non-precoded CSI-RS, extending the existing numbers {1, 2, 4, 8, 12, 16} of CSI-RS antenna ports for support of {20, 24, 28, 32} CSI-RS ports with mechanism for reducing the overhead for CSI-RS transmission*

The following agreements about the CSI-RS enhancement have been achieved in RAN1#85:

Agreement:
- For {20, 24, 28, 32} ports, a CSI-RS resource for class A CSI reporting is aggregated as follows (where M_k is the # of CSI-RS ports in a CSI-RS configuration)
  - For {24, 32} ports, $\sum_k M_k \in \{24, 32\}$, M_k is either 4 or 8, where the same $M_k = M$ used for all k
    - Possible down-selection till RAN1#86 regarding M_k=4 vs. 8
  - For {20, 28} ports, FFS till RAN1#86 (including possible down-selection)
    - Alt 1: $\sum_k M_k \in \{20, 28\}$, M_k is either 4 or 8, where the same $M_k = M$ used for all k
      - Possible down-selection till RAN1#86 regarding M_k=4 vs. 8.
      - If M_k=8 is supported, FFS the details
    - Alt 2: $\sum_k M_k \in \{20, 28\}$, $M_k \in \{4, 8\}$, where M_k may be different for different k
  - FFS port numbering
  - FFS N vs. M

This contribution presents our views on CSI-RS design for {20,24,28,32} ports.

2. Discussion

According to the above agreement, the {20, 24, 28, 32} ports CSI-RS is aggregated by *K* CSI-RS configurations. For {24, 32} ports, the same M_k is used for all k, whereas for {20, 28} ports, one alternative is to use different M_k for different k. If this CSI-RS configuration is allowed in Rel-14, there are two possibilities when CDM is considered:

1) Inherit CDM from Rel-13 for each M_k. Then in case of CDM-4, the RE patterns per port are different, since the CDM group is different for M_k=4 (non-adjacent REs in the frequency domain) and M_k=8 (adjacent REs in the frequency domain) in Rel-13. In this way, the channel estimation of each port may be inconsistent.
2) Redesign CDM for Rel-14 CSI-RS. One consideration of using different M_k is to support port sharing with Rel-13 and Rel-12 UEs. Such target will not be achieved if CDM in Rel-14 is redesigned,

Thus, the same principle as Rel-13, i.e. the same M_k is used for all k, should be maintained.

Proposal:

- *Same M_k shall be used for all k for {20, 24, 28, 32} ports.*

The number of REs in the kth configuration M_k determines the aggregation flexibility. However reliable CSI-RS coverage is also required since the CSI-RS transmit power impacts pilot estimation accuracy and CSI accuracy. For non-precoded CSI-RS, the power of each CSI-RS port decreases linearly as the antenna port number increases, e.g. for 24, 32 ports CSI-RS, each CSI-RS port can utilize 1/24, 1/32 of the total power with 24/32 TXRUs. Therefore, the CSI-RS coverage issue is more important for FD-MIMO with increased port number. CSI-RS power boosting could alleviate this issue. But there is a maximum 6dB CSI-RS boosting limitation enforced by practical implementation constraints based on RAN4 inputs [3]. If the 6dB power-boosting restriction is not relaxed, the full-power utilization will not be achieved for 20 ports and above with either CDM-2 or CDM-4. Regarding backward compatibility, the port sharing with Rel-12/13 UEs will severely compromise coverage of the legacy UE.

In the following, the impact of non-full power utilization to both legacy Rel-12 UE and Rel-14 UE through system level simulations is evaluated. We assume there are 50% Rel-14 UE with 32 ports and 50% Rel-12 UE with 8 ports in the system. Two transmission schemes are compared:

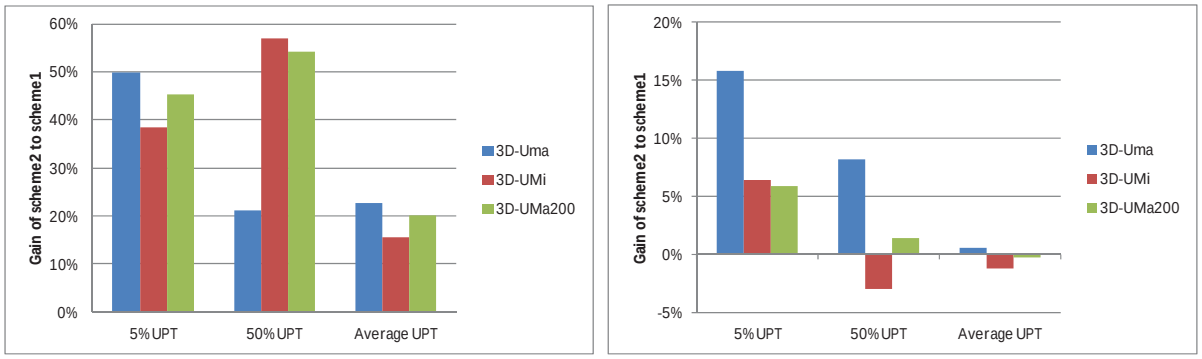
Scheme 1: Port sharing between Rel-12 and Rel-14 UEs with CDM-2. In this scheme, one 32 port Class A CSI-RS resource is configured in a cell for Rel-14 UE, and Rel-12 UE is configured with K=4 8 ports CSI-RS resources. These 8 port CSI-RS resources share the same 32 port CSI-RS resource, i.e. the 32 port CSI-RS resource is divided into 4 groups, which results in 8 port of each group. Because of the port sharing, there is 6dB CSI-RS power loss compared with individual CSI-RS transmission for Rel-12 UEs.

Scheme 2: Full power utilization for both Rel-12 and Rel-14 UEs. In this scheme, separate CSI-RS resources are configured for Rel-12 UE and Rel-14 UE. For Rel-14 UE, one CDM-8 32 port Class A CSI-RS resource is configured. For Rel-12 UE, K=4 beamformed CDM-2 CSI-RS resources are configured. Each resource has 8 ports, which is beamformed on 32 TXRUs.

In the simulation, the CSI-RS channel estimation error is modeled as below. The estimated channel $\tilde{H}$ is expressed as:

$$\tilde{H} = \alpha(H + E)$$

where H is the perfect channel response in frequency domain, E is the white complex Gaussian variables with zero mean and variance σ^2, α is the scaling factor to maintain proper normalization, which is expressed by $\alpha = \sqrt{\frac{1}{1+\sigma^2}}$. The value of σ^2 is inversely proportional to the SINR of CSI-RS, and is calculated by $\sigma^2 = \frac{1}{SINR_{RS} \times \Delta}$. Here Δ is a factor reflecting the processing gain of channel estimation algorithm, which is acquired from link level simulation. SU-MIMO and rank adaptive (up to rank 2) transmission for each UE are assumed. FTP traffic with the user arrival rate $\lambda = 2$ under 3D-UMa and 3D-UMi are simulated and the detailed simulation parameters are given in the appendix Table A1. We compare these two schemes assuming CSI-RS collides with the other cells' PDSCH. The simulation results are individually summarized for Rel-12 and Rel-14 UEs as given in the appendix Table A2-3. To be intuitive, Figure 1 depicts the gain of scheme2 over scheme1.



(a) Rel-12 UE (b) Rel-14 UE

Figure 1: Performance comparison between port sharing and full power utilization

From Figure 1(a), for Rel-12 UE, scheme 2 achieves significant throughput gain (up to 57%) due to full power utilization. This means the 6dB CSI-RS power reduction severely influences the system performance, which is more than the meager gain due to CSI-RS overhead reduction from CSI-RS sharing between Rel-12 and Rel-14 UEs. Hence, sharing CSI-RS between legacy UE and Rel-14 UE is not justifiable from the system performance point of view. For Rel-14 UE, according to Figure 1(b), CDM-8 based scheme 2 also shows up to 15% gain compared to the non-full power scheme 1. These results prove that full power utilization is beneficial to improve the system performance.

Observations:

- *Port sharing between Rel-12 UE and Rel-14 UE will severely compromise coverage of the legacy UE.*
- *With full power utilization, there is significant throughput gain both for legacy UE and Rel-14 UE.*

Full-power utilization is important to retain the competitiveness of non-precoded CSI-RS against beamformed CSI-RS, otherwise the system may simply use beamformed CSI-RS instead. Due to such reason, CDM-8 should be introduced for non-precoded CSI-RS above 16 ports. One possible CDM-8 CSI-RS mapping pattern is shown in Figure 2. One CDM RE set (labeled by the same letter) is constructed by the combination of 4 TDM REs (OFDM symbol 5,6 of slot 0 and slot 1) and 4 TDM/FDM REs (OFDM symbol 2,3 of slot 1). Length-8 Walsh codes can be applied across the 8 REs. Compared with the CDM-4 8-ports pattern used in Rel-13 16 ports CSI-RS, the proposed CDM-8 pattern could both achieve full-power utilization and guarantee equal power-boosting for each antenna port.

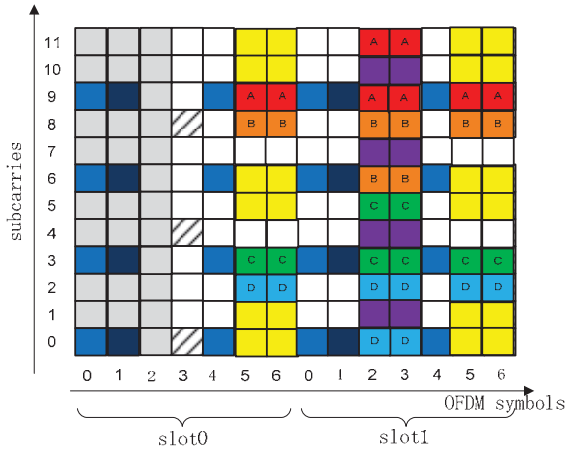


Figure 2: CDM-8 RE set construction

According to the above pattern design, (*M*,*K*)=(8,3) and (*M*,*K*)=(8,4) are used for 24 ports CSI-RS and 32 ports CSI-RS aggregation, respectively. The CDM-8 pattern is also applicable to 20 and 28 ports CSI-RS with (*M*,*K*)=(8,4). In this way, *L* antenna ports are multiplexed within a CDM group using OCC=8 sequences. The other *M*-*L* antenna ports within each CDM group could be set to be zero power. For 20 ports CSI-RS, *L*=5 and for 28 ports CSI-RS, *L*=7. Although a total of 32 REs are used for 20 and 28 ports CSI-RS, the throughput gain from full power utilization will be much more significant than the minor overhead increase. Furthermore, it is possible to decrease the CSI-RS density to be less than 1RE/PRB/port if combined with potential CSI-RS overhead reduction in the frequency domain.

Proposal:

- *Introduce CDM-8 to achieve full-power utilization with 6 dB power-boosting.*

3. Conclusions

In this contribution we presented our views on CSI-RS enhancement. Besides CSI-RS aggregation, the coverage issue is also investigated through system level simulations. The evaluation results prove that full power utilization is beneficial to improve the system performance. We have the following proposals:

Observations:

- *Port sharing between Rel-12 UE and Rel-14 UE will severely compromise coverage of the legacy UE.*
- *With full power utilization, there is significant throughput gain both for legacy UE and Rel-14 UE.*

Proposals:

- *Same M_k shall be used for all k for {20, 24, 28, 32} ports.*
- *Introduce CDM-8 to achieve full-power utilization with 6 dB power-boosting.*

References

[1] RP-160623, “New WID proposal: Enhancement of Full-Dimension (FD) MIMO for LTE,” Gothenburg, Sweden, March 7-10, 2016

[2] R1-157710, “WF on FD-MIMO CSI-RS”, Samsung, Ericsson, NTT DOCOMO, Intel, AT&T, CHTTL, Fraunhofer HHI, ITRI, Qualcomm, Nokia Networks, ITL, ALU, ASB, Panasonic, Fujitsu, LGE, DT, China Telecom, Anaheim, US, 16th - 20th November 2015

[3] R4-102236, “Reply LS on CSI RS boosting impact on BS transmission distortion”, Montreal, Canada, May 10th –14th, 2010

Appendix

Table A1: Simulation assumptions

Parameter	Value
Antenna configuration	Horizontal: X-pol (+/-45), 0.5λ space

	Vertical: 0.8λ space (M,N,P,Q)=(8,4,2,32) for 8H4V
Scenario	3D-UMi with 200m ISD, 3D-UMa with 500m and 200m ISD
System bandwidth	10MHz (50RBs)
Carrier frequency	2GHz
UE distribution	Follows 36.873 3D-UMa, 3D-UMi
UE speed	3km/h
Model of cross polarization	36.814
Traffic model	Full buffer model, FTP traffic model 1, lamda=2
Rank adaptive	SU, rank adaptive
Scheduling algorithm	PF
Receiver	Realistic channel estimation Realistic interference estimation
	MMSE-IRC receiver
HARQ	Max 4 transmissions
CSI feedback	PUSCH 3-2
	CQI, PMI reporting triggered per 10ms
Wrapping method	Geographical distance based
Handover margin	3 dB
CSI-RS planning	CSI-RS collides with other cells' PDSCH reuse factor = 1 without muting

Table A2: Rel-12 UE, FTP traffic model, $\lambda = 2$

Scenarios		5% UPT (Mbps)	5% UPT Gain	50% UPT (Mbps)	50% UPT Gain	Mean UPT (Mbps)	Mean UPT Gain	RU
3D-UMa	Scheme 1	6.71	0.00%	25.59	0.00%	28.27	0.00%	23%
	Scheme 2	10.06	49.93%	31.01	21.18%	34.68	22.66%	19%
3D-UMi	Scheme 1	11.15	0.00%	28.93	0.00%	34.77	0.00%	18%
	Scheme 2	15.43	38.41%	45.43	57.03%	40.21	15.64%	15%
3D-UMa (ISD=200m)	Scheme 1	11.11	0.00%	28.68	0.00%	33.01	0.00%	18%
	Scheme 2	16.15	45.37%	44.18	54.05%	39.69	20.23%	15%

Table A3: Rel-14 UE, FTP traffic model, $\lambda = 2$

Scenarios		5% UPT (Mbps)	5% UPT Gain	50% UPT (Mbps)	50% UPT Gain	Mean UPT (Mbps)	Mean UPT Gain	RU
3D-UMa	Scheme 1	11.52	0.00%	31.39	0.00%	35.88	0.00%	23%
	Scheme 2	13.33	15.77%	33.95	8.17%	36.09	0.58%	19%
3D-UMi	Scheme 1	15.47	0.00%	47.53	0.00%	41.05	0.00%	18%
	Scheme 2	16.46	6.34%	46.08	-3.05%	40.55	-1.22%	15%
3D-UMa (ISD=200m)	Scheme 1	15.70	0.00%	43.60	0.00%	40.00	0.00%	18%
	Scheme 2	16.63	5.88%	44.18	1.34%	39.89	-0.26%	15%

APPENDIX 8

3GPP TSG-RAN WG2 #93bis **Tdoc R2-162762**
Dubrovnik, Croatia, 11 – 15 April 2016

Agenda Item: **9.5.3**

Source: **Ericsson**

Title: **Active Mode Mobility in NR: SINR drops in higher frequencies**

Document for: **Discussion, Decision**

1 Introduction

Overall requirements for the Next Generation (NG) architecture [1] and, more specifically the NG Access Technology [2] will impact the design of the Active Mode Mobility solutions for the new RAT (NR) [3] compared to the current mobility solution in LTE. Some of these requirements are the need to support network energy efficiency mechanisms, future-proofness and the need to support a very wide range of frequencies (up to 100 GHz [3] [4]).

Energy efficiency and future proofness have been addressed in [5] where an initial analysis is provided focusing on the design of reference signal(s) and mechanisms associated with RRM measurements.

This contribution provides an initial analysis of the requirement that NR needs to support a wide range of frequencies, including very high frequencies (up to 100 GHz) and its impact to the design of active mode mobility. One of the main differences comes from the fact that propagation in frequencies above the ones allocated to LTE is more challenging so that the massive usage of beamforming becomes an essential component of NR.

2 Discussion

2.1 Introduction

To support long-term traffic demands and to enable the very wide transmission bandwidths needed for multi-Gb/s data rates (20 Gbps for downlink and 10 Gbps for uplink [2]), NR should be able to use any spectrum band up to 100 GHz that may be made available for wireless communications even in a more distant future [3]. In comparison to the current frequency bands allocated to LTE, some of the new bands will have much more challenging propagation properties such as lower diffraction and higher outdoor/indoor penetration losses. As a consequence signals will have less ability to propagate around corners and penetrate walls. In addition, in high frequency bands atmospheric/rain attenuation and higher body losses render the coverage of NR signals even more spotty [5].



Figure 1 Impairments associated to propagation in higher frequencies

Fortunately, the operation in higher frequencies makes it possible to use smaller antenna elements, which enables antenna arrays with many antenna elements. Such antenna arrays facilitate beamforming, where multiple antenna elements are used to form narrow beams and thereby compensate for the challenging propagation properties.

Petitioners' Exhibit 1003, p. 1063
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Observation 1 **The extensive use of beamforming, in particular at the network side, will be an essential part of the NR design for high frequency carriers**

Beamforming in higher frequencies will lead to some challenges to the design of active mode mobility in NR. Some of these challenges are discussed in the following.

2.2 Sudden SINR drops in higher frequencies

Despite the link budget gains provided by beamforming solutions, reliability of a system purely relying on beamforming and operating in higher frequencies might be challenging, since the coverage might be more sensitive to both time and space variations. As a consequence of that the SINR of that narrow link can drop much quicker than in the case of LTE.

Using antenna arrays at access nodes with the number of elements in the hundreds, fairly regular grid-of-beams coverage patterns with tens or hundreds of candidate beams per node may be created. The coverage area of an individual beam from such array may be small, down to the order of some tens of meters in width. As a consequence, channel quality degradation outside the current serving beam area is quicker than in the case of wide area coverage, as provided by LTE.

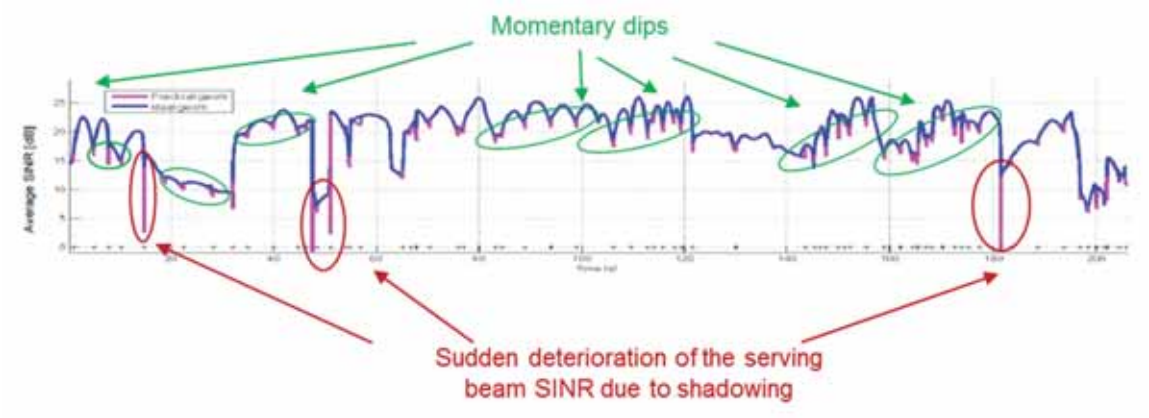


Figure 2 Quick SINR drops due to high frequency propagation phenomena

Figure 2 shows an example of average SINR variations along a UE route in a deployment employing a large-array grid of beams in a 15 GHz carrier frequency. An *optimal beam selection* scheme is compared with a *simplified measurement-based scheme* based on an estimated SINR and reference signals transmitted over 6 PRBs and 1 subframe (equivalent to 144 samples). The comparison of the simplified measurement-based scheme to the optimal serving beam choice shows some momentary dips below the optimal performance (It has also been observed that the SINR distributions are hardly affected by these dips at most vehicular speeds). On the other hand, we see also some deeper dips that indicate a sudden deterioration of the serving beam SINR due to shadowing, e.g. in “around the corner” situations. The serving beam SIR may drop by over 20 dB within 5-10ms. Further results have also shown that these occasional drops will be unavoidable at 10-30 GHz.

Infrequent interruptions due to low SINR occurrences may not be critical for the User Plane (UP) flows. However, Control Plane (CP) flows transmitted over these beams might be carrying mobility related signalling such as transmission of measurement reports and reception of handover commands which might lead to many error cases, leading to high handover failures and radio link problems.

Proposal 1 **Active mode mobility in NR should be designed to avoid and/or quickly react to sudden SINR drops due to beamforming in higher frequencies**

In order to handle this issue, different aspects should be considered. A first aspect that needs to be studied is the design of **mobility reference signals (MRSs) and its configurations** used for link quality monitoring (for the serving beam) and neighbour link measurements and **UE reporting mechanisms**. Differently from LTE, these reference signals need to be designed to possibly be beamformed in wide and/or narrow beams. Assuming a network based approach as a baseline (as in LTE) the UE should be capable of synchronize and detect this signal(s) from neighbour beams(s), report some indication to the network (e.g. absolute or relative neighbour beam quality/measurements) in order to get some sort of mobility command from the serving beam to the UE so the UE can synchronize and access the target selected beam before the sudden SINR drop occurs. The delay of this kind of procedure should be studied and alternatives should be considered (e.g. UL-

Petitioners' Exhibit 1003, p. 1064
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

based measurement procedures relying on UL sounding signals) for both intra-node beam mobility and inter-node beam mobility should be studied.



Figure 3 Beam-centric mobility and multi-connectivity

Multi-connectivity in NR for mobility robustness

According to [2] the NR architecture shall support connectivity through multiple transmission points, either collocated or non-collocated. In a beam-centric design, relying on multiple NR beams, possibly from multiple nodes (with the qualities of beams uncorrelated) could be a way to improve robustness and avoid the react on sudden SINR degradation in many different ways such as

- Control Plane (CP) diversity to improve mobility robustness;
- UP/CP split where the beam where CP measures are carried is anchored in wide beams, possibly in low frequency carriers.

The way these solutions could be realized, e.g. on which protocol layers is FFSs.

Proposal 2 Multi-connectivity mechanisms such as CP diversity and UP/CP split should be considered to address sudden SINR drops

It is also stated in [2] that the RAN architecture shall support tight interworking between the NR and LTE including high performing inter-RAT mobility and multi-RAT aggregation / connectivity aggregation in both collocated and non-collocated site deployments. The fact that frequencies where LTE is currently deployed have better propagation conditions than the frequencies where NR would be initially deployed, multi-connectivity features exploiting the tight integration of LTE and NR (such as control plane diversity and UP/CP split) should be studied.

Proposal 3 CP diversity and UP/CP split should possibly be enabled by the tight integration of LTE and NR in order to improve mobility robustness

These should be considered with both ideal and non-ideal backhaul conditions, preferably having some gradual performance degradation versus the backhaul quality.

2.3 Harmonization of lower and higher frequency solutions

Sudden drops of SINR due to shadowing might occur mainly when narrow beamforming is used in higher frequencies. Despite the fact that the same phenomena are not expected as often in other frequency bands (e.g. in lower frequencies bands) a harmonized solution for a wide range of frequencies should be targeted.

Aspects related to that harmonization should be studied. One example is the use of **beam identities**. In lower frequency scenarios a neighbour beam to be measured to either establish a secondary link or to perform mobility could look like an LTE cell, from a propagation and coverage detection perspective. However, the usage of a wide beam identity would lead to a harmonized solution where the higher layers could rely on similar procedures. That would efficiently support inter-frequency mobility between low frequency and high frequency carriers or the addition of a secondary carrier in higher frequency, which might occur often in order to boost the UP capacity.

Another aspect to be potentially harmonized relates to the usage of similar procedures for the different beamforming architectures that would likely need to be supported i.e. analog, hybrid and digital. Especially in the case of hybrid and digital beamforming, similar challenges may lead to the need of beam finding /sweeping procedures [4].

Petitioners' Exhibit 1003, p. 1065
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Proposal 4 **Study the aspects that should be harmonized in beam-based mobility for lower and higher frequencies**

3 Conclusions

This contribution discussed in more details the requirement that NR will need to support a wide range of frequencies (up to 100 GHz) and beamforming is standing out as an optimal way to operate the carriers with various frequency bands. Henceforth, NR also needs to support massive beamforming as an essential feature to overcome the propagation challenges in higher frequencies. The following has been observed:

Observation 1 **The extensive use of beamforming, in particular at the network side, will be an essential part of the NR design for high frequency carriers**

The following has been proposed:

No table of contents entries found.

4 References

[1] TR 23.799, Study on Architecture for Next Generation

[2] TR 38.913, Study on Scenarios and Requirements for Next Generation Access Technologies

[3] RP-160671, New SID Proposal: Study on New Radio Access Technology, DoCoMo

[4] METIS-II White Paper on 5G RAN Architecture and Functional design

[5] R2-162761, Active Mode Mobility (AMM) in NR: future proofness and energy efficiency, RAN2#93bis, 11 - 15 April 2016

Petitioners' Exhibit 1003, p. 1066
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

APPENDIX 9

ETSI TS 136 211 V13.1.0 (2016-04)



LTE;
Evolved Universal Terrestrial Radio Access (E-UTRA);
Physical channels and modulation
(3GPP TS 36.211 version 13.1.0 Release 13)

Petitioners' Exhibit 1003, p. 1068
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Reference
RTS/TSGR-0136211vd10

Keywords
LTE

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

Important notice

The present document can be downloaded from:
http://www.etsi.org/standards-search

The present document may be made available in electronic versions and/or in print. The content of any electronic and/or print versions of the present document shall not be modified without the prior written authorization of ETSI. In case of any existing or perceived difference in contents between such versions and/or in print, the only prevailing document is the print of the Portable Document Format (PDF) version kept on a specific network drive within ETSI Secretariat.

Users of the present document should be aware that the document may be subject to revision or change of status.
Information on the current status of this and other ETSI documents is available at
http://portal.etsi.org/tb/status/status.asp

If you find errors in the present document, please send your comment to one of the following services:
https://portal.etsi.org/People/CommiteeSupportStaff.aspx

Copyright Notification

No part may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm except as authorized by written permission of ETSI.
The content of the PDF version shall not be modified without the written authorization of ETSI.
The copyright and the foregoing restriction extend to reproduction in all media.

© European Telecommunications Standards Institute 2016.
All rights reserved.

DECT™, **PLUGTESTS**™, **UMTS**™ and the ETSI logo are Trade Marks of ETSI registered for the benefit of its Members.
3GPP™ and **LTE**™ are Trade Marks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners.
GSM® and the GSM logo are Trade Marks registered and owned by the GSM Association.

Petitioners' Exhibit 1003, p. 1069
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Intellectual Property Rights

IPRs essential or potentially essential to the present document may have been declared to ETSI. The information pertaining to these essential IPRs, if any, is publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (https://ipr.etsi.org/).

Pursuant to the ETSI IPR Policy, no investigation, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Foreword

This Technical Specification (TS) has been produced by ETSI 3rd Generation Partnership Project (3GPP).

The present document may refer to technical specifications or reports using their 3GPP identities, UMTS identities or GSM identities. These should be interpreted as being references to the corresponding ETSI deliverables.

The cross reference between GSM, UMTS, 3GPP and ETSI identities can be found under http://webapp.etsi.org/key/queryform.asp.

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Petitioners' Exhibit 1003, p. 1070
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Contents

Intellectual Property Rights 2
Foreword 2
Modal verbs terminology 2
Foreword 7
1 Scope 8
2 References 8
3 Symbols and abbreviations 8
3.1 Symbols 8
3.2 Abbreviations 11
4 Frame structure 12
4.1 Frame structure type 1 12
4.2 Frame structure type 2 13
4.3 Frame structure type 3 14
5 Uplink 16
5.1 Overview 16
5.1.1 Physical channels 16
5.1.2 Physical signals 16
5.2 Slot structure and physical resources 16
5.2.1 Resource grid 16
5.2.2 Resource elements 18
5.2.3 Resource blocks 18
5.2.4 Narrowbands 18
5.2.5 Guard period for narrowband retuning 19
5.3 Physical uplink shared channel 20
5.3.1 Scrambling 20
5.3.2 Modulation 21
5.3.2A Layer mapping 22
5.3.2A.1 Layer mapping for transmission on a single antenna port 22
5.3.2A.2 Layer mapping for spatial multiplexing 22
5.3.3 Transform precoding 23
5.3.3A Precoding 23
5.3.3A.1 Precoding for transmission on a single antenna port 23
5.3.3A.2 Precoding for spatial multiplexing 23
5.3.4 Mapping to physical resources 26
5.4 Physical uplink control channel 29
5.4.1 PUCCH formats 1, 1a and 1b 29
5.4.2 PUCCH formats 2, 2a and 2b 33
5.4.2A PUCCH format 3 34
5.4.2B PUCCH format 4 36
5.4.2C PUCCH format 5 36
5.4.3 Mapping to physical resources 37
5.5 Reference signals 40
5.5.1 Generation of the reference signal sequence 40
5.5.1.1 Base sequences of length $3N_{sc}^{RB}$ or larger 40
5.5.1.2 Base sequences of length less than $3N_{sc}^{RB}$ 41
5.5.1.3 Group hopping 43
5.5.1.4 Sequence hopping 44
5.5.1.5 Determining virtual cell identity for sequence generation 44
5.5.2 Demodulation reference signal 45
5.5.2.1 Demodulation reference signal for PUSCH 45
5.5.2.1.1 Reference signal sequence 45

Petitioners' Exhibit 1003, p. 1071
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.5.2.1.2 Mapping to physical resources 47
5.5.2.2 Demodulation reference signal for PUCCH 47
5.5.2.2.1 Reference signal sequence 47
5.5.2.2.2 Mapping to physical resources 49
5.5.3 Sounding reference signal 50
5.5.3.1 Sequence generation 50
5.5.3.2 Mapping to physical resources 50
5.5.3.3 Sounding reference signal subframe configuration 53
5.6 SC-FDMA baseband signal generation 54
5.7 Physical random access channel 55
5.7.1 Time and frequency structure 55
5.7.2 Preamble sequence generation 61
5.7.3 Baseband signal generation 64
5.8 Modulation and upconversion 65

6 Downlink 66
6.1 Overview 66
6.1.1 Physical channels 66
6.1.2 Physical signals 66
6.2 Slot structure and physical resource elements 67
6.2.1 Resource grid 67
6.2.2 Resource elements 68
6.2.3 Resource blocks 69
6.2.3.1 Virtual resource blocks of localized type 69
6.2.3.2 Virtual resource blocks of distributed type 69
6.2.4 Resource-element groups 71
6.2.4A Enhanced Resource-Element Groups (EREGs) 72
6.2.5 Guard period for half-duplex FDD operation 72
6.2.6 Guard Period for TDD Operation 72
6.2.7 Narrowbands 72
6.2.8 Guard period for narrowband retuning 72
6.3 General structure for downlink physical channels 74
6.3.1 Scrambling 74
6.3.2 Modulation 75
6.3.3 Layer mapping 75
6.3.3.1 Layer mapping for transmission on a single antenna port 75
6.3.3.2 Layer mapping for spatial multiplexing 76
6.3.3.3 Layer mapping for transmit diversity 77
6.3.4 Precoding 77
6.3.4.1 Precoding for transmission on a single antenna port 77
6.3.4.2 Precoding for spatial multiplexing using antenna ports with cell-specific reference signals 77
6.3.4.2.1 Precoding without CDD 78
6.3.4.2.2 Precoding for large delay CDD 78
6.3.4.2.3 Codebook for precoding and CSI reporting 79
6.3.4.3 Precoding for transmit diversity 80
6.3.4.4 Precoding for spatial multiplexing using antenna ports with UE-specific reference signals 81
6.3.5 Mapping to resource elements 82
6.4 Physical downlink shared channel 83
6.4.1 Physical downlink shared channel for BL/CE UEs 84
6.5 Physical multicast channel 85
6.6 Physical broadcast channel 86
6.6.1 Scrambling 86
6.6.2 Modulation 86
6.6.3 Layer mapping and precoding 86
6.6.4 Mapping to resource elements 86
6.7 Physical control format indicator channel 88
6.7.1 Scrambling 88
6.7.2 Modulation 88
6.7.3 Layer mapping and precoding 88
6.7.4 Mapping to resource elements 89
6.8 Physical downlink control channel 90
6.8.1 PDCCH formats 90

Petitioners' Exhibit 1003, p. 1072
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.8.2 PDCCH multiplexing and scrambling 90
6.8.3 Modulation 90
6.8.4 Layer mapping and precoding 91
6.8.5 Mapping to resource elements 91
6.8A Enhanced physical downlink control channel 92
6.8A.1 EPDCCH formats 92
6.8A.2 Scrambling 93
6.8A.3 Modulation 93
6.8A.4 Layer mapping and precoding 94
6.8A.5 Mapping to resource elements 94
6.8B MTC physical downlink control channel 95
6.8B.1 MPDCCH formats 95
6.8B.2 Scrambling 96
6.8B.3 Modulation 96
6.8B.4 Layer mapping and precoding 96
6.8B.5 Mapping to resource elements 96
6.9 Physical hybrid ARQ indicator channel 99
6.9.1 Modulation 99
6.9.2 Resource group alignment, layer mapping and precoding 100
6.9.3 Mapping to resource elements 102
6.10 Reference signals 104
6.10.1 Cell-specific Reference Signal (CRS) 104
6.10.1.1 Sequence generation 104
6.10.1.2 Mapping to resource elements 104
6.10.2 MBSFN reference signals 108
6.10.2.1 Sequence generation 108
6.10.2.2 Mapping to resource elements 108
6.10.3 UE-specific reference signals associated with PDSCH 110
6.10.3.1 Sequence generation 110
6.10.3.2 Mapping to resource elements 111
6.10.3A Demodulation reference signals associated with EPDCCH or MPDCCH 116
6.10.3A.1 Sequence generation 116
6.10.3A.2 Mapping to resource elements 117
6.10.4 Positioning reference signals 119
6.10.4.1 Sequence generation 119
6.10.4.2 Mapping to resource elements 119
6.10.4.3 Positioning reference signal subframe configuration 120
6.10.5 CSI reference signals 122
6.10.5.1 Sequence generation 122
6.10.5.2 Mapping to resource elements 122
6.10.5.3 CSI reference signal subframe configuration 128
6.11 Synchronization signals 129
6.11.1 Primary synchronization signal (PSS) 129
6.11.1.1 Sequence generation 129
6.11.1.2 Mapping to resource elements 129
6.11.2 Secondary synchronization signal (SSS) 130
6.11.2.1 Sequence generation 130
6.11.2.2 Mapping to resource elements 132
6.11A Discovery signal 132
6.12 OFDM baseband signal generation 134
6.13 Modulation and upconversion 134

7 Generic functions 135
7.1 Modulation mapper 135
7.1.1 BPSK 135
7.1.2 QPSK 135
7.1.3 16QAM 136
7.1.4 64QAM 137
7.1.5 256QAM 138
7.2 Pseudo-random sequence generation 141

8 Timing 141

Petitioners' Exhibit 1003, p. 1073
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

8.1 Uplink-downlink frame timing 141

9 Sidelink 141
9.1 Overview 141
9.1.1 Physical channels 141
9.1.2 Physical signals 142
9.1.3 Handling of simultaneous sidelink and uplink/downlink transmissions 142
9.2 Slot structure and physical resources 143
9.2.1 Resource grid 143
9.2.2 Resource elements 143
9.2.3 Resource blocks 143
9.2.4 Resource pool 144
9.2.5 Guard period 144
9.3 Physical Sidelink Shared Channel 144
9.3.1 Scrambling 144
9.3.2 Modulation 144
9.3.3 Layer mapping 144
9.3.4 Transform precoding 145
9.3.5 Precoding 145
9.3.6 Mapping to physical resources 145
9.4 Physical Sidelink Control Channel 146
9.4.1 Scrambling 146
9.4.2 Modulation 146
9.4.3 Layer mapping 146
9.4.4 Transform precoding 146
9.4.5 Precoding 146
9.4.6 Mapping to physical resources 146
9.5 Physical Sidelink Discovery Channel 146
9.5.1 Scrambling 146
9.5.2 Modulation 147
9.5.3 Layer mapping 147
9.5.4 Transform precoding 147
9.5.5 Precoding 147
9.5.6 Mapping to physical resources 147
9.6 Physical Sidelink Broadcast Channel 147
9.6.1 Scrambling 147
9.6.2 Modulation 147
9.6.3 Layer mapping 148
9.6.4 Transform precoding 148
9.6.5 Precoding 148
9.6.6 Mapping to physical resources 148
9.7 Sidelink Synchronization Signals 148
9.7.1 Primary sidelink synchronization signal 148
9.7.1.1 Sequence generation 148
9.7.1.2 Mapping to resource elements 148
9.7.2 Secondary sidelink synchronization signal 149
9.7.2.1 Sequence generation 149
9.7.2.2 Mapping to resource elements 149
9.8 Demodulation reference signals 149
9.9 SC-FDMA baseband signal generation 150
9.10 Timing 150

Annex A (informative): Change history 152

History 156

Petitioners' Exhibit 1003, p. 1074
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

- x the first digit:
  - 1 presented to TSG for information;
  - 2 presented to TSG for approval;
  - 3 or greater indicates TSG approved document under change control.
- y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.
- z the third digit is incremented when editorial only changes have been incorporated in the document.

Petitioners' Exhibit 1003, p. 1075
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

1 Scope

The present document describes the physical channels for evolved UTRA.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document.*

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TS 36.201: "Evolved Universal Terrestrial Radio Access (E-UTRA); LTE physical layer; General description".

[3] 3GPP TS 36.212: "Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding".

[4] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures".

[5] 3GPP TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements".

[6] 3GPP TS 36.104: "Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception".

[7] 3GPP TS 36.101: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception".

[8] 3GPP TS 36.321, "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification".

[9] 3GPP TS 36.331, 'Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) Protocol specification'

[10] 3GPP TS 36.304, 'Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode'

3 Symbols and abbreviations

3.1 Symbols

For the purposes of the present document, the following symbols apply:

(k,l) Resource element with frequency-domain index k and time-domain index l

Petitioners' Exhibit 1003, p. 1076
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$a_{k,l}^{(p)}$	Value of resource element (k,l) [for antenna port p]
D	Matrix for supporting cyclic delay diversity
D_{RA}	Density of random access opportunities per radio frame
f_0	Carrier frequency
f_{RA}	PRACH resource frequency index within the considered time-domain location
$f_{\mathrm{PRB,hop}}^{\mathrm{PRACH}}$	PRACH frequency hopping offset, expressed as a number of resource blocks
$M_{\mathrm{sc}}^{\mathrm{PSBCH}}$	Bandwidth for PSBCH transmission, expressed as a number of subcarriers
$M_{\mathrm{RB}}^{\mathrm{PSBCH}}$	Bandwidth for PSBCH transmission, expressed as a number of resource blocks
$M_{\mathrm{sc}}^{\mathrm{PSCCH}}$	Bandwidth for PSCCH transmission, expressed as a number of subcarriers
$M_{\mathrm{RB}}^{\mathrm{PSCCH}}$	Bandwidth for PSCCH transmission, expressed as a number of resource blocks
$M_{\mathrm{sc}}^{\mathrm{PSDCH}}$	Bandwidth for PSDCH transmission, expressed as a number of subcarriers
$M_{\mathrm{RB}}^{\mathrm{PSDCH}}$	Bandwidth for PSDCH transmission, expressed as a number of resource blocks
$M_{\mathrm{sc}}^{\mathrm{PSSCH}}$	Scheduled bandwidth for PSSCH transmission, expressed as a number of subcarriers
$M_{\mathrm{RB}}^{\mathrm{PSSCH}}$	Scheduled bandwidth for PSSCH transmission, expressed as a number of resource blocks
$M_{\mathrm{sc}}^{\mathrm{PUSCH}}$	Scheduled bandwidth for uplink transmission, expressed as a number of subcarriers
$M_{\mathrm{RB}}^{\mathrm{PUSCH}}$	Scheduled bandwidth for uplink transmission, expressed as a number of resource blocks
$M_{\mathrm{bit}}^{(q)}$	Number of coded bits to transmit on a physical channel [for codeword q]
$M_{\mathrm{symb}}^{(q)}$	Number of modulation symbols to transmit on a physical channel [for codeword q]
$M_{\mathrm{symb}}^{\mathrm{layer}}$	Number of modulation symbols to transmit per layer for a physical channel
$M_{\mathrm{symb}}^{\mathrm{ap}}$	Number of modulation symbols to transmit per antenna port for a physical channel
N	A constant equal to 2048 for $\Delta f = 15\,\mathrm{kHz}$ and 4096 for $\Delta f = 7.5\,\mathrm{kHz}$
$N_{\mathrm{CP},l}$	Downlink cyclic prefix length for OFDM symbol l in a slot
N_{CS}	Cyclic shift value used for random access preamble generation
$N_{\mathrm{cs}}^{(1)}$	Number of cyclic shifts used for PUCCH formats 1/1a/1b in a resource block with a mix of formats 1/1a/1b and 2/2a/2b
$N_{\mathrm{RB}}^{(2)}$	Bandwidth available for use by PUCCH formats 2/2a/2b, expressed in multiples of $N_{\mathrm{sc}}^{\mathrm{RB}}$
$N_{\mathrm{RB}}^{\mathrm{HO}}$	The offset used for PUSCH frequency hopping, expressed in number of resource blocks (set by higher layers)
$N_{\mathrm{ID}}^{\mathrm{cell}}$	Physical layer cell identity
$N_{\mathrm{ID}}^{\mathrm{MBSFN}}$	MBSFN area identity
$N_{\mathrm{ID}}^{\mathrm{SL}}$	Physical layer sidelink synchronization identity
$N_{\mathrm{RB}}^{\mathrm{DL}}$	Downlink bandwidth configuration, expressed in multiples of $N_{\mathrm{sc}}^{\mathrm{RB}}$
$N_{\mathrm{RB}}^{\mathrm{min,DL}}$	Smallest downlink bandwidth configuration, expressed in multiples of $N_{\mathrm{sc}}^{\mathrm{RB}}$
$N_{\mathrm{RB}}^{\mathrm{max,DL}}$	Largest downlink bandwidth configuration, expressed in multiples of $N_{\mathrm{sc}}^{\mathrm{RB}}$
$N_{\mathrm{RB}}^{\mathrm{UL}}$	Uplink bandwidth configuration, expressed in multiples of $N_{\mathrm{sc}}^{\mathrm{RB}}$
$N_{\mathrm{RB}}^{\mathrm{min,UL}}$	Smallest uplink bandwidth configuration, expressed in multiples of $N_{\mathrm{sc}}^{\mathrm{RB}}$
$N_{\mathrm{RB}}^{\mathrm{max,UL}}$	Largest uplink bandwidth configuration, expressed in multiples of $N_{\mathrm{sc}}^{\mathrm{RB}}$
$N_{\mathrm{RB}}^{\mathrm{SL}}$	Sidelink bandwidth configuration, expressed in multiples of $N_{\mathrm{sc}}^{\mathrm{RB}}$
$N_{\mathrm{NB}}^{\mathrm{UL}}$	Total number of uplink narrowbands
N_{acc}	Number of consecutive absolute subframes over which the scrambling sequence stays the same
$N_{\mathrm{abs}}^{\mathrm{PUSCH}}$	Total number of absolute subframes a PUSCH with repetition spans , expressed as a number of absolute subframes
$N_{\mathrm{rep}}^{\mathrm{PUSCH}}$	Number of repetititions of a PUSCH transmission

Petitioners' Exhibit 1003, p. 1077
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$N_{\text{NB}}^{\text{ch,UL}}$	Number of consecutive absolute subframes over which PUCCH or PUSCH stays at the same narrowband before hopping to another narrowband, expressed as a number of absolute subframes
$f_{\text{NB,hop}}^{\text{PUSCH}}$	Narrowband offset between one narrowband and the next narrowband a PUSCH hops to, expressed as a number of uplink narrowbands
$N_{\text{abs}}^{\text{PUCCH}}$	Total number of absolute subframes a PUCCH with repetition spans, expressed as a number of absolute subframes
$N_{\text{rep}}^{\text{PUCCH}}$	Number of repetititions of a PUCCH transmission
$N_{\text{rep}}^{\text{PRACH}}$	Number of PRACH repetitions per preamble transmission attempt
$N_{\text{sf}}^{\text{RA}}$	Number of subframes allowed for preamble transmission within a 1024-frame interval
$N_{\text{start}}^{\text{PRACH}}$	PRACH starting subframe periodicity
$N_{\text{NB}}^{\text{DL}}$	Total number of downlink narrowbands
$N_{\text{abs}}^{\text{PDSCH}}$	Total number of absolute subframes a PDSCH with repetition spans, expressed as a number of absolute subframes
$N_{\text{rep}}^{\text{PDSCH}}$	Number of repetititions of a PDSCH transmission
$N_{\text{NB}}^{\text{ch,DL}}$	Number of consecutive absolute subframes over which MPDCCH or PDSCH stays at the same narrowband before hopping to another narrowband, expressed as a number of absolute subframes
$N_{\text{NB,hop}}^{\text{ch,DL}}$	Number of narrowbands over which MPDCCH or PDSCH frequency hops
$f_{\text{NB,hop}}^{\text{DL}}$	Narrowband offset between one narrowband and the next narrowband an MPDCCH or PDSCH hops to, expressed as a number of downlink narrowbands
$N_{\text{PDSCH}}^{\text{SIB1-BR}}$	Number of times a PDSCH carrying SIB1-BR is transmitted over 8 radio frames
$N_{\text{abs}}^{\text{MPDCCH}}$	Total number of absolute subframes a MPDCCH with repetition spans , expressed as a number of absolute subframes
$N_{\text{rep}}^{\text{MPDCCH}}$	Number of repetititions of a MPDCCH transmission
$N_{\text{ECCE}}^{\text{MPDCCH}}$	Number of ECCEs in a subframe for one MPDCCH
$N_{\text{symb}}^{\text{DL}}$	Number of OFDM symbols in a downlink slot
$N_{\text{symb}}^{\text{UL}}$	Number of SC-FDMA symbols in an uplink slot
$N_{\text{symb}}^{\text{SL}}$	Number of SC-FDMA symbols in a sidelink slot
$N_{\text{sc}}^{\text{RB}}$	Resource block size in the frequency domain, expressed as a number of subcarriers
N_{sb}	Number of sub-bands for PUSCH frequency-hopping with predefined hopping pattern
$N_{\text{RB}}^{\text{sb}}$	Size of each sub-band for PUSCH frequency-hopping with predefined hopping pattern, expressed as a number of resource blocks
N_{SP}	Number of downlink to uplink switch points within the radio frame
$N_{\text{RS}}^{\text{PUCCH}}$	Number of reference symbols per slot for PUCCH
N_{TA}	Timing offset between uplink and downlink radio frames at the UE, expressed in units of T_s
$N_{\text{TA offset}}$	Fixed timing advance offset, expressed in units of T_s
$N_{\text{TA,SL}}$	Timing offset between sidelink and timing reference frames at the UE, expressed in units of T_s
$n_{\text{PUCCH}}^{(1,\tilde{p})}$	Resource index for PUCCH formats 1/1a/1b
$n_{\text{PUCCH}}^{(2,\tilde{p})}$	Resource index for PUCCH formats 2/2a/2b
$n_{\text{PUCCH}}^{(3,\tilde{p})}$	Resource index for PUCCH formats 3
n_{PDCCH}	Number of PDCCHs present in a subframe
n_{PRB}	Physical resource block number
$n_{\text{PRB}}^{\text{RA}}$	First physical resource block occupied by PRACH resource considered
$n_{\text{PRB offset}}^{\text{RA}}$	First physical resource block available for PRACH
n_{VRB}	Virtual resource block number

Petitioners' Exhibit 1003, p. 1078
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

n_{RNTI}	Radio network temporary identifier
$n_{\text{ID}}^{\text{SA}}$	Sidelink group destination identity
n_{f}	System frame number
n_{s}	Slot number within a radio frame
$n_{\text{sf}}^{\text{abs}}$	Absolute subframe number
$n_{\text{sf}}^{\text{RA}}$	Index for subframes allowed for preamble transmission
P	Number of antenna ports used for transmission of a channel
p	Antenna port number
q	Codeword number
r_{RA}	Index for PRACH versions with same preamble format and PRACH density
Q_m	Modulation order: 2 for QPSK, 4 for 16QAM, 6 for 64QAM and 8 for 256QAM transmissions
$s_l^{(p)}(t)$	Time-continuous baseband signal for antenna port p and OFDM symbol l in a slot
$t_{\text{RA}}^{(0)}$	Radio frame indicator index of PRACH opportunity
$t_{\text{RA}}^{(1)}$	Half frame index of PRACH opportunity within the radio frame
$t_{\text{RA}}^{(2)}$	Uplink subframe number for start of PRACH opportunity within the half frame
T_{f}	Radio frame duration
T_{s}	Basic time unit
T_{slot}	Slot duration
W	Precoding matrix for downlink spatial multiplexing
β_{PRACH}	Amplitude scaling for PRACH
β_{PUCCH}	Amplitude scaling for PUCCH
β_{PUSCH}	Amplitude scaling for PUSCH
β_{SRS}	Amplitude scaling for sounding reference symbols
Δf	Subcarrier spacing
Δf_{RA}	Subcarrier spacing for the random access preamble
υ	Number of transmission layers

3.2 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply.
An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

CCE	Control Channel Element
CDD	Cyclic Delay Diversity
CRS	Cell-specific Reference Signal
CSI	Channel-State Information
DCI	Downlink Control Information
DM-RS	Demodulation Reference Signal
ECCE	Enhanced Control Channel Element
EPDCCH	Enhanced Physical Downlink Control CHannel
EREG	Enhanced Resource-Element Group
MPDCCH	MTC Physical Downlink Control Channel
PBCH	Physical Broadcast CHannel
PCFICH	Physical Control Format Indicator CHannel
PDCCH	Physical Downlink Control CHannel
PDSCH	Physical Downlink Shared CHannel
PHICH	Physical Hybrid-ARQ Indicator CHannel
PMCH	Physical Multicast CHannel
PRACH	Physical Random Access CHannel
PRB	Physical Resource Block
PRS	Positioning Reference Signal

Petitioners' Exhibit 1003, p. 1079
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

PSBCH	Physical Sidelink Broadcast CHannel
PSCCH	Physical Sidelink Control CHannel
PSDCH	Physical Sidelink Discovery CHannel
PSSCH	Physical Sidelink Shared CHannel
PUCCH	Physical Uplink Control CHannel
PUSCH	Physical Uplink Shared CHannel
REG	Resource-Element Group
SCG	Secondary Cell Group
SRS	Sounding Reference Signal
VRB	Virtual Resource Block

4 Frame structure

Throughout this specification, unless otherwise noted, the size of various fields in the time domain is expressed as a number of time units $T_s = 1/(15000 \times 2048)$ seconds.

Downlink, uplink and sidelink transmissions are organized into radio frames with $T_f = 307200 \times T_s = 10\,\text{ms}$ duration. Three radio frame structures are supported:

- Type 1, applicable to FDD only,
- Type 2, applicable to TDD only,
- Type 3, applicable to LAA secondary cell operation only.

NOTE: LAA secondary cell operation only applies to frame structure type 3.

Transmissions in multiple cells can be aggregated where up to 31 secondary cells can be used in addition to the primary cell. Unless otherwise noted, the description in this specification applies to each of the up to 32 serving cells. In case of multi-cell aggregation, different frame structures can be used in the different serving cells.

4.1 Frame structure type 1

Frame structure type 1 is applicable to both full duplex and half duplex FDD only. Each radio frame is $T_f = 307200 \cdot T_s = 10\,\text{ms}$ long and consists of 20 slots of length $T_{slot} = 15360 \cdot T_s = 0.5\,\text{ms}$, numbered from 0 to 19. A subframe is defined as two consecutive slots where subframe i consists of slots $2i$ and $2i+1$. Subframe i in frame n_f has an absolute subframe number $n_{sf}^{abs} = 10n_f + i$ where n_f is the system frame number.

For FDD, 10 subframes are available for downlink transmission and 10 subframes are available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain. In half-duplex FDD operation, the UE cannot transmit and receive at the same time while there are no such restrictions in full-duplex FDD.

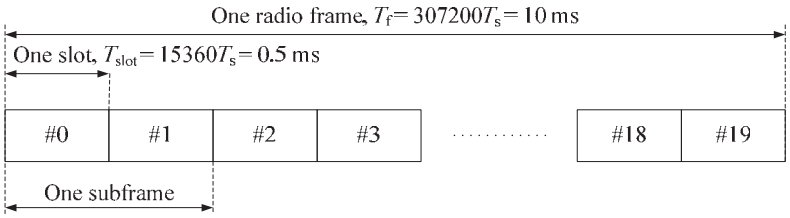


Figure 4.1-1: Frame structure type 1

Petitioners' Exhibit 1003, p. 1080
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

4.2 Frame structure type 2

Frame structure type 2 is applicable to TDD only. Each radio frame of length $T_f = 307200 \cdot T_s = 10\,\text{ms}$ consists of two half-frames of length $153600 \cdot T_s = 5\,\text{ms}$ each. Each half-frame consists of five subframes of length $30720 \cdot T_s = 1\,\text{ms}$. Each subframe i is defined as two slots, $2i$ and $2i+1$, of length $T_{slot} = 15360 \cdot T_s = 0.5\,\text{ms}$ each. Subframe i in frame n_f has an absolute subframe number $n_{sf}^{abs} = 10n_f + i$ where n_f is the system frame number.

The uplink-downlink configuration in a cell may vary between frames and controls in which subframes uplink or downlink transmissions may take place in the current frame. The uplink-downlink configuration in the current frame is obtained according to Section 13 in [4].

The supported uplink-downlink configurations are listed in Table 4.2-2 where, for each subframe in a radio frame, "D" denotes a downlink subframe reserved for downlink transmissions, "U" denotes an uplink subframe reserved for uplink transmissions and "S" denotes a special subframe with the three fields DwPTS, GP and UpPTS. The length of DwPTS and UpPTS is given by Table 4.2-1 subject to the total length of DwPTS, GP and UpPTS being equal to $30720 \cdot T_s = 1\,\text{ms}$ where X is the number of additional SC-FDMA symbols in UpPTS provided by the higher layer parameter *srs-UpPtsAdd* if configured otherwise X is equal to 0. The UE is not expected to be configured with 2 additional UpPTS SC-FDMA symbols for special subframe configurations {3, 4, 7, 8} for normal cyclic prefix in downlink and special subframe configurations {2, 3, 5, 6} for extended cyclic prefix in downlink and 4 additional UpPTS SC-FDMA symbols for special subframe configurations {1 2, 3, 4, 6, 7, 8} for normal cyclic prefix in downlink and special subframe configurations {1, 2, 3, 5, 6} for extended cyclic prefix in downlink.

Uplink-downlink configurations with both 5 ms and 10 ms downlink-to-uplink switch-point periodicity are supported.

- In case of 5 ms downlink-to-uplink switch-point periodicity, the special subframe exists in both half-frames.
- In case of 10 ms downlink-to-uplink switch-point periodicity, the special subframe exists in the first half-frame only.

Subframes 0 and 5 and DwPTS are always reserved for downlink transmission. UpPTS and the subframe immediately following the special subframe are always reserved for uplink transmission.

In case multiple cells are aggregated, the UE may assume that the guard period of the special subframe in the cells using frame structure type 2 have an overlap of at least $1456 \cdot T_s$.

In case multiple cells with different uplink-downlink configurations in the current radio frame are aggregated and the UE is not capable of simultaneous reception and transmission in the aggregated cells, the following constraints apply:

- if the subframe in the primary cell is a downlink subframe, the UE shall not transmit any signal or channel on a secondary cell in the same subframe
- if the subframe in the primary cell is an uplink subframe, the UE is not expected to receive any downlink transmissions on a secondary cell in the same subframe
- if the subframe in the primary cell is a special subframe and the same subframe in a secondary cell is a downlink subframe, the UE is not expected to receive PDSCH/EPDCCH/PMCH/PRS transmissions in the secondary cell in the same subframe, and the UE is not expected to receive any other signals on the secondary cell in OFDM symbols that overlaps with the guard period or UpPTS in the primary cell.

Petitioners' Exhibit 1003, p. 1081
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

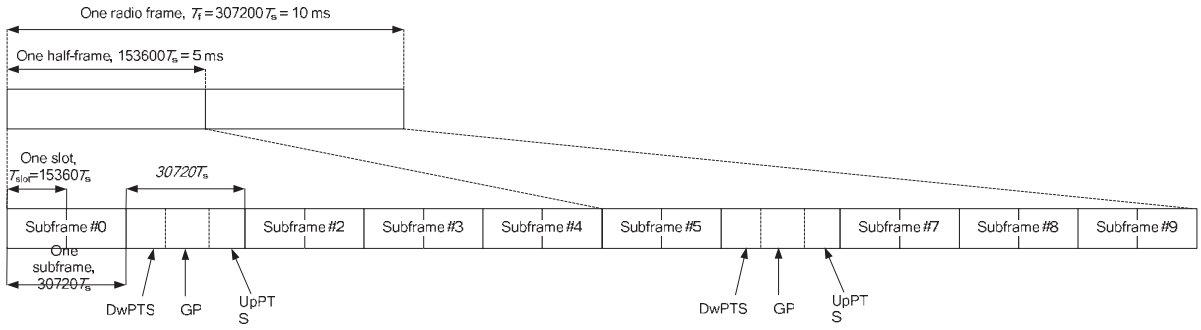


Figure 4.2-1: Frame structure type 2 (for 5 ms switch-point periodicity)

Table 4.2-1: Configuration of special subframe (lengths of DwPTS/GP/UpPTS)

Special subframe configuration	Normal cyclic prefix in downlink			Extended cyclic prefix in downlink		
	DwPTS	UpPTS		DwPTS	UpPTS	
		Normal cyclic prefix in uplink	Extended cyclic prefix in uplink		Normal cyclic prefix in uplink	Extended cyclic prefix in uplink
0	$6592 \cdot T_s$	$(1+X) \cdot 2192 \cdot T_s$	$(1+X) \cdot 2560 \cdot T_s$	$7680 \cdot T_s$	$(1+X) \cdot 2192 \cdot T_s$	$(1+X) \cdot 2560 \cdot T_s$
1	$19760 \cdot T_s$			$20480 \cdot T_s$		
2	$21952 \cdot T_s$			$23040 \cdot T_s$		
3	$24144 \cdot T_s$			$25600 \cdot T_s$		
4	$26336 \cdot T_s$			$7680 \cdot T_s$	$(2+X) \cdot 2192 \cdot T_s$	$(2+X) \cdot 2560 \cdot T_s$
5	$6592 \cdot T_s$	$(2+X) \cdot 2192 \cdot T_s$	$(2+X) \cdot 2560 \cdot T_s$	$20480 \cdot T_s$		
6	$19760 \cdot T_s$			$23040 \cdot T_s$		
7	$21952 \cdot T_s$			$12800 \cdot T_s$		
8	$24144 \cdot T_s$			-	-	-
9	$13168 \cdot T_s$			-	-	-

Table 4.2-2: Uplink-downlink configurations

Uplink-downlink configuration	Downlink-to-Uplink Switch-point periodicity	Subframe number									
		0	1	2	3	4	5	6	7	8	9
0	5 ms	D	S	U	U	U	D	S	U	U	U
1	5 ms	D	S	U	U	D	D	S	U	U	D
2	5 ms	D	S	U	D	D	D	S	U	D	D
3	10 ms	D	S	U	U	U	D	D	D	D	D
4	10 ms	D	S	U	U	D	D	D	D	D	D
5	10 ms	D	S	U	D	D	D	D	D	D	D
6	5 ms	D	S	U	U	U	D	S	U	U	D

4.3 Frame structure type 3

Frame structure type 3 is applicable to LAA secondary cell operation with normal cyclic prefix only. Each radio frame is $T_f = 307200 \cdot T_s = 10\,\text{ms}$ long and consists of 20 slots of length $T_{slot} = 15360 \cdot T_s = 0.5\,\text{ms}$, numbered from 0 to 19. A subframe is defined as two consecutive slots where subframe i consists of slots $2i$ and $2i+1$.

The 10 subframes within a radio frame are available for downlink transmissions. Downlink transmissions occupy one or more consecutive subframes, starting anywhere within a subframe and ending with the last subframe either fully occupied or following one of the DwPTS durations in Table 4.2-1.

Petitioners' Exhibit 1003, p. 1082
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Petitioners' Exhibit 1003, p. 1083
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5 Uplink

5.1 Overview

The smallest resource unit for uplink transmissions is denoted a resource element and is defined in clause 5.2.2.

5.1.1 Physical channels

An uplink physical channel corresponds to a set of resource elements carrying information originating from higher layers and is the interface defined between 3GPP TS 36.212 [3] and the present document 3GPP TS 36.211.
The following uplink physical channels are defined:

- Physical Uplink Shared Channel, PUSCH
- Physical Uplink Control Channel, PUCCH
- Physical Random Access Channel, PRACH

5.1.2 Physical signals

An uplink physical signal is used by the physical layer but does not carry information originating from higher layers.
The following uplink physical signals are defined:

- Reference signal

5.2 Slot structure and physical resources

5.2.1 Resource grid

The transmitted signal in each slot is described by one or several resource grids of $N_{\mathrm{RB}}^{\mathrm{UL}} N_{\mathrm{sc}}^{\mathrm{RB}}$ subcarriers and $N_{\mathrm{symb}}^{\mathrm{UL}}$ SC-FDMA symbols. The resource grid is illustrated in Figure 5.2.1-1. The quantity $N_{\mathrm{RB}}^{\mathrm{UL}}$ depends on the uplink transmission bandwidth configured in the cell and shall fulfil

$$N_{\mathrm{RB}}^{\mathrm{min,UL}} \le N_{\mathrm{RB}}^{\mathrm{UL}} \le N_{\mathrm{RB}}^{\mathrm{max,UL}}$$

where $N_{\mathrm{RB}}^{\mathrm{min,UL}} = 6$ and $N_{\mathrm{RB}}^{\mathrm{max,UL}} = 110$ are the smallest and largest uplink bandwidths, respectively, supported by the current version of this specification. The set of allowed values for $N_{\mathrm{RB}}^{\mathrm{UL}}$ is given by 3GPP TS 36.101 [7].

The number of SC-FDMA symbols in a slot depends on the cyclic prefix length configured by the higher layer parameter *UL-CyclicPrefixLength* and is given in Table 5.2.3-1.

An antenna port is defined such that the channel over which a symbol on the antenna port is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed. There is one resource grid per antenna port. The antenna ports used for transmission of a physical channel or signal depends on the number of antenna ports configured for the physical channel or signal as shown in Table 5.2.1-1. The index $\tilde{p}$ is used throughout clause 5 when a sequential numbering of the antenna ports is necessary.

Petitioners' Exhibit 1003, p. 1084
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

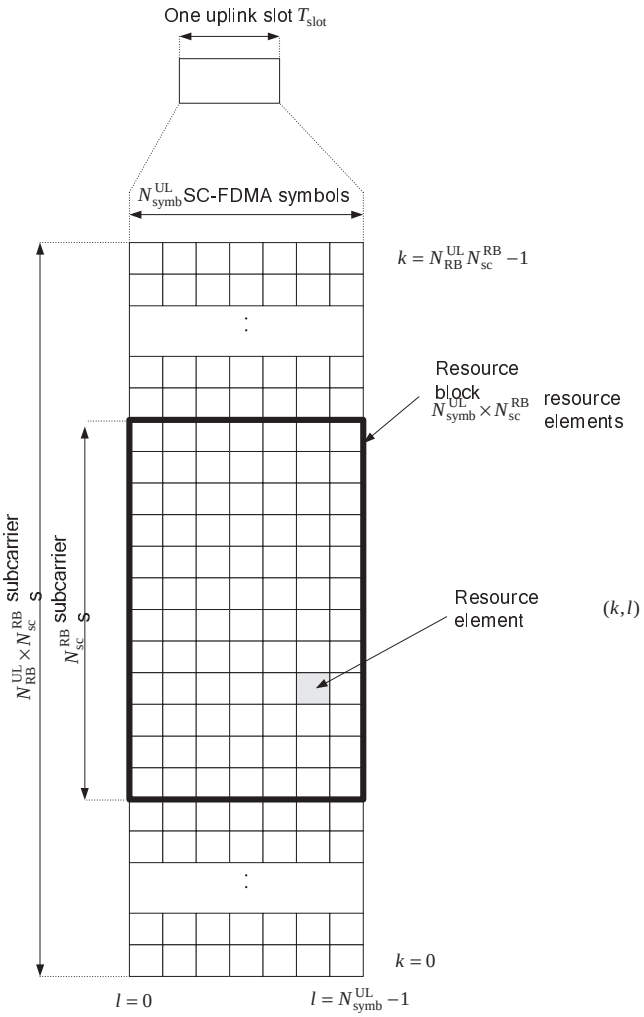


Figure 5.2.1-1: Uplink resource grid

Table 5.2.1-1: Antenna ports used for different physical channels and signals

Physical channel or signal	Index $\tilde{p}$	Antenna port number p as a function of the number of antenna ports configured for the respective physical channel/signal		
		1	2	4
PUSCH	0	10	20	40
	1	-	21	41
	2	-	-	42
	3	-	-	43
SRS	0	10	20	40
	1	-	21	41
	2	-	-	42
	3	-	-	43
PUCCH	0	100	200	-
	1	-	201	-

Petitioners' Exhibit 1003, p. 1085
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.2.2 Resource elements

Each element in the resource grid is called a resource element and is uniquely defined by the index pair (k,l) in a slot where $k = 0,...,N_{\text{RB}}^{\text{UL}}N_{\text{sc}}^{\text{RB}} - 1$ and $l = 0,...,N_{\text{symb}}^{\text{UL}} - 1$ are the indices in the frequency and time domains, respectively. Resource element (k,l) on antenna port p corresponds to the complex value $a_{k,l}^{(p)}$.
When there is no risk for confusion, or no particular antenna port is specified, the index p may be dropped.
Quantities $a_{k,l}^{(p)}$ corresponding to resource elements not used for transmission of a physical channel or a physical signal in a slot shall be set to zero.

5.2.3 Resource blocks

A physical resource block is defined as $N_{\text{symb}}^{\text{UL}}$ consecutive SC-FDMA symbols in the time domain and $N_{\text{sc}}^{\text{RB}}$ consecutive subcarriers in the frequency domain, where $N_{\text{symb}}^{\text{UL}}$ and $N_{\text{sc}}^{\text{RB}}$ are given by Table 5.2.3-1.
A physical resource block in the uplink thus consists of $N_{\text{symb}}^{\text{UL}} \times N_{\text{sc}}^{\text{RB}}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.

Table 5.2.3-1: Resource block parameters

Configuration	$N_{\text{sc}}^{\text{RB}}$	$N_{\text{symb}}^{\text{UL}}$
Normal cyclic prefix	12	7
Extended cyclic prefix	12	6

The relation between the physical resource block number n_{PRB} in the frequency domain and resource elements (k,l) in a slot is given by

$$n_{\text{PRB}} = \left\lfloor \frac{k}{N_{\text{sc}}^{\text{RB}}} \right\rfloor$$

5.2.4 Narrowbands

A narrowband is defined as six non-overlapping consecutive physical resource blocks in the frequency domain. The total number of uplink narrowbands in the uplink transmission bandwidth configured in the cell is given by

$$N_{\text{NB}}^{\text{UL}} = \left\lfloor \frac{N_{\text{RB}}^{\text{UL}}}{6} \right\rfloor$$

The narrowbands are numbered $n_{\text{NB}} = 0,...,N_{\text{NB}}^{\text{UL}} - 1$ in order of increasing physical resource-block number where narrowband n_{NB} is composed of physical resorce-block indices

$$\begin{cases} 6n_{\text{NB}} + i_0 + i & \text{if } N_{\text{RB}}^{\text{UL}} \bmod 2 = 0 \\ 6n_{\text{NB}} + i_0 + i & \text{if } N_{\text{RB}}^{\text{UL}} \bmod 2 = 1 \text{ and } n_{\text{NB}} < N_{\text{NB}}^{\text{UL}}/2 \\ 6n_{\text{NB}} + i_0 + i + 1 & \text{if } N_{\text{RB}}^{\text{UL}} \bmod 2 = 1 \text{ and } n_{\text{NB}} \geq N_{\text{NB}}^{\text{UL}}/2 \end{cases}$$

where

$$i = 0,1,...,5$$

$$i_0 = \left\lfloor \frac{N_{\text{RB}}^{\text{UL}}}{2} \right\rfloor - \frac{6N_{\text{NB}}^{\text{UL}}}{2}$$

Petitioners' Exhibit 1003, p. 1086
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.2.5 Guard period for narrowband retuning

For BL/CE UEs, a guard period is created for Tx-to-Tx frequency retuning between two consecutive subframes.

- If the UE retunes from a first narrowband carrying PUSCH to a second narrowband carrying PUSCH, or if the UE retunes from a first narrowband carrying PUCCH to a second narrowband carrying PUCCH,
  - a guard period is created by the UE not transmitting the last SC-FDMA symbol in the first subframe and the first SC-FDMA symbol in the second subframe.
- If the UE retunes from a first narrowband carrying PUCCH to a second narrowband carrying PUSCH,
  - if the PUCCH uses a shortened PUCCH format, a guard period is created by the UE not transmitting the first SC-FDMA symbol in the second subframe,
  - otherwise a guard period is created by the UE not transmitting the first two SC-FDMA symbols in the second subframe.
- If the UE retunes from a first narrowband carrying PUSCH to a second narrowband carrying PUCCH,
  - a guard period is created by the UE not transmitting the last two SC-FDMA symbols in the first subframe.

Petitioners' Exhibit 1003, p. 1087
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.3 Physical uplink shared channel

The baseband signal representing the physical uplink shared channel is defined in terms of the following steps:

- scrambling
- modulation of scrambled bits to generate complex-valued symbols
- mapping of the complex-valued modulation symbols onto one or several transmission layers
- transform precoding to generate complex-valued symbols
- precoding of the complex-valued symbols
- mapping of precoded complex-valued symbols to resource elements
- generation of complex-valued time-domain SC-FDMA signal for each antenna port

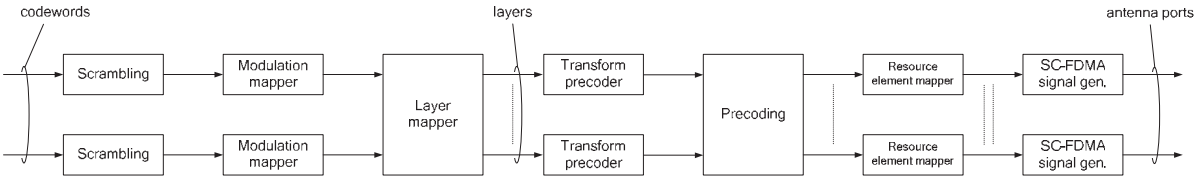


Figure 5.3-1: Overview of uplink physical channel processing

5.3.1 Scrambling

For each codeword q, the block of bits $b^{(q)}(0),...,b^{(q)}(M_{\text{bit}}^{(q)}-1)$, where $M_{\text{bit}}^{(q)}$ is the number of bits transmitted in codeword q on the physical uplink shared channel in one subframe, shall be scrambled with a UE-specific scrambling sequence prior to modulation, resulting in a block of scrambled bits $\tilde{b}^{(q)}(0),...,\tilde{b}^{(q)}(M_{\text{bit}}^{(q)}-1)$ according to the following pseudo code

Set $i = 0$

while $i < M_{\text{bit}}^{(q)}$

if $b^{(q)}(i) = \text{x}$ // ACK/NACK or Rank Indication placeholder bits

$\tilde{b}^{(q)}(i) = 1$

else

if $b^{(q)}(i) = \text{y}$ // ACK/NACK or Rank Indication repetition placeholder bits

$\tilde{b}^{(q)}(i) = \tilde{b}^{(q)}(i-1)$

else // Data or channel quality coded bits, Rank Indication coded bits or ACK/NACK coded bits

$\tilde{b}^{(q)}(i) = \left(b^{(q)}(i) + c^{(q)}(i)\right) \bmod 2$

end if

end if

$i = i + 1$

Petitioners' Exhibit 1003, p. 1088
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

end while

where x and y are tags defined in 3GPP TS 36.212 [3] clause 5.2.2.6 and where the scrambling sequence $c^{(q)}(i)$ is given by clause 7.2. The scrambling sequence generator shall be initialised with $c_{\text{init}} = n_{\text{RNTI}} \cdot 2^{14} + q \cdot 2^{13} + \lfloor n_s/2 \rfloor \cdot 2^9 + N_{\text{ID}}^{\text{cell}}$ at the start of each subframe where n_{RNTI} corresponds to the RNTI associated with the PUSCH transmission as described in clause 8 in 3GPP TS 36.213 [4].

For BL/CE UEs, the same scrambling sequence is applied per subframe to PUSCH for a given block of N_{acc} subframes. For the jth block of N_{acc} subframes, the scrambling sequence generator shall be initialised with

$$c_{\text{init}} = n_{\text{RNTI}} \cdot 2^{14} + q \cdot 2^{13} + \left[(j_0 + j) N_{\text{acc}} \bmod 10\right] \cdot 2^9 + N_{\text{ID}}^{\text{cell}}$$

where

$$j = 0,1,\ldots,\left\lfloor \frac{i_0 + N_{\text{abs}}^{\text{PUSCH}} - 1}{N_{\text{acc}}} \right\rfloor - j_0$$

$$j_0 = \lfloor i_0 / N_{\text{acc}} \rfloor$$

and i_0 is the absolute subframe number of the first uplink subframe intended for PUSCH. The PUSCH transmission spans $N_{\text{abs}}^{\text{PUSCH}}$ consecutive subframes including invalid subframes where the UE postpones the PUSCH transmission. For a BL/CE UE configured in CEModeA, $N_{\text{acc}} = 1$. For a BL/CE UE configured with CEModeB, $N_{\text{acc}} = 4$ for frame structure type 1 and $N_{\text{acc}} = 5$ for frame structure type 2.

Up to two codewords can be transmitted in one subframe, i.e., $q \in \{0,1\}$. In the case of single-codeword transmission, $q = 0$.

5.3.2 Modulation

For each codeword q, the block of scrambled bits $\tilde{b}^{(q)}(0),\ldots,\tilde{b}^{(q)}(M_{\text{bit}}^{(q)} - 1)$ shall be modulated as described in clause 7.1, resulting in a block of complex-valued symbols $d^{(q)}(0),\ldots,d^{(q)}(M_{\text{symb}}^{(q)} - 1)$. Table 5.3.2-1 specifies the modulation mappings applicable for the physical uplink shared channel.

Table 5.3.2-1: Uplink modulation schemes

Physical channel	Modulation schemes
PUSCH	QPSK, 16QAM, 64QAM

Petitioners' Exhibit 1003, p. 1089
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.3.2A Layer mapping

The complex-valued modulation symbols for each of the codewords to be transmitted are mapped onto one or two layers. Complex-valued modulation symbols $d^{(q)}(0),...,d^{(q)}(M_{\text{symb}}^{(q)}-1)$ for codeword q shall be mapped onto the layers $x(i)=\left[x^{(0)}(i) \quad ... \quad x^{(\upsilon-1)}(i)\right]^T$, $i=0,1,...,M_{\text{symb}}^{\text{layer}}-1$ where υ is the number of layers and $M_{\text{symb}}^{\text{layer}}$ is the number of modulation symbols per layer.

5.3.2A.1 Layer mapping for transmission on a single antenna port

For transmission on a single antenna port, a single layer is used, $\upsilon=1$, and the mapping is defined by

$$x^{(0)}(i)=d^{(0)}(i)$$

with $M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}$.

5.3.2A.2 Layer mapping for spatial multiplexing

For spatial multiplexing, the layer mapping shall be done according to Table 5.3.2A.2-1. The number of layers υ is less than or equal to the number of antenna ports P used for transmission of the physical uplink shared channel.
The case of a single codeword mapped to multiple layers is only applicable when the number of antenna ports used for PUSCH is four.

Table 5.3.2A.2-1: Codeword-to-layer mapping for spatial multiplexing

Number of layers	Number of codewords	Codeword-to-layer mapping $i=0,1,...,M_{\text{symb}}^{\text{layer}}-1$	
1	1	$x^{(0)}(i)=d^{(0)}(i)$	$M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}$
2	1	$x^{(0)}(i)=d^{(0)}(2i)$ $x^{(1)}(i)=d^{(0)}(2i+1)$	$M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}/2$
2	2	$x^{(0)}(i)=d^{(0)}(i)$ $x^{(1)}(i)=d^{(1)}(i)$	$M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}=M_{\text{symb}}^{(1)}$
3	2	$x^{(0)}(i)=d^{(0)}(i)$ $x^{(1)}(i)=d^{(1)}(2i)$ $x^{(2)}(i)=d^{(1)}(2i+1)$	$M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}=M_{\text{symb}}^{(1)}/2$
4	2	$x^{(0)}(i)=d^{(0)}(2i)$ $x^{(1)}(i)=d^{(0)}(2i+1)$ $x^{(2)}(i)=d^{(1)}(2i)$ $x^{(3)}(i)=d^{(1)}(2i+1)$	$M_{\text{symb}}^{\text{layer}}=M_{\text{symb}}^{(0)}/2=M_{\text{symb}}^{(1)}/2$

Petitioners' Exhibit 1003, p. 1090
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.3.3 Transform precoding

For each layer $\lambda = 0,1,...,\upsilon-1$ the block of complex-valued symbols $x^{(\lambda)}(0),...,x^{(\lambda)}(M_{\text{symb}}^{\text{layer}}-1)$ is divided into $M_{\text{symb}}^{\text{layer}} \big/ M_{\text{sc}}^{\text{PUSCH}}$ sets, each corresponding to one SC-FDMA symbol. Transform precoding shall be applied according to

$$y^{(\lambda)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + k) = \frac{1}{\sqrt{M_{\text{sc}}^{\text{PUSCH}}}} \sum_{i=0}^{M_{\text{sc}}^{\text{PUSCH}}-1} x^{(\lambda)}(l \cdot M_{\text{sc}}^{\text{PUSCH}} + i) e^{-j\frac{2\pi ik}{M_{\text{sc}}^{\text{PUSCH}}}}$$
$$k = 0,...,M_{\text{sc}}^{\text{PUSCH}}-1$$
$$l = 0,...,M_{\text{symb}}^{\text{layer}} \big/ M_{\text{sc}}^{\text{PUSCH}}-1$$

resulting in a block of complex-valued symbols $y^{(\lambda)}(0),...,y^{(\lambda)}(M_{\text{symb}}^{\text{layer}}-1)$. The variable $M_{\text{sc}}^{\text{PUSCH}} = M_{\text{RB}}^{\text{PUSCH}} \cdot N_{\text{sc}}^{\text{RB}}$, where $M_{\text{RB}}^{\text{PUSCH}}$ represents the bandwidth of the PUSCH in terms of resource blocks, and shall fulfil

$$M_{\text{RB}}^{\text{PUSCH}} = 2^{\alpha_2} \cdot 3^{\alpha_3} \cdot 5^{\alpha_5} \le N_{\text{RB}}^{\text{UL}}$$

where $\alpha_2, \alpha_3, \alpha_5$ is a set of non-negative integers.

5.3.3A Precoding

The precoder takes as input a block of vectors $\left[y^{(0)}(i) \quad ... \quad y^{(\upsilon-1)}(i)\right]^T$, $i = 0,1,...,M_{\text{symb}}^{\text{layer}}-1$ from the transform precoder and generates a block of vectors $\left[z^{(0)}(i) \quad \ldots \quad z^{(P-1)}(i)\right]^T$, $i = 0,1,...,M_{\text{symb}}^{\text{ap}}-1$ to be mapped onto resource elements.

5.3.3A.1 Precoding for transmission on a single antenna port

For transmission on a single antenna port, precoding is defined by

$$z^{(0)}(i) = y^{(0)}(i)$$

where $i = 0,1,...,M_{\text{symb}}^{\text{ap}}-1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

5.3.3A.2 Precoding for spatial multiplexing

Precoding for spatial multiplexing is only used in combination with layer mapping for spatial multiplexing as described in clause 5.3.2A.2. Spatial multiplexing supports $P = 2$ or $P = 4$ antenna ports where the set of antenna ports used for spatial multiplexing is $p \in \{20,21\}$ and $p \in \{40,41,42,43\}$, respectively.

Precoding for spatial multiplexing is defined by

$$\begin{bmatrix} z^{(0)}(i) \\ \vdots \\ z^{(P-1)}(i) \end{bmatrix} = W \begin{bmatrix} y^{(0)}(i) \\ \vdots \\ y^{(\upsilon-1)}(i) \end{bmatrix}$$

where $i = 0,1,...,M_{\text{symb}}^{\text{ap}}-1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

The precoding matrix W of size $P \times \upsilon$ is given by one of the entries in Table 5.3.3A.2-1 for $P = 2$ and by Tables 5.3.3A.2-2 through 5.3.3A.2-5 for $P = 4$ where the entries in each row are ordered from left to right in increasing order of codebook indices.

Petitioners' Exhibit 1003, p. 1091
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.3.3A.2-1: Codebook for transmission on antenna ports $\{20,21\}$

Codebook index	Number of layers	
	$\upsilon=1$	$\upsilon=2$
0	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\1\end{bmatrix}$	$\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}$
1	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-1\end{bmatrix}$	-
2	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\j\end{bmatrix}$	-
3	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-j\end{bmatrix}$	-
4	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\0\end{bmatrix}$	-
5	$\frac{1}{\sqrt{2}}\begin{bmatrix}0\\1\end{bmatrix}$	-

Table 5.3.3A.2-2: Codebook for transmission on antenna ports $\{40,41,42,43\}$ with $\upsilon=1$

Codebook index	Number of layers $\upsilon=1$							
0 – 7	$\frac{1}{2}\begin{bmatrix}1\\1\\1\\-1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\1\\j\\j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\1\\-1\\1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\1\\-j\\-j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\j\\1\\j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\j\\j\\1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\j\\-1\\-j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\j\\-j\\-1\end{bmatrix}$
8 – 15	$\frac{1}{2}\begin{bmatrix}1\\-1\\1\\1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\-1\\j\\-j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\-1\\-1\\-1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\-1\\-j\\j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\-j\\1\\-j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\-j\\j\\-1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\-j\\-1\\j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\-j\\-j\\1\end{bmatrix}$
16 – 23	$\frac{1}{2}\begin{bmatrix}1\\0\\1\\0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\0\\-1\\0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\0\\j\\0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1\\0\\-j\\0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}0\\1\\0\\1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}0\\1\\0\\-1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}0\\1\\0\\j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}0\\1\\0\\-j\end{bmatrix}$

Petitioners' Exhibit 1003, p. 1092
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.3.3A.2-3: Codebook for transmission on antenna ports $\{40,41,42,43\}$ with $\upsilon = 2$

Codebook index	Number of layers $\upsilon = 2$			
0 – 3	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 1 & 0\\ 0 & 1\\ 0 & -j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 1 & 0\\ 0 & 1\\ 0 & j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ -j & 0\\ 0 & 1\\ 0 & 1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ -j & 0\\ 0 & 1\\ 0 & -1\end{bmatrix}$
4 – 7	$\frac{1}{2}\begin{bmatrix}1 & 0\\ -1 & 0\\ 0 & 1\\ 0 & -j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ -1 & 0\\ 0 & 1\\ 0 & j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ j & 0\\ 0 & 1\\ 0 & 1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ j & 0\\ 0 & 1\\ 0 & -1\end{bmatrix}$
8 – 11	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ 1 & 0\\ 0 & 1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ 1 & 0\\ 0 & -1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ -1 & 0\\ 0 & 1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ -1 & 0\\ 0 & -1\end{bmatrix}$
12 – 15	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ 0 & 1\\ 1 & 0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ 0 & -1\\ 1 & 0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ 0 & 1\\ -1 & 0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0\\ 0 & 1\\ 0 & -1\\ -1 & 0\end{bmatrix}$

Table 5.3.3A.2-4: Codebook for transmission on antenna ports $\{40,41,42,43\}$ with $\upsilon = 3$

Codebook index	Number of layers $\upsilon = 3$			
0 – 3	$\frac{1}{2}\begin{bmatrix}1 & 0 & 0\\ 1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0 & 0\\ -1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 1 & 0 & 0\\ 0 & 0 & 1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ -1 & 0 & 0\\ 0 & 0 & 1\end{bmatrix}$
4 – 7	$\frac{1}{2}\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\\ 1 & 0 & 0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\\ -1 & 0 & 0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}0 & 1 & 0\\ 1 & 0 & 0\\ 1 & 0 & 0\\ 0 & 0 & 1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}0 & 1 & 0\\ 1 & 0 & 0\\ -1 & 0 & 0\\ 0 & 0 & 1\end{bmatrix}$
8 – 11	$\frac{1}{2}\begin{bmatrix}0 & 1 & 0\\ 1 & 0 & 0\\ 0 & 0 & 1\\ 1 & 0 & 0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}0 & 1 & 0\\ 1 & 0 & 0\\ 0 & 0 & 1\\ -1 & 0 & 0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ 1 & 0 & 0\\ 1 & 0 & 0\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ 1 & 0 & 0\\ -1 & 0 & 0\end{bmatrix}$

Table 5.3.3A.2-5: Codebook for transmission on antenna ports $\{40,41,42,43\}$ with $\upsilon = 4$

Codebook index	Number of layers $\upsilon = 4$
0	$\frac{1}{2}\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}$

Petitioners' Exhibit 1003, p. 1093
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.3.4 Mapping to physical resources

For each antenna port p used for transmission of the PUSCH in a subframe the block of complex-valued symbols $z^{(\tilde{p})}(0),...,z^{(\tilde{p})}(M^{\text{ap}}_{\text{symb}}-1)$ shall be multiplied with the amplitude scaling factor β_{PUSCH} in order to conform to the transmit power P_{PUSCH} specified in clause 5.1.1.1 in 3GPP TS 36.213 [4], and mapped in sequence starting with $z^{(\tilde{p})}(0)$ to physical resource blocks on antenna port p and assigned for transmission of PUSCH. The relation between the index $\tilde{p}$ and the antenna port number p is given by Table 5.2.1-1. The mapping to resource elements (k,l) corresponding to the physical resource blocks assigned for transmission and

- not used for transmission of reference signals, and
- not part of the last SC-FDMA symbol in a subframe, if the UE transmits SRS in the same subframe in the same serving cell, and
- not part of the last SC-FDMA symbol in a subframe configured with cell-specific SRS for non-BL/CE UEs and BL/CE UEs in CEModeA, if the PUSCH transmission partly or fully overlaps with the cell-specific SRS bandwidth, and
- not part of an SC-FDMA symbol reserved for possible SRS transmission in a UE-specific aperiodic SRS subframe in the same serving cell, and
- not part of an SC-FDMA symbol reserved for possible SRS transmission in a UE-specific periodic SRS subframe in the same serving cell when the UE is configured with multiple TAGs, and
- not part of an SC-FDMA symbol left empty for guard period for narrowband retuning for BL/CE UEs in CEModeA

shall be in increasing order of first the index k, then the index l, starting with the first slot in the subframe.

For BL/CE UEs in CEModeB, resource elements in the last SC-FDMA symbol in a subframe configured with cell-specific SRS shall be counted in the PUSCH mapping but not used for transmission of the PUSCH.

For BL/CE UEs in CEModeB, if one or more SC-FDMA symbol(s) are left empty due to guard period for narrowband retuning, the affected SC-FDMA symbol(s) shall be counted in the PUSCH mapping but not used for transmission of the PUSCH.

If uplink frequency-hopping is disabled or the resource blocks allocated for PUSCH transmission are not contiguous in frequency, the set of physical resource blocks to be used for transmission is given by $n_{\text{PRB}} = n_{\text{VRB}}$ where n_{VRB} is obtained from the uplink scheduling grant as described in clause 8.1 in 3GPP TS 36.213 [4].

If uplink frequency-hopping with type 1 PUSCH hopping is enabled, the set of physical resource blocks to be used for transmission is given by clause 8.4.1 in 3GPP TS 36.213 [4].

If uplink frequency-hopping with predefined hopping pattern is enabled, the set of physical resource blocks to be used for transmission in slot n_{s} is given by the scheduling grant together with a predefined pattern according to

$$\tilde{n}_{\text{PRB}}(n_{\text{s}}) = \left(\tilde{n}_{\text{VRB}} + f_{\text{hop}}(i)\cdot N^{\text{sb}}_{\text{RB}} + \left(\left(N^{\text{sb}}_{\text{RB}}-1\right)-2\left(\tilde{n}_{\text{VRB}} \bmod N^{\text{sb}}_{\text{RB}}\right)\right)\cdot f_{\text{m}}(i)\right)\bmod\left(N^{\text{sb}}_{\text{RB}}\cdot N_{\text{sb}}\right)$$

$$i = \begin{cases} \lfloor n_{\text{s}}/2 \rfloor & \text{inter-subframe hopping} \\ n_{\text{s}} & \text{intra and inter-subframe hopping} \end{cases}$$

$$n_{\text{PRB}}(n_{\text{s}}) = \begin{cases} \tilde{n}_{\text{PRB}}(n_{\text{s}}) & N_{sb}=1 \\ \tilde{n}_{\text{PRB}}(n_{\text{s}}) + \left\lceil N^{\text{HO}}_{\text{RB}}/2 \right\rceil & N_{sb}>1 \end{cases}$$

$$\tilde{n}_{\text{VRB}} = \begin{cases} n_{\text{VRB}} & N_{sb}=1 \\ n_{\text{VRB}} - \left\lceil N^{\text{HO}}_{\text{RB}}/2 \right\rceil & N_{sb}>1 \end{cases}$$

where n_{VRB} is obtained from the scheduling grant as described in clause 8.1 in 3GPP TS 36.213 [4]. The parameter *pusch-HoppingOffset*, $N^{\text{HO}}_{\text{RB}}$, is provided by higher layers. The size $N^{\text{sb}}_{\text{RB}}$ of each sub-band is given by,

Petitioners' Exhibit 1003, p. 1094
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$N_{\mathrm{RB}}^{\mathrm{sb}} = \begin{cases} N_{\mathrm{RB}}^{\mathrm{UL}} & N_{\mathrm{sb}} = 1 \\ \left\lfloor \left(N_{\mathrm{RB}}^{\mathrm{UL}} - N_{\mathrm{RB}}^{\mathrm{HO}} - N_{\mathrm{RB}}^{\mathrm{HO}} \bmod 2 \right) / N_{\mathrm{sb}} \right\rfloor & N_{\mathrm{sb}} > 1 \end{cases}$$

where the number of sub-bands N_{sb} is given by higher layers. The function $f_{\mathrm{m}}(i) \in \{0,1\}$ determines whether mirroring is used or not. The parameter *Hopping-mode* provided by higher layers determines if hopping is "inter-subframe" or "intra and inter-subframe".

The hopping function $f_{\mathrm{hop}}(i)$ and the function $f_{\mathrm{m}}(i)$ are given by

$$f_{\mathrm{hop}}(i) = \begin{cases} 0 & N_{\mathrm{sb}} = 1 \\ \left(f_{\mathrm{hop}}(i-1) + \sum_{k=i\cdot 10+1}^{i\cdot 10+9} c(k) \times 2^{k-(i\cdot 10+1)} \right) \bmod N_{\mathrm{sb}} & N_{\mathrm{sb}} = 2 \\ \left(f_{\mathrm{hop}}(i-1) + \left(\sum_{k=i\cdot 10+1}^{i\cdot 10+9} c(k) \times 2^{k-(i\cdot 10+1)} \right) \bmod (N_{\mathrm{sb}} - 1) + 1 \right) \bmod N_{\mathrm{sb}} & N_{\mathrm{sb}} > 2 \end{cases}$$

$$f_{\mathrm{m}}(i) = \begin{cases} i \bmod 2 & N_{\mathrm{sb}} = 1 \text{ and intra and inter} - \text{subframe hopping} \\ \mathrm{CURRENT\_TX\_NB} \bmod 2 & N_{\mathrm{sb}} = 1 \text{ and inter} - \text{subframe hopping} \\ c(i \cdot 10) & N_{\mathrm{sb}} > 1 \end{cases}$$

where $f_{\mathrm{hop}}(-1) = 0$ and the pseudo-random sequence $c(i)$ is given by clause 7.2 and CURRENT_TX_NB indicates the transmission number for the transport block transmitted in slot n_{s} as defined in [8]. The pseudo-random sequence generator shall be initialised with $c_{\mathrm{init}} = N_{\mathrm{ID}}^{\mathrm{cell}}$ for frame structure type 1 and $c_{\mathrm{init}} = 2^9 \cdot (n_{\mathrm{f}} \bmod 4) + N_{\mathrm{ID}}^{\mathrm{cell}}$ for frame structure type 2 at the start of each frame.

For BL/CE UEs, the PRB resources within the narrowband $n_{\mathrm{NB}}^{(i_0)}$ for PUSCH transmission in the first subframe are obtained from the DCI as described in clauses 5.3.3.1.10 and 5.3.3.1.11 in [3]. The PUSCH is transmitted with $N_{\mathrm{rep}}^{\mathrm{PUSCH}} \geq 1$ repetitions. The PUSCH transmission spans $N_{\mathrm{abs}}^{\mathrm{PUSCH}} \geq N_{\mathrm{rep}}^{\mathrm{PUSCH}}$ consecutive subframes, including invalid subframes where the UE postpones the PUSCH transmission. For BL/CE UE in CEModeA, PUSCH frequency hopping is enabled when the higher-layer parameter *pusch-HoppingConfig* is set and the frequency hopping flag in DCI format 6-0A indicates frequency hopping, otherwise frequency hopping is disabled. If frequency hopping is not enabled for PUSCH, the PUSCH repetitions are located at the same PRB resources at the same narrowband $n_{\mathrm{NB}}^{(i_0)}$. If frequency hopping is enabled for PUSCH, PUSCH is transmitted in subframe i within the $N_{\mathrm{abs}}^{\mathrm{PUSCH}}$ consecutive uplink subframes using the same PRB resources within narrowband

$$n_{\mathrm{NB}}^{(i)} = \begin{cases} n_{\mathrm{NB}}^{(i_0)} & \text{if } \left\lfloor i / N_{\mathrm{NB}}^{\mathrm{ch,UL}} - j_0 \right\rfloor \bmod 2 = 0 \\ \left(n_{\mathrm{NB}}^{(i_0)} + f_{\mathrm{NB,hop}}^{\mathrm{PUSCH}} \right) \bmod N_{\mathrm{NB}}^{\mathrm{UL}} & \text{if } \left\lfloor i / N_{\mathrm{NB}}^{\mathrm{ch,UL}} - j_0 \right\rfloor \bmod 2 = 1 \end{cases}$$

$$j_0 = \left\lfloor i_0 / N_{\mathrm{NB}}^{\mathrm{ch,UL}} \right\rfloor$$

$$i_0 \leq i \leq i_0 + N_{\mathrm{abs}}^{\mathrm{PUSCH}} - 1$$

where i_0 is the absolute subframe number of the first UL subframe intended for carrying the PUSCH and $N_{\mathrm{NB}}^{\mathrm{ch,UL}}$ and $f_{\mathrm{NB,hop}}^{\mathrm{PUSCH}}$ are a cell-specific higher-layer parameters. For the $N_{\mathrm{abs}}^{\mathrm{PUSCH}}$ consecutive subframes, the UE shall not transmit PUSCH in subframe i if it is not a valid uplink subframe.

For BL/CE UEs, PUSCH transmission associated with Temporary C-RNTI, frequency hopping of the PUSCH is enabled when higher layer parameter *rar-HoppingConfig* is set. Further

- if PRACH CE level 0 or 1 is used for the last PRACH attempt, $N_{\mathrm{NB}}^{\mathrm{ch,UL}}$ is set to the higher layer parameter *interval-UlHoppingConfigCommonModeA*;
- if PRACH CE level 2 or 3 is used for the last PRACH attempt, $N_{\mathrm{NB}}^{\mathrm{ch,UL}}$ is set to the higher layer parameter *interval-UlHoppingConfigCommonModeB*.

Petitioners' Exhibit 1003, p. 1095
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Petitioners' Exhibit 1003, p. 1096
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.4 Physical uplink control channel

The physical uplink control channel, PUCCH, carries uplink control information. Simultaneous transmission of PUCCH and PUSCH from the same UE is supported if enabled by higher layers. For frame structure type 2, the PUCCH is not transmitted in the UpPTS field.

The physical uplink control channel supports multiple formats as shown in Table 5.4-1 with different number of bits per subframe, where $M_{\mathrm{RB}}^{\mathrm{PUCCH4}}$ represents the bandwidth of the PUCCH format 4 as defined by clause 5.4.2B, and N_0^{PUCCH} and N_1^{PUCCH} are defined in Table 5.4.2C-1.

Formats 2a and 2b are supported for normal cyclic prefix only.

Table 5.4-1: Supported PUCCH formats

PUCCH format	Modulation scheme	Number of bits per subframe, M_{bit}
1	N/A	N/A
1a	BPSK	1
1b	QPSK	2
2	QPSK	20
2a	QPSK+BPSK	21
2b	QPSK+QPSK	22
3	QPSK	48
4	QPSK	$M_{\mathrm{RB}}^{\mathrm{PUCCH4}} \cdot N_{\mathrm{sc}}^{\mathrm{RB}} \cdot \left(N_0^{\mathrm{PUCCH}} + N_1^{\mathrm{PUCCH}}\right) \cdot 2$
5	QPSK	$N_{\mathrm{sc}}^{\mathrm{RB}} \cdot \left(N_0^{\mathrm{PUCCH}} + N_1^{\mathrm{PUCCH}}\right)$

All PUCCH formats use a cyclic shift, $n_{\mathrm{cs}}^{\mathrm{cell}}(n_{\mathrm{s}}, l)$, which varies with the symbol number l and the slot number n_{s} according to

$$n_{\mathrm{cs}}^{\mathrm{cell}}(n_{\mathrm{s}}, l) = \sum_{i=0}^{7} c(8N_{\mathrm{symb}}^{\mathrm{UL}} \cdot n_{\mathrm{s}} + 8l + i) \cdot 2^i$$

where the pseudo-random sequence $c(i)$ is defined by clause 7.2. The pseudo-random sequence generator shall be initialized with $c_{\mathrm{init}} = n_{\mathrm{ID}}^{\mathrm{RS}}$, where $n_{\mathrm{ID}}^{\mathrm{RS}}$ is given by clause 5.5.1.5 with $N_{\mathrm{ID}}^{\mathrm{cell}}$ corresponding to the primary cell, at the beginning of each radio frame.

The physical resources used for PUCCH depends on two parameters, $N_{\mathrm{RB}}^{(2)}$ and $N_{\mathrm{cs}}^{(1)}$, given by higher layers. The variable $N_{\mathrm{RB}}^{(2)} \geq 0$ denotes the bandwidth in terms of resource blocks that are available for use by PUCCH formats 2/2a/2b transmission in each slot. The variable $N_{\mathrm{cs}}^{(1)}$ denotes the number of cyclic shift used for PUCCH formats 1/1a/1b in a resource block used for a mix of formats 1/1a/1b and 2/2a/2b. The value of $N_{\mathrm{cs}}^{(1)}$ is an integer multiple of $\Delta_{\mathrm{shift}}^{\mathrm{PUCCH}}$ within the range of {0, 1, …, 7}, where $\Delta_{\mathrm{shift}}^{\mathrm{PUCCH}}$ is provided by higher layers. No mixed resource block is present if $N_{\mathrm{cs}}^{(1)} = 0$. At most one resource block in each slot supports a mix of formats 1/1a/1b and 2/2a/2b. Resources used for transmission of PUCCH formats 1/1a/1b, 2/2a/2b, 3, 4, and 5 are represented by the non-negative indices $n_{\mathrm{PUCCH}}^{(1,\tilde{p})}$, $n_{\mathrm{PUCCH}}^{(2,\tilde{p})} < N_{\mathrm{RB}}^{(2)} N_{\mathrm{sc}}^{\mathrm{RB}} + \left\lceil \frac{N_{\mathrm{cs}}^{(1)}}{8} \right\rceil \cdot (N_{\mathrm{sc}}^{\mathrm{RB}} - N_{\mathrm{cs}}^{(1)} - 2)$, $n_{\mathrm{PUCCH}}^{(3,\tilde{p})}$, $n_{\mathrm{PUCCH}}^{(4)}$ and $n_{\mathrm{PUCCH}}^{(5)}$, respectively.

5.4.1 PUCCH formats 1, 1a and 1b

For PUCCH format 1, information is carried by the presence/absence of transmission of PUCCH from the UE. In the remainder of this clause, $d(0) = 1$ shall be assumed for PUCCH format 1.

For PUCCH formats 1a and 1b, one or two explicit bits are transmitted, respectively. The block of bits $b(0),...,b(M_{\mathrm{bit}} - 1)$ shall be modulated as described in Table 5.4.1-1, resulting in a complex-valued symbol $d(0)$. The modulation schemes for the different PUCCH formats are given by Table 5.4-1.

Petitioners' Exhibit 1003, p. 1097
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The complex-valued symbol $d(0)$ shall be multiplied with a cyclically shifted length $N_{\text{seq}}^{\text{PUCCH}} = 12$ sequence $r_{u,v}^{(\alpha_{\tilde{p}})}(n)$ for each of the P antenna ports used for PUCCH transmission according to

$$y^{(\tilde{p})}(n) = \frac{1}{\sqrt{P}} d(0) \cdot r_{u,v}^{(\alpha_{\tilde{p}})}(n), \qquad n = 0,1,\ldots, N_{\text{seq}}^{\text{PUCCH}} - 1$$

where $r_{u,v}^{(\alpha_{\tilde{p}})}(n)$ is defined by clause 5.5.1 with $M_{\text{sc}}^{\text{RS}} = N_{\text{seq}}^{\text{PUCCH}}$. The antenna-port specific cyclic shift $\alpha_{\tilde{p}}$ varies between symbols and slots as defined below.

The block of complex-valued symbols $y^{(\tilde{p})}(0),\ldots, y^{(\tilde{p})}(N_{\text{seq}}^{\text{PUCCH}} - 1)$ shall be scrambled by $S(n_s)$ and block-wise spread with the antenna-port specific orthogonal sequence $w_{n_{\text{oc}}^{(\tilde{p})}}(i)$ according to

$$z^{(\tilde{p})}\left(m' \cdot N_{\text{SF}}^{\text{PUCCH}} \cdot N_{\text{seq}}^{\text{PUCCH}} + m \cdot N_{\text{seq}}^{\text{PUCCH}} + n\right) = S(n_{\text{s}}) \cdot w_{n_{\text{oc}}^{(\tilde{p})}}(m) \cdot y^{(\tilde{p})}(n)$$

where

$$\begin{aligned} m &= 0,\ldots, N_{\text{SF}}^{\text{PUCCH}} - 1 \\ n &= 0,\ldots, N_{\text{seq}}^{\text{PUCCH}} - 1 \\ m' &= 0,1 \end{aligned}$$

and

$$S(n_{\text{s}}) = \begin{cases} 1 & \text{if } n'_{\tilde{p}}(n_{\text{s}}) \bmod 2 = 0 \\ e^{j\pi/2} & \text{otherwise} \end{cases}$$

with $N_{\text{SF}}^{\text{PUCCH}}$ for the two slots in a subframe given by Table 5.4.1-1a. The sequence $w_{n_{\text{oc}}^{(\tilde{p})}}(i)$ is given by Table 5.4.1-2 and Table 5.4.1-3 and $n'_{\tilde{p}}(n_{\text{s}})$ is defined below.

Resources used for transmission of PUCCH format 1, 1a and 1b are identified by a resource index $n_{\text{PUCCH}}^{(1,\tilde{p})}$ from which the orthogonal sequence index $n_{\text{oc}}^{(\tilde{p})}(n_{\text{s}})$ and the cyclic shift $\alpha_{\tilde{p}}(n_{\text{s}}, l)$ are determined according to

$$n_{\text{oc}}^{(\tilde{p})}(n_{\text{s}}) = \begin{cases} \left\lfloor n'_{\tilde{p}}(n_{\text{s}}) \cdot \Delta_{\text{shift}}^{\text{PUCCH}} / N' \right\rfloor & \text{for normal cyclic prefix} \\ 2 \cdot \left\lfloor n'_{\tilde{p}}(n_{\text{s}}) \cdot \Delta_{\text{shift}}^{\text{PUCCH}} / N' \right\rfloor & \text{for extended cyclic prefix} \end{cases}$$

$$\alpha_{\tilde{p}}(n_{\text{s}}, l) = 2\pi \cdot n_{\text{cs}}^{(\tilde{p})}(n_{\text{s}}, l) / N_{\text{sc}}^{\text{RB}}$$

$$n_{\text{cs}}^{(\tilde{p})}(n_{\text{s}}, l) = \begin{cases} \left[n_{\text{cs}}^{\text{cell}}(n_{\text{s}}, l) + \left(n'_{\tilde{p}}(n_{\text{s}}) \cdot \Delta_{\text{shift}}^{\text{PUCCH}} + \left(n_{\text{oc}}^{(\tilde{p})}(n_{\text{s}}) \bmod \Delta_{\text{shift}}^{\text{PUCCH}} \right) \right) \bmod N' \right] \bmod N_{\text{sc}}^{\text{RB}} & \text{for normal cyclic prefix} \\ \left[n_{\text{cs}}^{\text{cell}}(n_{\text{s}}, l) + \left(n'_{\tilde{p}}(n_{\text{s}}) \cdot \Delta_{\text{shift}}^{\text{PUCCH}} + n_{\text{oc}}^{(\tilde{p})}(n_{\text{s}}) / 2 \right) \bmod N' \right] \bmod N_{\text{sc}}^{\text{RB}} & \text{for extended cyclic prefix} \end{cases}$$

where

$$N' = \begin{cases} N_{\text{cs}}^{(1)} & \text{if } n_{\text{PUCCH}}^{(1,\tilde{p})} < c \cdot N_{\text{cs}}^{(1)} / \Delta_{\text{shift}}^{\text{PUCCH}} \\ N_{\text{sc}}^{\text{RB}} & \text{otherwise} \end{cases}$$

$$c = \begin{cases} 3 & \text{normal cyclic prefix} \\ 2 & \text{extended cyclic prefix} \end{cases}$$

The resource indices within the two resource blocks in the two slots of a subframe to which the PUCCH is mapped are given by

Petitioners' Exhibit 1003, p. 1098
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$n'_{\tilde{p}}(n_s)=\begin{cases} n^{(1,\tilde{p})}_{\text{PUCCH}} & \text{if } n^{(1,\tilde{p})}_{\text{PUCCH}} < c\cdot N^{(1)}_{\text{cs}}/\Delta^{\text{PUCCH}}_{\text{shift}} \\ \left(n^{(1,\tilde{p})}_{\text{PUCCH}} - c\cdot N^{(1)}_{\text{cs}}/\Delta^{\text{PUCCH}}_{\text{shift}}\right)\bmod\left(c\cdot N^{\text{RB}}_{\text{sc}}/\Delta^{\text{PUCCH}}_{\text{shift}}\right) & \text{otherwise} \end{cases}$$

for $n_s \bmod 2 = 0$ and by

$$n'_{\tilde{p}}(n_s)=\begin{cases} \left[c\left(n'_{\tilde{p}}(n_s-1)+1\right)\right] \bmod\left(cN^{\text{RB}}_{\text{sc}}/\Delta^{\text{PUCCH}}_{\text{shift}}+1\right)-1 & n^{(1,\tilde{p})}_{\text{PUCCH}} \geq c\cdot N^{(1)}_{\text{cs}}/\Delta^{\text{PUCCH}}_{\text{shift}} \\ \left\lfloor h_{\tilde{p}}/c \right\rfloor + \left(h_{\tilde{p}} \bmod c\right)N'/\Delta^{\text{PUCCH}}_{\text{shift}} & \text{otherwise} \end{cases}$$

for $n_s \bmod 2 = 1$, where $h_{\tilde{p}} = \left(n'_{\tilde{p}}(n_s-1)+d\right)\bmod\left(cN'/\Delta^{\text{PUCCH}}_{\text{shift}t}\right)$, with $d=2$ for normal CP and $d=0$ for extended CP.

The parameter *deltaPUCCH-Shift* $\Delta^{\text{PUCCH}}_{\text{shift}}$ is provided by higher layers.

Table 5.4.1-1: Modulation symbol $d(0)$ for PUCCH formats 1a and 1b

PUCCH format	$b(0),...,b(M_{\text{bit}}-1)$	$d(0)$
1a	0	1
	1	−1
1b	00	1
	01	$-j$
	10	j
	11	−1

Table 5.4.1-1a: The quantity $N^{\text{PUCCH}}_{\text{SF}}$ for PUCCH formats 1a and 1b

PUCCH format	$N^{\text{PUCCH}}_{\text{SF}}$	
	first slot	second slot
normal 1/1a/1b	4	4
type-0 shortened 1/1a/1b	4	3
type-1 shortened 1/1a/1b	3	4
type-2 shortened 1/1a/1b	3	3

Table 5.4.1-2: Orthogonal sequences $\left[w(0) \quad \cdots \quad w(N^{\text{PUCCH}}_{\text{SF}}-1)\right]$ for $N^{\text{PUCCH}}_{\text{SF}}=4$

Sequence index $n^{(\tilde{p})}_{\text{oc}}(n_s)$	Orthogonal sequences $\left[w(0) \quad \cdots \quad w(N^{\text{PUCCH}}_{\text{SF}}-1)\right]$
0	$[+1 \quad +1 \quad +1 \quad +1]$
1	$[+1 \quad -1 \quad +1 \quad -1]$
2	$[+1 \quad -1 \quad -1 \quad +1]$

Petitioners' Exhibit 1003, p. 1099
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.4.1-3: Orthogonal sequences $\begin{bmatrix} w(0) & \cdots & w(N_{\mathrm{SF}}^{\mathrm{PUCCH}}-1) \end{bmatrix}$ for $N_{\mathrm{SF}}^{\mathrm{PUCCH}}=3$

Sequence index $n_{\mathrm{oc}}^{(\tilde{p})}(n_s)$	Orthogonal sequences $\begin{bmatrix} w(0) & \cdots & w(N_{\mathrm{SF}}^{\mathrm{PUCCH}}-1) \end{bmatrix}$
0	$\begin{bmatrix} 1 & 1 & 1 \end{bmatrix}$
1	$\begin{bmatrix} 1 & e^{j2\pi/3} & e^{j4\pi/3} \end{bmatrix}$
2	$\begin{bmatrix} 1 & e^{j4\pi/3} & e^{j2\pi/3} \end{bmatrix}$

Petitioners' Exhibit 1003, p. 1100
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.4.2 PUCCH formats 2, 2a and 2b

The block of bits $b(0),...,b(19)$ shall be scrambled with a UE-specific scrambling sequence, resulting in a block of scrambled bits $\tilde{b}(0),...,\tilde{b}(19)$ according to

$$\tilde{b}(i) = \left(b(i) + c(i)\right) \bmod 2$$

where the scrambling sequence $c(i)$ is given by clause 7.2. The scrambling sequence generator shall be initialised with $c_{\text{init}} = \left(\lfloor n_s/2 \rfloor + 1\right) \cdot \left(2N_{\text{ID}}^{\text{cell}} + 1\right) \cdot 2^{16} + n_{\text{RNTI}}$ at the start of each subframe where n_{RNTI} is C-RNTI.

The block of scrambled bits $\tilde{b}(0),...,\tilde{b}(19)$ shall be QPSK modulated as described in clause 7.1, resulting in a block of complex-valued modulation symbols $d(0),...,d(9)$.

Each complex-valued symbol $d(0),...,d(9)$ shall be multiplied with a cyclically shifted length $N_{\text{seq}}^{\text{PUCCH}} = 12$ sequence $r_{u,v}^{(\alpha_{\tilde{p}})}(n)$ for each of the P antenna ports used for PUCCH transmission according to

$$z^{(\tilde{p})}(N_{\text{seq}}^{\text{PUCCH}} \cdot n + i) = \frac{1}{\sqrt{P}} d(n) \cdot r_{u,v}^{(\alpha_{\tilde{p}})}(i)$$
$$n = 0,1,...,9$$
$$i = 0,1,...,N_{\text{sc}}^{\text{RB}} - 1$$

where $r_{u,v}^{(\alpha_{\tilde{p}})}(i)$ is defined by clause 5.5.1 with $M_{\text{sc}}^{\text{RS}} = N_{\text{seq}}^{\text{PUCCH}}$.

Resources used for transmission of PUCCH formats 2/2a/2b are identified by a resource index $n_{\text{PUCCH}}^{(2,\tilde{p})}$ from which the cyclic shift $\alpha_{\tilde{p}}(n_s, l)$ is determined according to

$$\alpha_{\tilde{p}}(n_s, l) = 2\pi \cdot n_{\text{cs}}^{(\tilde{p})}(n_s, l) \big/ N_{\text{sc}}^{\text{RB}}$$

where

$$n_{\text{cs}}^{(\tilde{p})}(n_s, l) = \left(n_{\text{cs}}^{\text{cell}}(n_s, l) + n'_{\tilde{p}}(n_s)\right) \bmod N_{\text{sc}}^{\text{RB}}$$

and

$$n'_{\tilde{p}}(n_s) = \begin{cases} n_{\text{PUCCH}}^{(2,\tilde{p})} \bmod N_{\text{sc}}^{\text{RB}} & \text{if } n_{\text{PUCCH}}^{(2,\tilde{p})} < N_{\text{sc}}^{\text{RB}} N_{\text{RB}}^{(2)} \\ \left(n_{\text{PUCCH}}^{(2,\tilde{p})} + N_{\text{cs}}^{(1)} + 1\right) \bmod N_{\text{sc}}^{\text{RB}} & \text{otherwise} \end{cases}$$

for $n_s \bmod 2 = 0$ and by

$$n'_{\tilde{p}}(n_s) = \begin{cases} \left[N_{\text{sc}}^{\text{RB}} \left(n'_{\tilde{p}}(n_s - 1) + 1\right)\right] \bmod \left(N_{\text{sc}}^{\text{RB}} + 1\right) - 1 & \text{if } n_{\text{PUCCH}}^{(2,\tilde{p})} < N_{\text{sc}}^{\text{RB}} N_{\text{RB}}^{(2)} \\ \left(N_{\text{sc}}^{\text{RB}} - 2 - n_{\text{PUCCH}}^{(2,\tilde{p})}\right) \bmod N_{\text{sc}}^{\text{RB}} & \text{otherwise} \end{cases}$$

for $n_s \bmod 2 = 1$.

For PUCCH formats 2a and 2b, supported for normal cyclic prefix only, the bit(s) $b(20),...,b(M_{\text{bit}} - 1)$ shall be modulated as described in Table 5.4.2-1 resulting in a single modulation symbol $d(10)$ used in the generation of the reference-signal for PUCCH format 2a and 2b as described in clause 5.5.2.2.1.

Petitioners' Exhibit 1003, p. 1101
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.4.2-1: Modulation symbol $d(10)$ for PUCCH formats 2a and 2b

PUCCH format	$b(20),...,b(M_{\text{bit}}-1)$	$d(10)$
2a	0	1
	1	-1
2b	00	1
	01	$-j$
	10	j
	11	-1

5.4.2A PUCCH format 3

The block of bits $b(0),...,b(M_{\text{bit}}-1)$ shall be scrambled with a UE-specific scrambling sequence, resulting in a block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{bit}}-1)$ according to

$$\tilde{b}(i) = \left(b(i) + c(i)\right) \bmod 2$$

where the scrambling sequence $c(i)$ is given by clause 7.2. The scrambling sequence generator shall be initialised with $c_{\text{init}} = \left(\lfloor n_s/2 \rfloor + 1\right) \cdot \left(2N_{\text{ID}}^{\text{cell}} + 1\right) \cdot 2^{16} + n_{\text{RNTI}}$ at the start of each subframe where n_{RNTI} is the C-RNTI.

The block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{bit}}-1)$ shall be QPSK modulated as described in Subclause 7.1, resulting in a block of complex-valued modulation symbols $d(0),...,d(M_{\text{symb}}-1)$ where $M_{\text{symb}} = M_{\text{bit}}/2 = 2N_{\text{sc}}^{\text{RB}}$.

The complex-valued symbols $d(0),...,d(M_{\text{symb}}-1)$ shall be block-wise spread with the orthogonal sequences $w_{n_{oc,0}^{(\tilde{p})}}(i)$ and $w_{n_{oc,1}^{(\tilde{p})}}(i)$ resulting in $N_{\text{SF},0}^{\text{PUCCH}} + N_{\text{SF},1}^{\text{PUCCH}}$ sets of $N_{\text{sc}}^{\text{RB}}$ values each according to

$$y_n^{(\tilde{p})}(i) = \begin{cases} w_{n_{oc,0}^{(\tilde{p})}}(\bar{n}) \cdot e^{j\pi \lfloor n_{\text{cs}}^{\text{cell}}(n_s,l)/64 \rfloor / 2} \cdot d(i) & n < N_{\text{SF},0}^{\text{PUCCH}} \\ w_{n_{oc,1}^{(\tilde{p})}}(\bar{n}) \cdot e^{j\pi \lfloor n_{\text{cs}}^{\text{cell}}(n_s,l)/64 \rfloor / 2} \cdot d(N_{\text{sc}}^{\text{RB}} + i) & \text{otherwise} \end{cases}$$

$$\bar{n} = n \bmod N_{\text{SF},0}^{\text{PUCCH}}$$

$$n = 0,..., N_{\text{SF},0}^{\text{PUCCH}} + N_{\text{SF},1}^{\text{PUCCH}} - 1$$

$$i = 0,1,..., N_{\text{sc}}^{\text{RB}} - 1$$

where $N_{\text{SF},0}^{\text{PUCCH}} = N_{\text{SF},1}^{\text{PUCCH}} = 5$ for both slots in a subframe using normal PUCCH format 3 and $N_{\text{SF},0}^{\text{PUCCH}} = 5$, $N_{\text{SF},1}^{\text{PUCCH}} = 4$ holds for the first and second slot, respectively, in a subframe using shortened PUCCH format 3. The orthogonal sequences $w_{n_{oc,0}^{(\tilde{p})}}(i)$ and $w_{n_{oc,1}^{(\tilde{p})}}(i)$ are given by Table 5.4.2A-1. Resources used for transmission of PUCCH formats 3 are identified by a resource index $n_{\text{PUCCH}}^{(3,\tilde{p})}$ from which the quantities $n_{\text{oc},0}^{(\tilde{p})}$ and $n_{\text{oc},1}^{(\tilde{p})}$ are derived according to

$$n_{\text{oc},0}^{(\tilde{p})} = n_{\text{PUCCH}}^{(3,\tilde{p})} \bmod N_{\text{SF},1}^{\text{PUCCH}}$$

$$n_{\text{oc},1}^{(\tilde{p})} = \begin{cases} \left(3n_{\text{oc},0}^{(\tilde{p})}\right) \bmod N_{\text{SF},1}^{\text{PUCCH}} & \text{if } N_{\text{SF},1}^{\text{PUCCH}} = 5 \\ n_{\text{oc},0}^{(\tilde{p})} \bmod N_{\text{SF},1}^{\text{PUCCH}} & \text{otherwise} \end{cases}$$

Each set of complex-valued symbols shall be cyclically shifted according to

$$\tilde{y}_n^{(\tilde{p})}(i) = y_n^{(\tilde{p})}\left(\left(i + n_{\text{cs}}^{\text{cell}}(n_s,l)\right) \bmod N_{\text{sc}}^{\text{RB}}\right)$$

where $n_{\text{cs}}^{\text{cell}}(n_s,l)$ is given by Subclause 5.4, n_s is the slot number within a radio frame and l is the SC-FDMA symbol number within a slot.

Petitioners' Exhibit 1003, p. 1102
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The shifted sets of complex-valued symbols shall be transform precoded according to

$$z^{(\tilde{p})}(n \cdot N_{\text{sc}}^{\text{RB}} + k) = \frac{1}{\sqrt{P}} \frac{1}{\sqrt{N_{\text{sc}}^{\text{RB}}}} \sum_{i=0}^{N_{\text{sc}}^{\text{RB}}-1} \tilde{y}_n^{(\tilde{p})}(i) e^{-j\frac{2\pi ik}{N_{\text{sc}}^{\text{RB}}}}$$

$$k = 0,\ldots, N_{\text{sc}}^{\text{RB}} - 1$$

$$n = 0,\ldots, N_{\text{SF},0}^{\text{PUCCH}} + N_{\text{SF},1}^{\text{PUCCH}} - 1$$

where P is the number of antenna ports used for PUCCH transmission, resulting in a block of complex-valued symbols $z^{(\tilde{p})}(0),\ldots, z^{(\tilde{p})}\left(\left(N_{\text{SF},0}^{\text{PUCCH}} + N_{\text{SF},1}^{\text{PUCCH}}\right)N_{\text{sc}}^{\text{RB}} - 1\right)$.

Table 5.4.2A-1: The orthogonal sequence $w_{n_{\text{oc}}}(i)$

Sequence index n_{oc}	Orthogonal sequence $\left[w_{n_{\text{oc}}}(0) \quad \cdots \quad w_{n_{\text{oc}}}(N_{\text{SF}}^{\text{PUCCH}} - 1)\right]$	
	$N_{\text{SF}}^{\text{PUCCH}} = 5$	$N_{\text{SF}}^{\text{PUCCH}} = 4$
0	$\left[1 \quad 1 \quad 1 \quad 1 \quad 1\right]$	$\left[+1 \quad +1 \quad +1 \quad +1\right]$
1	$\left[1 \quad e^{j2\pi/5} \quad e^{j4\pi/5} \quad e^{j6\pi/5} \quad e^{j8\pi/5}\right]$	$\left[+1 \quad -1 \quad +1 \quad -1\right]$
2	$\left[1 \quad e^{j4\pi/5} \quad e^{j8\pi/5} \quad e^{j2\pi/5} \quad e^{j6\pi/5}\right]$	$\left[+1 \quad +1 \quad -1 \quad -1\right]$
3	$\left[1 \quad e^{j6\pi/5} \quad e^{j2\pi/5} \quad e^{j8\pi/5} \quad e^{j4\pi/5}\right]$	$\left[+1 \quad -1 \quad -1 \quad +1\right]$
4	$\left[1 \quad e^{j8\pi/5} \quad e^{j6\pi/5} \quad e^{j4\pi/5} \quad e^{j2\pi/5}\right]$	-

Petitioners' Exhibit 1003, p. 1103
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.4.2B PUCCH format 4

The block of bits $b(0),...,b(M_{\text{bit}}-1)$ shall be scrambled with a UE-specific scrambling sequence, resulting in a block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{bit}}-1)$ according to

$$\tilde{b}(i) = \left(b(i) + c(i)\right) \bmod 2$$

where the scrambling sequence $c(i)$ is given by clause 7.2. The scrambling sequence generator shall be initialised with $c_{\text{init}} = \left(\lfloor n_s/2 \rfloor + 1\right) \cdot \left(2N_{\text{ID}}^{\text{cell}} + 1\right) \cdot 2^{16} + n_{\text{RNTI}}$ at the start of each subframe where n_{RNTI} is the C-RNTI.

The block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{bit}}-1)$ shall be QPSK modulated as described in Subclause 7.1, resulting in a block of complex-valued modulation symbols $d(0),...,d(M_{\text{symb}}-1)$ where $M_{\text{symb}} = M_{\text{bit}}/2$.

The block of complex-valued symbols $d(0),...,d(M_{\text{symb}}-1)$ is divided into $N_0^{\text{PUCCH}} + N_1^{\text{PUCCH}}$ sets, each corresponding to one SC-FDMA symbol. Transform precoding shall be applied according to

$$z^{(\tilde{p})}(l \cdot M_{\text{sc}}^{\text{PUCCH4}} + k) = \frac{1}{\sqrt{M_{\text{sc}}^{\text{PUCCH4}}}} \sum_{i=0}^{M_{\text{sc}}^{\text{PUCCH4}}-1} d(l \cdot M_{\text{sc}}^{\text{PUCCH4}} + i) e^{-j\frac{2\pi ik}{M_{\text{sc}}^{\text{PUCCH4}}}}$$
$$k = 0,..., M_{\text{sc}}^{\text{PUCCH4}} - 1$$
$$l = 0,..., N_0^{\text{PUCCH}} + N_1^{\text{PUCCH}} - 1$$

where $\tilde{p} = 0$, N_0^{PUCCH} and N_1^{PUCCH} are given by Table 5.4.2C-1 for normal PUCCH format 4 and shortened PUCCH format 4, resulting in a block of complex-valued symbols $z^{(\tilde{p})}(0),...,z^{(\tilde{p})}(M_{\text{symb}}-1)$. The variable $M_{\text{sc}}^{\text{PUCCH4}} = M_{\text{RB}}^{\text{PUCCH4}} \cdot N_{\text{sc}}^{\text{RB}}$, where $M_{\text{RB}}^{\text{PUCCH4}}$ represents the bandwidth of the PUCCH format 4 in terms of resource blocks, shall fulfil

$$M_{\text{RB}}^{\text{PUCCH4}} = 2^{\alpha_2} \cdot 3^{\alpha_3} \cdot 5^{\alpha_5} \le N_{\text{RB}}^{\text{UL}}$$

where $\alpha_2, \alpha_3, \alpha_5$ is a set of non-negative integers.

5.4.2C PUCCH format 5

The block of bits $b(0),...,b(M_{\text{bit}}-1)$ shall be scrambled with a UE-specific scrambling sequence, resulting in a block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{bit}}-1)$ according to

$$\tilde{b}(i) = \left(b(i) + c(i)\right) \bmod 2$$

where the scrambling sequence $c(i)$ is given by clause 7.2. The scrambling sequence generator shall be initialised with $c_{\text{init}} = \left(\lfloor n_s/2 \rfloor + 1\right) \cdot \left(2N_{\text{ID}}^{\text{cell}} + 1\right) \cdot 2^{16} + n_{\text{RNTI}}$ at the start of each subframe where n_{RNTI} is the C-RNTI.

The block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{bit}}-1)$ shall be QPSK modulated as described in Subclause 7.1, resulting in a block of complex-valued modulation symbols $d(0),...,d(M_{\text{symb}}-1)$ where $M_{\text{symb}} = M_{\text{bit}}/2$.

The complex-valued symbols $d(0),...,d(M_{\text{symb}}-1)$ shall be divided into $N_0^{\text{PUCCH}} + N_1^{\text{PUCCH}}$ sets, each corresponding to one SC-FDMA symbol. Block-wise spreading shall be applied according to

$$y_n(i) = w_{n_{\text{oc}}}(i) \cdot d\left(i \bmod N_{\text{sc}}^{\text{RB}} / N_{\text{SF}}^{\text{PUCCH}} + n \cdot N_{\text{sc}}^{\text{RB}} / N_{\text{SF}}^{\text{PUCCH}}\right)$$
$$n = 0,..., N_0^{\text{PUCCH}} + N_1^{\text{PUCCH}} - 1$$
$$i = 0,1,..., N_{\text{sc}}^{\text{RB}} - 1$$

Petitioners' Exhibit 1003, p. 1104
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

where $N_{\mathrm{SF}}^{\mathrm{PUCCH}} = 2$, N_0^{PUCCH} and N_1^{PUCCH} are given by Table 5.4.2C-1 for normal PUCCH format 5 and shortened PUCCH format 5, and $w_{n_{\mathrm{oc}}}(i)$ is given by Table 5.4.2C-2 with n_{oc} provided by higher layers.

The block-wise spread complex-valued symbols shall be transform precoded according to

$$z^{(\tilde{p})}(n \cdot N_{\mathrm{sc}}^{\mathrm{RB}} + k) = \frac{1}{\sqrt{N_{\mathrm{sc}}^{\mathrm{RB}}}} \sum_{i=0}^{N_{\mathrm{sc}}^{\mathrm{RB}}-1} y_n(i) e^{-j\frac{2\pi ik}{N_{\mathrm{sc}}^{\mathrm{RB}}}}$$
$$k = 0,\ldots, N_{\mathrm{sc}}^{\mathrm{RB}} - 1$$
$$n = 0,\ldots, N_0^{\mathrm{PUCCH}} + N_1^{\mathrm{PUCCH}} - 1$$

where $\tilde{p} = 0$, resulting in a block of complex-valued symbols $z^{(\tilde{p})}(0),\ldots, z^{(\tilde{p})}\left(\left(N_0^{\mathrm{PUCCH}} + N_1^{\mathrm{PUCCH}}\right)N_{\mathrm{sc}}^{\mathrm{RB}} - 1\right)$.

Table 5.4.2C-1: The quantities N_0^{PUCCH} and N_1^{PUCCH}

PUCCH format type	Normal cyclic prefix		Extended cyclic prefix	
	N_0^{PUCCH}	N_1^{PUCCH}	N_0^{PUCCH}	N_1^{PUCCH}
Normal PUCCH format	6	6	5	5
Shortened PUCCH format	6	5	5	4

Table 5.4.2C-2: Orthogonal sequences $w_{n_{\mathrm{oc}}}(i)$

n_{oc}	Orthogonal sequences $\left[w_{n_{CDM}}(0) \quad \cdots \quad w_{n_{CDM}}\left(N_{sc}^{RB}-1\right)\right]$
0	$[+1 \ +1 \ +1 \ +1 \ +1 \ +1 \ +1 \ +1 \ +1 \ +1 \ +1 \ +1]$
1	$[+1 \ +1 \ +1 \ +1 \ +1 \ +1 \ -1 \ -1 \ -1 \ -1 \ -1 \ -1]$

5.4.3 Mapping to physical resources

The block of complex-valued symbols $z^{(\tilde{p})}(i)$ shall be multiplied with the amplitude scaling factor β_{PUCCH} in order to conform to the transmit power P_{PUCCH} specified in Subclause 5.1.2.1 in 3GPP TS 36.213 [4], and mapped in sequence starting with $z^{(\tilde{p})}(0)$ to resource elements. PUCCH uses one or more resource block in each of the two slots in a subframe. Within the physical resource block(s) used for transmission, the mapping of $z^{(\tilde{p})}(i)$ to resource elements (k,l) on antenna port p and not used for transmission of reference signals shall be in increasing order of first k, then l and finally the slot number, starting with the first slot in the subframe. The relation between the index $\tilde{p}$ and the antenna port number p is given by Table 5.2.1-1.

For non-BL/CE UEs, except for PUCCH format 4, the physical resource blocks to be used for transmission of PUCCH in slot n_{s} are given by

$$n_{\mathrm{PRB}} = \begin{cases} \left\lfloor \frac{m}{2} \right\rfloor & \text{if } (m + n_{\mathrm{s}} \bmod 2) \bmod 2 = 0 \\ N_{\mathrm{RB}}^{\mathrm{UL}} - 1 - \left\lfloor \frac{m}{2} \right\rfloor & \text{if } (m + n_{\mathrm{s}} \bmod 2) \bmod 2 = 1 \end{cases}$$

For BL/CE UEs, PUCCH is transmitted with $N_{\mathrm{rep}}^{\mathrm{PUCCH}} \geq 1$ repetitions. The PUCCH transmission spans $N_{\mathrm{abs}}^{\mathrm{PUCCH}} \geq N_{\mathrm{rep}}^{\mathrm{PUCCH}}$ consecutive subframes, including invalid subframes where the UE postpones the PUCCH transmission. The quantity $N_{\mathrm{rep}}^{\mathrm{PUCCH}}$ is given by the higher-layer parameter *pucch-NumRepetitionCE-Msg4* for

Petitioners' Exhibit 1003, p. 1105
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

transmission of Msg4 in the random-access procedure [8], otherwise by *pucch-NumRepetitionCE-Format1* for PUCCH format 1/1a and *pucch-NumRepetitionCE-Format2* for PUCCH format 2/2a/2b,

The physical resource blocks to be used for transmission of PUCCH in subframe i within the $N_{\text{abs}}^{\text{PUCCH}}$ consecutive subframes are given by

$$n_{\text{PRB}}(i) = \begin{cases} m'(j)/2 & \text{if } m'(j) \bmod 2 = 0 \\ N_{\text{RB}}^{\text{UL}} - 1 - \lfloor m'(j)/2 \rfloor & \text{if } m'(j) \bmod 2 = 1 \end{cases}$$

$$m'(j) = \begin{cases} m & \text{if } j \bmod 2 = 0 \\ m+1 & \text{if } j \bmod 2 = 1 \text{ and } m \bmod 2 = 0 \\ m-1 & \text{if } j \bmod 2 = 1 \text{ and } m \bmod 2 = 1 \end{cases}$$

$$j = \left\lfloor \frac{i}{N_{\text{NB}}^{\text{ch,UL}}} \right\rfloor$$

$$i_0 \le i \le i_0 + N_{\text{abs}}^{\text{PUCCH}} - 1$$

where i_0 is the absolute subframe number of the first uplink subframe intended for PUCCH.

The variable m depends on the PUCCH format.

- Formats 1, 1a and 1b:

$$m = \begin{cases} N_{\text{RB}}^{(2)} & \text{if } n_{\text{PUCCH}}^{(1,\tilde{p})} < c \cdot N_{\text{cs}}^{(1)} / \Delta_{\text{shift}}^{\text{PUCCH}} \\ \left\lfloor \dfrac{n_{\text{PUCCH}}^{(1,\tilde{p})} - c \cdot N_{\text{cs}}^{(1)} / \Delta_{\text{shift}}^{\text{PUCCH}}}{c \cdot N_{\text{sc}}^{\text{RB}} / \Delta_{\text{shift}}^{\text{PUCCH}}} \right\rfloor + N_{\text{RB}}^{(2)} + \left\lceil \dfrac{N_{\text{cs}}^{(1)}}{8} \right\rceil & \text{otherwise} \end{cases}$$

$$c = \begin{cases} 3 & \text{normal cyclic prefix} \\ 2 & \text{extended cyclic prefix} \end{cases}$$

- Formats 2, 2a and 2b:

$$m = \left\lfloor n_{\text{PUCCH}}^{(2,\tilde{p})} / N_{\text{sc}}^{\text{RB}} \right\rfloor$$

- Format 3:

$$m = \left\lfloor n_{\text{PUCCH}}^{(3,\tilde{p})} / N_{\text{SF},0}^{\text{PUCCH}} \right\rfloor$$

- Format 5 (non-BL/CE UEs only):

$$m = n_{\text{PUCCH}}^{(5)}$$

For non-BL/CE UEs, for PUCCH format 4, the physical resource blocks to be used for transmission of PUCCH in slot n_{s} are given by

$$n_{\text{PRB}} = \begin{cases} m & \text{if } n_{\text{s}} \bmod 2 = 0 \\ N_{\text{RB}}^{\text{UL}} - 1 - m & \text{if } n_{\text{s}} \bmod 2 = 1 \end{cases}$$

$$m = n_{\text{PUCCH}}^{(4)}, n_{\text{PUCCH}}^{(4)} + 1, \ldots, n_{\text{PUCCH}}^{(4)} + M_{\text{RB}}^{\text{PUCCH4}} - 1$$

where $M_{\text{RB}}^{\text{PUCCH4}}$ is obtained from [4].

Mapping of modulation symbols for the physical uplink control channel for PUCCH formats 1 – 3 is illustrated in Figure 5.4.3-1.

In case of simultaneous transmission of sounding reference signal and PUCCH format 1, 1a, 1b, 3, 4 or 5 when there is one serving cell configured, a type-0 shortened PUCCH format shall be used where the last SC-FDMA symbol in the second slot of a subframe shall be left empty.

Petitioners' Exhibit 1003, p. 1106
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

In case of guard period for narrowband retuning for BL/CE UEs,

- For PUCCH format 1, 1a,
  - if the only SC-FDMA symbol affected by the guard period is the last SC-FDMA symbol in the second slot, a type-0 shortened PUCCH format shall be used.
  - if the first SC-FDMA symbol in the first slot of a subframe is left empty due to guard period, while the last SC-FDMA symbol is available for PUCCH transmission, a type-1shortened PUCCH format shall be used.
  - if the first SC-FDMA symbol in the first slot of a subframe is left empty due to guard period, and the last SC-FDMA symbol in the second slot of a subframe is left empty due to either guard period or sounding reference signal, a type-2shortened PUCCH format shall be used.
- For PUCCH format 2, 2a, if an SC-FDMA symbol is left empty due to guard period, the SC-FDMA symbol shall be counted in in the PUCCH mapping but not used for transmission of the PUCCH. The SC-FDMA symbol affected by the guard period can be the first SC-FDMA symbol in the first slot of a subframe and/or the last SC-FDMA symbol in the second slot of a subframe.

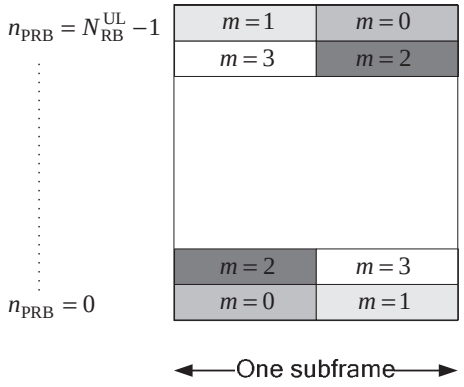


Figure 5.4.3-1: Mapping to physical resource blocks for PUCCH formats 1 – 3 for non-BL/CE UEs.

Petitioners' Exhibit 1003, p. 1107
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.5 Reference signals

Two types of uplink reference signals are supported:

- Demodulation reference signal, associated with transmission of PUSCH or PUCCH
- Sounding reference signal, not associated with transmission of PUSCH or PUCCH

The same set of base sequences is used for demodulation and sounding reference signals.

5.5.1 Generation of the reference signal sequence

Reference signal sequence $r_{u,v}^{(\alpha)}(n)$ is defined by a cyclic shift α of a base sequence $\bar{r}_{u,v}(n)$ according to

$$r_{u,v}^{(\alpha)}(n) = e^{j\alpha n}\bar{r}_{u,v}(n), \quad 0 \le n < M_{\text{sc}}^{\text{RS}}$$

where $M_{\text{sc}}^{\text{RS}} = mN_{\text{sc}}^{\text{RB}}$ is the length of the reference signal sequence and $1 \le m \le N_{\text{RB}}^{\max,\text{UL}}$. Multiple reference signal sequences are defined from a single base sequence through different values of α.

Base sequences $\bar{r}_{u,v}(n)$ are divided into groups, where $u \in \{0,1,...,29\}$ is the group number and v is the base sequence number within the group, such that each group contains one base sequence ($v = 0$) of each length $M_{\text{sc}}^{\text{RS}} = mN_{\text{sc}}^{\text{RB}}$, $1 \le m \le 5$ and two base sequences ($v = 0,1$) of each length $M_{\text{sc}}^{\text{RS}} = mN_{\text{sc}}^{\text{RB}}$, $6 \le m \le N_{\text{RB}}^{\max,\text{UL}}$. The sequence group number u and the number v within the group may vary in time as described in clauses 5.5.1.3 and 5.5.1.4, respectively. The definition of the base sequence $\bar{r}_{u,v}(0),...,\bar{r}_{u,v}(M_{\text{sc}}^{\text{RS}}-1)$ depends on the sequence length $M_{\text{sc}}^{\text{RS}}$.

5.5.1.1 Base sequences of length $3N_{\text{sc}}^{\text{RB}}$ or larger

For $M_{\text{sc}}^{\text{RS}} \ge 3N_{\text{sc}}^{\text{RB}}$, the base sequence $\bar{r}_{u,v}(0),...,\bar{r}_{u,v}(M_{\text{sc}}^{\text{RS}}-1)$ is given by

$$\bar{r}_{u,v}(n) = x_q(n \bmod N_{\text{ZC}}^{\text{RS}}), \quad 0 \le n < M_{\text{sc}}^{\text{RS}}$$

where the qth root Zadoff-Chu sequence is defined by

$$x_q(m) = e^{-j\frac{\pi q m(m+1)}{N_{\text{ZC}}^{\text{RS}}}}, \quad 0 \le m \le N_{\text{ZC}}^{\text{RS}}-1$$

with q given by

$$q = \lfloor \bar{q} + 1/2 \rfloor + v \cdot (-1)^{\lfloor 2\bar{q} \rfloor}$$
$$\bar{q} = N_{\text{ZC}}^{\text{RS}} \cdot (u+1)/31$$

The length $N_{\text{ZC}}^{\text{RS}}$ of the Zadoff-Chu sequence is given by the largest prime number such that $N_{\text{ZC}}^{\text{RS}} < M_{\text{sc}}^{\text{RS}}$.

Petitioners' Exhibit 1003, p. 1108
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.5.1.2 Base sequences of length less than $3N_{sc}^{RB}$

For $M_{sc}^{RS} = N_{sc}^{RB}$ and $M_{sc}^{RS} = 2N_{sc}^{RB}$, base sequence is given by

$$\bar{r}_{u,v}(n) = e^{j\varphi(n)\pi/4}, \quad 0 \le n \le M_{sc}^{RS} - 1$$

where the value of $\varphi(n)$ is given by Table 5.5.1.2-1 and Table 5.5.1.2-2 for $M_{sc}^{RS} = N_{sc}^{RB}$ and $M_{sc}^{RS} = 2N_{sc}^{RB}$, respectively.

Table 5.5.1.2-1: Definition of $\varphi(n)$ for $M_{sc}^{RS} = N_{sc}^{RB}$.

u	$\varphi(0),...,\varphi(11)$											
0	-1	1	3	-3	3	3	1	1	3	1	-3	3
1	1	1	3	3	3	-1	1	-3	-3	1	-3	3
2	1	1	-3	-3	-3	-1	-3	-3	1	-3	1	-1
3	-1	1	1	1	1	-1	-3	-3	1	-3	3	-1
4	-1	3	1	-1	1	-1	-3	-1	1	-1	1	3
5	1	-3	3	-1	-1	1	1	-1	-1	3	-3	1
6	-1	3	-3	-3	-3	3	1	-1	3	3	-3	1
7	-3	-1	-1	-1	1	-3	3	-1	1	-3	3	1
8	1	-3	3	1	-1	-1	-1	1	1	3	-1	1
9	1	-3	-1	3	3	-1	-3	1	1	1	1	1
10	-1	3	-1	1	1	-3	-3	-1	-3	-3	3	-1
11	3	1	-1	-1	3	3	-3	1	3	1	3	3
12	1	-3	1	1	-3	1	1	1	-3	-3	-3	1
13	3	3	-3	3	-3	1	1	3	-1	-3	3	3
14	-3	1	-1	-3	-1	3	1	3	3	3	-1	1
15	3	-1	1	-3	-1	-1	1	1	3	1	-1	-3
16	1	3	1	-1	1	3	3	3	-1	-1	3	-1
17	-3	1	1	3	-3	3	-3	-3	3	1	3	-1
18	-3	3	1	1	-3	1	-3	-3	-1	-1	1	-3
19	-1	3	1	3	1	-1	-1	3	-3	-1	-3	-1
20	-1	-3	1	1	1	1	3	1	-1	1	-3	-1
21	-1	3	-1	1	-3	-3	-3	-3	-3	1	-1	-3
22	1	1	-3	-3	-3	-3	-1	3	-3	1	-3	3
23	1	1	-1	-3	-1	-3	1	-1	1	3	-1	1
24	1	1	3	1	3	3	-1	1	-1	-3	-3	1
25	1	-3	3	3	1	3	3	1	-3	-1	-1	3
26	1	3	-3	-3	3	-3	1	-1	-1	3	-1	-3
27	-3	-1	-3	-1	-3	3	1	-1	1	3	-3	-3
28	-1	3	-3	3	-1	3	3	-3	3	3	-1	-1
29	3	-3	-3	-1	-1	-3	-1	3	-3	3	1	-1

Petitioners' Exhibit 1003, p. 1109
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.5.1.2-2: Definition of $\varphi(n)$ for $M_{sc}^{RS} = 2N_{sc}^{RB}$

u	$\varphi(0),...,\varphi(23)$																							
0	-1	3	1	-3	3	-1	1	3	-3	3	1	3	-3	3	1	1	-1	1	3	-3	3	-3	-1	-3
1	-3	3	-3	-3	-3	1	-3	-3	3	-1	1	1	1	3	1	-1	3	-3	-3	1	3	1	1	-3
2	3	-1	3	3	1	1	-3	3	3	3	3	1	-1	3	-1	1	1	-1	-3	-1	-1	1	3	3
3	-1	-3	1	1	3	-3	1	1	-3	-1	-1	1	3	1	3	1	-1	3	1	1	-3	-1	-3	-1
4	-1	-1	-1	-3	-3	-1	1	1	3	3	-1	3	-1	1	-1	-3	1	-1	-3	-3	1	-3	-1	-1
5	-3	1	1	3	-1	1	3	1	-3	1	-3	1	1	-1	-1	3	-1	-3	3	-3	-3	-3	1	1
6	1	1	-1	-1	3	-3	-3	3	-3	1	-1	-1	1	-1	1	1	-1	-3	-1	1	-1	3	-1	-3
7	-3	3	3	-1	-1	-3	-1	3	1	3	1	3	1	1	-1	3	1	-1	1	3	-3	-1	-1	1
8	-3	1	3	-3	1	-1	-3	3	-3	3	-1	-1	-1	-1	1	-3	-3	-3	1	-3	-3	-3	1	-3
9	1	1	-3	3	3	-1	-3	-1	3	-3	3	3	3	-1	1	1	-3	1	-1	1	1	-3	1	1
10	-1	1	-3	-3	3	-1	3	-1	-1	-3	-3	-3	-1	-3	-3	1	-1	1	3	3	-1	1	-1	3
11	1	3	3	-3	-3	1	3	1	-1	-3	-3	-3	3	3	-3	3	3	-1	-3	3	-1	1	-3	1
12	1	3	3	1	1	1	-1	-1	1	-3	3	-1	1	1	-3	3	3	-1	-3	3	-3	-1	-3	-1
13	3	-1	-1	-1	-1	-3	-1	3	3	1	-1	1	3	3	3	-1	1	1	-3	1	3	-1	-3	3
14	-3	-3	3	1	3	1	-3	3	1	3	1	1	3	3	-1	-1	-3	1	-3	-1	3	1	1	3
15	-1	-1	1	-3	1	3	-3	1	-1	-3	-1	3	1	3	1	-1	-3	-3	-1	-1	-3	-3	-3	-1
16	-1	-3	3	-1	-1	-1	-1	1	1	-3	3	1	3	3	1	-1	1	-3	1	-3	1	1	-3	-1
17	1	3	-1	3	3	-1	-3	1	-1	-3	3	3	3	-1	1	1	3	-1	-3	-1	3	-1	-1	-1
18	1	1	1	1	1	-1	3	-1	-3	1	1	3	-3	1	-3	-1	1	1	-3	-3	3	1	1	-3
19	1	3	3	1	-1	-3	3	-1	3	3	3	-3	1	-1	1	-1	-3	-1	1	3	-1	3	-3	-3
20	-1	-3	3	-3	-3	-3	-1	-1	-3	-1	-3	3	1	3	-3	-1	3	-1	1	-1	3	-3	1	-1
21	-3	-3	1	1	-1	1	-1	1	-1	3	1	-3	-1	1	-1	1	-1	-1	3	3	-3	-1	1	-3
22	-3	-1	-3	3	1	-1	-3	-1	-3	-3	3	-3	3	-3	-1	1	3	1	-3	1	3	3	-1	-3
23	-1	-1	-1	-1	3	3	3	1	3	3	-3	1	3	-1	3	-1	3	3	-3	3	1	-1	3	3
24	1	-1	3	3	-1	-3	3	-3	-1	-1	3	-1	3	-1	-1	1	1	1	1	-1	-1	-3	-1	3
25	1	-1	1	-1	3	-1	3	1	1	-1	-1	-3	1	1	-3	1	3	-3	1	1	-3	-3	-1	-1
26	-3	-1	1	3	1	1	-3	-1	-1	-3	3	-3	3	1	-3	3	-3	1	-1	1	-3	1	1	1
27	-1	-3	3	3	1	1	3	-1	-3	-1	-1	-1	3	1	-3	-3	-1	3	-3	-1	-3	-1	-3	-1
28	-1	-3	-1	-1	1	-3	-1	-1	1	-1	-3	1	1	-3	1	-3	-3	3	1	1	-1	3	-1	-1
29	1	1	-1	-1	-3	-1	3	-1	3	-1	1	3	1	-1	3	1	3	-3	-3	1	-1	-1	1	3

Petitioners' Exhibit 1003, p. 1110
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.5.1.3 Group hopping

The sequence-group number u in slot n_s is defined by a group hopping pattern $f_{gh}(n_s)$ and a sequence-shift pattern f_{ss} according to

$$u = \left(f_{gh}(n_s) + f_{ss}\right) \bmod 30$$

There are 17 different hopping patterns and 30 different sequence-shift patterns. Sequence-group hopping can be enabled or disabled by means of the cell-specific parameter *Group-hopping-enabled* provided by higher layers. Sequence-group hopping for PUSCH can be disabled for a certain UE through the higher-layer parameter *Disable-sequence-group-hopping* despite being enabled on a cell basis unless the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure.

The group-hopping pattern $f_{gh}(n_s)$ may be different for PUSCH, PUCCH and SRS and is given by

$$f_{gh}(n_s) = \begin{cases} 0 & \text{if group hopping is disabled} \\ \left(\sum_{i=0}^{7} c(8n_s + i) \cdot 2^i\right) \bmod 30 & \text{if group hopping is enabled} \end{cases}$$

where the pseudo-random sequence $c(i)$ is defined by clause 7.2. The pseudo-random sequence generator shall be initialized with $c_{init} = \left\lfloor \frac{n_{ID}^{RS}}{30} \right\rfloor$ at the beginning of each radio frame where n_{ID}^{RS} is given by clause 5.5.1.5.

The sequence-shift pattern f_{ss} definition differs between PUCCH, PUSCH and SRS.

For PUCCH, the sequence-shift pattern f_{ss}^{PUCCH} is given by $f_{ss}^{PUCCH} = n_{ID}^{RS} \bmod 30$ where n_{ID}^{RS} is given by clause 5.5.1.5.

For PUSCH, the sequence-shift pattern f_{ss}^{PUSCH} is given by $f_{ss}^{PUSCH} = \left(N_{ID}^{cell} + \Delta_{ss}\right) \bmod 30$, where $\Delta_{ss} \in \{0,1,...,29\}$ is configured by higher layers, if no value for n_{ID}^{PUSCH} is provided by higher layers or if the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure, otherwise it is given by $f_{ss}^{PUSCH} = n_{ID}^{RS} \bmod 30$ with n_{ID}^{RS} given by clause 5.5.1.5.

For SRS, the sequence-shift pattern f_{ss}^{SRS} is given by $f_{ss}^{SRS} = n_{ID}^{RS} \bmod 30$ where n_{ID}^{RS} is given by clause 5.5.1.5.

Petitioners' Exhibit 1003, p. 1111
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.5.1.4 Sequence hopping

Sequence hopping only applies for reference-signals of length $M_{sc}^{RS} \geq 6N_{sc}^{RB}$.

For reference-signals of length $M_{sc}^{RS} < 6N_{sc}^{RB}$, the base sequence number v within the base sequence group is given by $v = 0$.

For reference-signals of length $M_{sc}^{RS} \geq 6N_{sc}^{RB}$, the base sequence number v within the base sequence group in slot n_s is defined by

$$v = \begin{cases} c(n_s) & \text{if group hopping is disabled and sequence hopping is enabled} \\ 0 & \text{otherwise} \end{cases}$$

where the pseudo-random sequence $c(i)$ is given by clause 7.2. The parameter *Sequence-hopping-enabled* provided by higher layers determines if sequence hopping is enabled or not. Sequence hopping for PUSCH can be disabled for a certain UE through the higher-layer parameter *Disable-sequence-group-hopping* despite being enabled on a cell basis unless the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure.

For PUSCH, the pseudo-random sequence generator shall be initialized with $c_{init} = \left\lfloor \frac{n_{ID}^{RS}}{30} \right\rfloor \cdot 2^5 + f_{ss}^{PUSCH}$ at the beginning of each radio frame where n_{ID}^{RS} is given by clause 5.5.1.5.

For SRS, the pseudo-random sequence generator shall be initialized with $c_{init} = \left\lfloor \frac{n_{ID}^{RS}}{30} \right\rfloor \cdot 2^5 + \left(n_{ID}^{RS} + \Delta_{ss}\right) \bmod 30$ at the beginning of each radio frame where n_{ID}^{RS} is given by clause 5.5.1.5 and Δ_{ss} is given by clause 5.5.1.3.

5.5.1.5 Determining virtual cell identity for sequence generation

The definition of n_{ID}^{RS} depends on the type of transmission.

Transmissions associated with PUSCH:

- $n_{ID}^{RS} = N_{ID}^{cell}$ if no value for n_{ID}^{PUSCH} is configured by higher layers or if the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure,
- $n_{ID}^{RS} = n_{ID}^{PUSCH}$ otherwise.

Transmissions associated with PUCCH:

- $n_{ID}^{RS} = N_{ID}^{cell}$ if no value for n_{ID}^{PUCCH} is configured by higher layers,
- $n_{ID}^{RS} = n_{ID}^{PUCCH}$ otherwise.

Sounding reference signals:

- $n_{ID}^{RS} = N_{ID}^{cell}$.

Petitioners' Exhibit 1003, p. 1112
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.5.2 Demodulation reference signal

5.5.2.1 Demodulation reference signal for PUSCH

5.5.2.1.1 Reference signal sequence

The PUSCH demodulation reference signal sequence $r_{\text{PUSCH}}^{(\lambda)}(\cdot)$ associated with layer $\lambda \in \{0,1,...,\upsilon-1\}$ is defined by

$$r_{\text{PUSCH}}^{(\lambda)}\left(m \cdot M_{\text{sc}}^{\text{RS}} + n\right) = w^{(\lambda)}(m) r_{u,v}^{(\alpha_\lambda)}(n)$$

where

$$m = 0,1$$
$$n = 0,...,M_{\text{sc}}^{\text{RS}} - 1$$

and

$$M_{\text{sc}}^{\text{RS}} = M_{\text{sc}}^{\text{PUSCH}}$$

Subclause 5.5.1 defines the sequence $r_{u,v}^{(\alpha_\lambda)}(0),...,r_{u,v}^{(\alpha_\lambda)}(M_{\text{sc}}^{\text{RS}}-1)$. The orthogonal sequence $w^{(\lambda)}(m)$ is given by $\left[w^{\lambda}(0) \quad w^{\lambda}(1)\right] = \left[1 \quad 1\right]$ for DCI format 0 if the higher-layer parameter *Activate-DMRS-with OCC* is not set or if the temporary C-RNTI was used to transmit the most recent uplink-related DCI for the transport block associated with the corresponding PUSCH transmission, otherwise it is given by Table 5.5.2.1.1-1 using the cyclic shift field in most recent uplink-related DCI 3GPP TS 36.212 [3] for the transport block associated with the corresponding PUSCH transmission.

The cyclic shift α_λ in a slot n_{s} is given as $\alpha_\lambda = 2\pi n_{\text{cs},\lambda}/12$ with

$$n_{\text{cs},\lambda} = \left(n_{\text{DMRS}}^{(1)} + n_{\text{DMRS},\lambda}^{(2)} + n_{\text{PN}}(n_{\text{s}})\right) \bmod 12$$

where the value of $n_{\text{DMRS}}^{(1)}$ is given by Table 5.5.2.1.1-2 according to the parameter *cyclicShift* provided by higher layers, for non-BL/CE UEs $n_{\text{DMRS},\lambda}^{(2)}$ is given by the cyclic shift for DMRS field in most recent uplink-related DCI 3GPP TS 36.212 [3] for the transport block associated with the corresponding PUSCH transmission where the value of $n_{\text{DMRS},\lambda}^{(2)}$ is given in Table 5.5.2.1.1-1. For BL/CE UEs, a cyclic shift field of "000" shall be assumed when determining $n_{\text{DMRS},\lambda}^{(2)}$ from Table 5.5.2.1.1-1.

The first row of Table 5.5.2.1.1-1 shall be used to obtain $n_{\text{DMRS},0}^{(2)}$ and $w^{(\lambda)}(m)$ if there is no uplink-related DCI for the same transport block associated with the corresponding PUSCH transmission, and

- if the initial PUSCH for the same transport block is semi-persistently scheduled, or
- if the initial PUSCH for the same transport block is scheduled by the random access response grant.

The quantity $n_{\text{PN}}(n_{\text{s}})$ is given by

$$n_{\text{PN}}(n_{\text{s}}) = \sum_{i=0}^{7} c(8N_{\text{symb}}^{\text{UL}} \cdot n_{\text{s}} + i) \cdot 2^i$$

where the pseudo-random sequence $c(i)$ is defined by clause 7.2. The application of $c(i)$ is cell-specific. The pseudo-random sequence generator shall be initialized with c_{init} at the beginning of each radio frame. The quantity c_{init} is given by $c_{\text{init}} = \left\lfloor \frac{N_{\text{ID}}^{\text{cell}}}{30} \right\rfloor \cdot 2^5 + \left(\left(N_{\text{ID}}^{\text{cell}} + \Delta_{\text{ss}}\right) \bmod 30\right)$ if no value for $N_{\text{ID}}^{\text{csh\_DMRS}}$ is configured by higher layers or the PUSCH transmission corresponds to a Random Access Response Grant or a retransmission of the same transport block

Petitioners' Exhibit 1003, p. 1113
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

as part of the contention based random access procedure, otherwise it is given by

$$c_{\text{init}} = \left\lfloor \frac{N_{\text{ID}}^{\text{csh\_DMRS}}}{30} \right\rfloor \cdot 2^5 + \left(N_{\text{ID}}^{\text{csh\_DMRS}} \bmod 30\right).$$

The vector of reference signals shall be precoded according to

$$\begin{bmatrix} \tilde{r}_{\text{PUSCH}}^{(0)} \\ \vdots \\ \tilde{r}_{\text{PUSCH}}^{(P-1)} \end{bmatrix} = W \begin{bmatrix} r_{\text{PUSCH}}^{(0)} \\ \vdots \\ r_{\text{PUSCH}}^{(\upsilon-1)} \end{bmatrix}$$

where P is the number of antenna ports used for PUSCH transmission.

For PUSCH transmission using a single antenna port, $P=1$, $W=1$ and $\upsilon=1$.

For spatial multiplexing, $P=2$ or $P=4$ and the precoding matrix W shall be identical to the precoding matrix used in clause 5.3.3A.2 for precoding of the PUSCH in the same subframe.

Table 5.5.2.1.1-1: Mapping of Cyclic Shift Field in uplink-related DCI format to $n_{\text{DMRS},\lambda}^{(2)}$ and $\left[w^{(\lambda)}(0) \quad w^{(\lambda)}(1)\right]$

Cyclic Shift Field in uplink-related DCI format [3]	$n_{\text{DMRS},\lambda}^{(2)}$				$\left[w^{(\lambda)}(0) \quad w^{(\lambda)}(1)\right]$			
	$\lambda=0$	$\lambda=1$	$\lambda=2$	$\lambda=3$	$\lambda=0$	$\lambda=1$	$\lambda=2$	$\lambda=3$
000	0	6	3	9	[1 1]	[1 1]	[1 −1]	[1 −1]
001	6	0	9	3	[1 −1]	[1 −1]	[1 1]	[1 1]
010	3	9	6	0	[1 −1]	[1 −1]	[1 1]	[1 1]
011	4	10	7	1	[1 1]	[1 1]	[1 1]	[1 1]
100	2	8	5	11	[1 1]	[1 1]	[1 1]	[1 1]
101	8	2	11	5	[1 −1]	[1 −1]	[1 −1]	[1 −1]
110	10	4	1	7	[1 −1]	[1 −1]	[1 −1]	[1 −1]
111	9	3	0	6	[1 1]	[1 1]	[1 −1]	[1 −1]

Table 5.5.2.1.1-2: Mapping of *cyclicShift* to $n_{\text{DMRS}}^{(1)}$ values

cyclicShift	$n_{\text{DMRS}}^{(1)}$
0	0
1	2
2	3
3	4
4	6
5	8
6	9
7	10

Petitioners' Exhibit 1003, p. 1114
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.5.2.1.2 Mapping to physical resources

For each antenna port used for transmission of the PUSCH, the sequence $\tilde{r}^{(\tilde{p})}_{\text{PUSCH}}(\cdot)$ shall be multiplied with the amplitude scaling factor β_{PUSCH} and mapped in sequence starting with $\tilde{r}^{(\tilde{p})}_{\text{PUSCH}}(0)$ to the resource blocks.
The set of physical resource blocks used in the mapping process and the relation between the index $\tilde{p}$ and the antenna port number p shall be identical to the corresponding PUSCH transmission as defined in clause 5.3.4.
The mapping to resource elements (k,l), with $l=3$ for normal cyclic prefix and $l=2$ for extended cyclic prefix, in the subframe shall be in increasing order of first k, then the slot number.

5.5.2.2 Demodulation reference signal for PUCCH

5.5.2.2.1 Reference signal sequence

The PUCCH demodulation reference signal sequence $r^{(\tilde{p})}_{\text{PUCCH}}(\cdot)$ for PUCCH formats 1, 1a, 1b, 2, 2a, 2b, and 3 is defined by

$$r^{(\tilde{p})}_{\text{PUCCH}}\left(m' N^{\text{PUCCH}}_{\text{RS}} M^{\text{RS}}_{\text{sc}} + mM^{\text{RS}}_{\text{sc}} + n\right) = \frac{1}{\sqrt{P}} \overline{w}^{(\tilde{p})}(m) z(m) r^{(\alpha_{\tilde{p}})}_{u,v}(n)$$

where

$$\begin{aligned} m &= 0,\ldots, N^{\text{PUCCH}}_{\text{RS}} - 1 \\ n &= 0,\ldots, M^{\text{RS}}_{\text{sc}} - 1 \\ m' &= 0,1 \end{aligned}$$

and P is the number of antenna ports used for PUCCH transmission. For PUCCH formats 2a and 2b, $z(m)$ equals $d(10)$ for $m=1$, where $d(10)$ is defined in clause 5.4.2. For all other cases, $z(m)=1$.

The sequence $r^{(\alpha_{\tilde{p}})}_{u,v}(n)$ is given by clause 5.5.1 with $M^{\text{RS}}_{\text{sc}}=12$ where the expression for the cyclic shift $\alpha_{\tilde{p}}$ is determined by the PUCCH format.

For PUCCH formats 1, 1a and 1b, $\alpha_{\tilde{p}}(n_{\text{s}},l)$ is given by

$$\overline{n}^{(\tilde{p})}_{\text{oc}}(n_{\text{s}}) = \left\lfloor n'_{\tilde{p}}(n_{\text{s}}) \cdot \Delta^{\text{PUCCH}}_{\text{shift}} \big/ N' \right\rfloor$$

$$\alpha_{\tilde{p}}(n_{\text{s}},l) = 2\pi \cdot \overline{n}^{(\tilde{p})}_{\text{cs}}(n_{\text{s}},l) \big/ N^{\text{RB}}_{\text{sc}}$$

$$\overline{n}^{(\tilde{p})}_{\text{cs}}(n_{\text{s}},l) = \begin{cases} \left[n^{\text{cell}}_{\text{cs}}(n_{\text{s}},l) + \left(n'_{\tilde{p}}(n_{\text{s}}) \cdot \Delta^{\text{PUCCH}}_{\text{shift}} + \left(\overline{n}^{(\tilde{p})}_{\text{oc}}(n_{\text{s}}) \bmod \Delta^{\text{PUCCH}}_{\text{shift}}\right)\right) \bmod N'\right] \bmod N^{\text{RB}}_{\text{sc}} & \text{for normal cyclic prefix} \\ \left[n^{\text{cell}}_{\text{cs}}(n_{\text{s}},l) + \left(n'_{\tilde{p}}(n_{\text{s}}) \cdot \Delta^{\text{PUCCH}}_{\text{shift}} + \overline{n}^{(\tilde{p})}_{\text{oc}}(n_{\text{s}})\right) \bmod N'\right] \bmod N^{\text{RB}}_{\text{sc}} & \text{for extended cyclic prefix} \end{cases}$$

where $n'_{\tilde{p}}(n_{\text{s}})$, N', $\Delta^{\text{PUCCH}}_{\text{shift}}$ and $n^{\text{cell}}_{\text{cs}}(n_{\text{s}},l)$ are defined by clause 5.4.1. The number of reference symbols per slot $N^{\text{PUCCH}}_{\text{RS}}$ and the sequence $\overline{w}(n)$ are given by Table 5.5.2.2.1-1 and 5.5.2.2.1-2, respectively.

For PUCCH formats 2, 2a and 2b, $\alpha_{\tilde{p}}(n_{\text{s}},l)$ is defined by clause 5.4.2. The number of reference symbols per slot $N^{\text{PUCCH}}_{\text{RS}}$ and the sequence $\overline{w}^{(\tilde{p})}(n)$ are given by Table 5.5.2.2.1-1 and 5.5.2.2.1-3, respectively.

For PUCCH format 3, $\alpha_{\tilde{p}}(n_{\text{s}},l)$ is given by

$$\alpha_{\tilde{p}}(n_{\text{s}},l) = 2\pi \cdot n^{(\tilde{p})}_{\text{cs}}(n_{\text{s}},l) \big/ N^{\text{RB}}_{\text{sc}}$$

$$n^{(\tilde{p})}_{\text{cs}}(n_{\text{s}},l) = \left(n^{\text{cell}}_{\text{cs}}(n_{\text{s}},l) + n'_{\tilde{p}}(n_{\text{s}})\right) \bmod N^{\text{RB}}_{\text{sc}}$$

Petitioners' Exhibit 1003, p. 1115
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

where $n'_{\tilde{p}}(n_s)$ is given by Table 5.5.2.2.1-4 and $n_{oc,0}^{(\tilde{p})}$ and $n_{oc,1}^{(\tilde{p})}$ for the first and second slot in a subframe, respectively, are obtained from clause 5.4.2A. The number of reference symbols per slot N_{RS}^{PUCCH} and the sequence $\overline{w}(n)$ are given by Table 5.5.2.2.1-1 and 5.5.2.2.1-3, respectively.

Table 5.5.2.2.1-1: Number of PUCCH demodulation reference symbols per slot N_{RS}^{PUCCH}

PUCCH format	Normal cyclic prefix	Extended cyclic prefix
1, 1a, 1b	3	2
2, 3	2	1
2a, 2b	2	N/A

Table 5.5.2.2.1-2: Orthogonal sequences $\left[\overline{w}^{(\tilde{p})}(0) \quad \cdots \quad \overline{w}^{(\tilde{p})}(N_{RS}^{PUCCH}-1)\right]$ for PUCCH formats 1, 1a and 1b

Sequence index $\overline{n}_{oc}^{(\tilde{p})}(n_s)$	Normal cyclic prefix	Extended cyclic prefix
0	$[1 \quad 1 \quad 1]$	$[1 \quad 1]$
1	$[1 \quad e^{j2\pi/3} \quad e^{j4\pi/3}]$	$[1 \quad -1]$
2	$[1 \quad e^{j4\pi/3} \quad e^{j2\pi/3}]$	N/A

Table 5.5.2.2.1-3: Orthogonal sequences $\left[\overline{w}^{(\tilde{p})}(0) \quad \cdots \quad \overline{w}^{(\tilde{p})}(N_{RS}^{PUCCH}-1)\right]$ for PUCCH formats 2, 2a, 2b and 3.

Normal cyclic prefix	Extended cyclic prefix
$[1 \quad 1]$	$[1]$

Table 5.5.2.2.1-4: Relation between $n_{oc}^{(\tilde{p})}$ and $n'_{\tilde{p}}(n_s)$ for PUCCH format 3.

$n_{oc}^{(\tilde{p})}$	$n'_{\tilde{p}}(n_s)$	
	$N_{SF,1}=5$	$N_{SF,1}=4$
0	0	0
1	3	3
2	6	6
3	8	9
4	10	N/A

The PUCCH demodulation reference signal sequence $r_{PUCCH}^{(\tilde{p})}(\cdot)$ for PUCCH formats 4 and 5 is defined by

$$r_{PUCCH}^{(\tilde{p})}\left(m \cdot M_{sc}^{RS}+n\right)=r_{u,v}^{(\alpha)}(n)$$

where

$$\tilde{p}=0$$
$$m=0,1$$
$$n=0,\ldots,M_{sc}^{RS}-1$$

and

Petitioners' Exhibit 1003, p. 1116
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$M_{\text{sc}}^{\text{RS}} = \begin{cases} M_{\text{sc}}^{\text{PUCCH4}} & \text{for PUCCH format 4} \\ N_{\text{sc}}^{\text{RB}} & \text{for PUCCH format 5} \end{cases}$$

Subclause 5.5.1 defines the sequence $r_{u,v}^{(\alpha_\lambda)}(0),...,r_{u,v}^{(\alpha_\lambda)}(M_{\text{sc}}^{\text{RS}}-1)$.

The cyclic shift α_λ in a slot n_{s} is given as $\alpha_\lambda = 2\pi n_{\text{cs},\lambda}/12$ with

$$n_{\text{cs},\lambda} = \left(n_{\text{DMRS}}^{(1)} + n_{\text{DMRS}}^{(2)} + n_{\text{PN}}(n_{\text{s}})\right) \bmod 12$$

where the values of $n_{\text{DMRS}}^{(1)}$ and $n_{\text{PN}}(n_{\text{s}})$ are given by Subclause 5.5.2.1.1 and

$$n_{\text{DMRS}}^{(2)} = \begin{cases} 0 & \text{PUCCH format 4} \\ 0 & \text{PUCCH format 5 with } n_{\text{oc}} = 0 \\ 6 & \text{PUCCH format 5 with } n_{\text{oc}} = 1 \end{cases}$$

with n_{oc} obtained as described in clause 5.4.2C.

5.5.2.2.2 Mapping to physical resources

The sequence $r_{\text{PUCCH}}^{(\tilde{p})}(\cdot)$ shall be multiplied with the amplitude scaling factor β_{PUCCH} and mapped in sequence starting with $r_{\text{PUCCH}}^{(\tilde{p})}(0)$ to resource elements (k,l) on antenna port p. The mapping shall be in increasing order of first k, then l and finally the slot number. The set of values for k and the relation between the index $\tilde{p}$ and the antenna port number p shall be identical to the values used for the corresponding PUCCH transmission. The values of the symbol index l in a slot are given by Table 5.5.2.2.2-1.

Table 5.5.2.2.2-1: Demodulation reference signal location for different PUCCH formats.

PUCCH format	Set of values for l	
	Normal cyclic prefix	Extended cyclic prefix
1, 1a, 1b	2, 3, 4	2, 3
2, 3	1, 5	3
2a, 2b	1, 5	N/A
4,5	3	2

Petitioners' Exhibit 1003, p. 1117
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.5.3 Sounding reference signal

5.5.3.1 Sequence generation

The sounding reference signal sequence $r_{\mathrm{SRS}}^{(\tilde{p})}(n) = r_{u,v}^{(\alpha_{\tilde{p}})}(n)$ is defined by clause 5.5.1, where u is the sequence-group number defined in clause 5.5.1.3 and v is the base sequence number defined in clause 5.5.1.4. The cyclic shift $\alpha_{\tilde{p}}$ of the sounding reference signal is given as

$$\alpha_{\tilde{p}} = 2\pi \frac{n_{\mathrm{SRS}}^{\mathrm{cs},\tilde{p}}}{n_{\mathrm{SRS}}^{\mathrm{cs,max}}}$$

$$n_{\mathrm{SRS}}^{\mathrm{cs},\tilde{p}} = \left(n_{\mathrm{SRS}}^{\mathrm{cs}} + \frac{n_{\mathrm{SRS}}^{\mathrm{cs,max}}\,\tilde{p}}{N_{\mathrm{ap}}} \right) \bmod n_{\mathrm{SRS}}^{\mathrm{cs,max}}\ ,$$

$$\tilde{p} \in \{0,1,\ldots,N_{\mathrm{ap}}-1\}$$

where $n_{\mathrm{SRS}}^{\mathrm{cs}} = \{0,1,\ldots,n_{\mathrm{SRS}}^{\mathrm{cs,max}}-1\}$ is configured separately for periodic and each configuration of aperiodic sounding by the higher-layer parameters *cyclicShift* and *cyclicShift-ap*, respectively, for each UE and N_{ap} is the number of antenna ports used for sounding reference signal transmission. The parameter $n_{\mathrm{SRS}}^{\mathrm{cs,max}} = 8$ if $K_{\mathrm{TC}} = 2$, otherwise $n_{\mathrm{SRS}}^{\mathrm{cs,max}} = 12$. The parameter K_{TC} is given by the higher layer parameter *transmissionCombNum* if configured, otherwise $K_{\mathrm{TC}} = 2$.

5.5.3.2 Mapping to physical resources

The sequence shall be multiplied with the amplitude scaling factor β_{SRS} in order to conform to the transmit power P_{SRS} specified in clause 5.1.3.1 in 3GPP TS 36.213 [4], and mapped in sequence starting with $r_{\mathrm{SRS}}^{(\tilde{p})}(0)$ to resource elements (k,l) on antenna port p according to

$$a_{K_{\mathrm{TC}}k'+k_0^{(p)},l}^{(p)} = \begin{cases} \dfrac{1}{\sqrt{N_{\mathrm{ap}}}} \beta_{\mathrm{SRS}} r_{SRS}^{(\tilde{p})}(k') & k' = 0,1,\ldots,M_{\mathrm{sc},b}^{\mathrm{RS}}-1 \\ 0 & \text{otherwise} \end{cases}$$

where N_{ap} is the number of antenna ports used for sounding reference signal transmission and the relation between the index $\tilde{p}$ and the antenna port p is given by Table 5.2.1-1. The set of antenna ports used for sounding reference signal transmission is configured independently for periodic and each configuration of aperiodic sounding. The quantity $k_0^{(p)}$ is the frequency-domain starting position of the sounding reference signal and for $b = B_{\mathrm{SRS}}$ and $M_{\mathrm{sc},b}^{\mathrm{RS}}$ is the length of the sounding reference signal sequence defined as

$$M_{\mathrm{sc},b}^{\mathrm{RS}} = m_{\mathrm{SRS},b} N_{\mathrm{sc}}^{\mathrm{RB}} / K_{\mathrm{TC}}$$

where $m_{\mathrm{SRS},b}$ is given by Table 5.5.3.2-1 through Table 5.5.3.2-4 for each uplink bandwidth $N_{\mathrm{RB}}^{\mathrm{UL}}$. The cell-specific parameter *srs-BandwidthConfig*, $C_{\mathrm{SRS}} \in \{0,1,2,3,4,5,6,7\}$ and the UE-specific parameter *srs-Bandwidth*, $B_{\mathrm{SRS}} \in \{0,1,2,3\}$ are given by higher layers. For UpPTS, $m_{\mathrm{SRS},0}$ shall be reconfigured to $m_{\mathrm{SRS},0}^{\max} = \max_{c \in C_{\mathrm{SRS}}} \{m_{\mathrm{SRS},0}^{c}\} \le \left(N_{\mathrm{RB}}^{\mathrm{UL}} - 6N_{\mathrm{RA}}\right)$ if this reconfiguration is enabled by the cell-specific parameter *srsMaxUpPts* given by higher layers, otherwise if the reconfiguration is disabled $m_{\mathrm{SRS},0}^{\max} = m_{\mathrm{SRS},0}$,where c is a SRS BW configuration and C_{SRS} is the set of SRS BW configurations from the Tables 5.5.3.2-1 to 5.5.3.2-4 for each uplink bandwidth $N_{\mathrm{RB}}^{\mathrm{UL}}$, N_{RA} is the number of format 4 PRACH in the addressed UpPTS and derived from Table 5.7.1-4.

The frequency-domain starting position $k_0^{(p)}$ is defined by

Petitioners' Exhibit 1003, p. 1118
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$k_0^{(p)} = \bar{k}_0^{(p)} + \sum_{b=0}^{B_{\mathrm{SRS}}} K_{\mathrm{TC}} M_{\mathrm{sc},b}^{\mathrm{RS}} n_b$$

where for normal uplink subframes $\bar{k}_0^{(p)}$ is defined by

$$\bar{k}_0^{(p)} = \left(\left\lfloor N_{\mathrm{RB}}^{\mathrm{UL}} / 2 \right\rfloor - m_{\mathrm{SRS},0}/2\right) N_{\mathrm{SC}}^{\mathrm{RB}} + k_{\mathrm{TC}}^{(p)}$$

and for UpPTS by

$$\bar{k}_0^{(p)} = \begin{cases} (N_{\mathrm{RB}}^{\mathrm{UL}} - m_{\mathrm{SRS},0}^{\max}) N_{\mathrm{sc}}^{\mathrm{RB}} + k_{\mathrm{TC}}^{(p)} & \text{if } \left((n_{\mathrm{f}} \bmod 2)\cdot(2 - N_{\mathrm{SP}}) + n_{\mathrm{hf}}\right) \bmod 2 = 0 \\ k_{\mathrm{TC}}^{(p)} & \text{otherwise} \end{cases}$$

The quantity $k_{\mathrm{TC}}^{(p)} \in \{0,1,\ldots,K_{\mathrm{TC}} - 1\}$ is given by

$$k_{\mathrm{TC}}^{(p)} = \begin{cases} 1 - \bar{k}_{\mathrm{TC}} & \text{if } n_{\mathrm{SRS}}^{\mathrm{cs}} \in \{4,5,6,7\} \text{ and } \tilde{p} \in \{1,3\} \text{ and } N_{\mathrm{ap}} = 4 \\ \bar{k}_{\mathrm{TC}} & \text{otherwise} \end{cases}$$

where the relation between the index $\tilde{p}$ and the antenna port p is given by Table 5.2.1-1, $\bar{k}_{\mathrm{TC}} \in \{0,1,\ldots,K_{\mathrm{TC}} - 1\}$ is given by the UE-specific parameter *transmissionComb* or *transmissionComb-ap* for periodic and each configuration of aperiodic transmission, respectively, provided by higher layers for the UE, and n_b is frequency position index. The variable n_{hf} is equal to 0 for UpPTS in the first half frame and equal to 1 for UpPTS in the second half frame of a radio frame.

The frequency hopping of the sounding reference signal is configured by the parameter $b_{\mathrm{hop}} \in \{0,1,2,3\}$, provided by higher-layer parameter *srs-HoppingBandwidth*. Frequency hopping is not supported for aperiodic transmission. If frequency hopping of the sounding reference signal is not enabled (i.e., $b_{\mathrm{hop}} \geq B_{\mathrm{SRS}}$), the frequency position index n_b remains constant (unless re-configured) and is defined by $n_{\mathrm{b}} = \lfloor 4n_{\mathrm{RRC}} / m_{\mathrm{SRS},b} \rfloor \bmod N_{\mathrm{b}}$ where the parameter n_{RRC} is given by higher-layer parameters *freqDomainPosition* and *freqDomainPosition-ap* for periodic and each configuration of aperiodic transmission, respectively. If frequency hopping of the sounding reference signal is enabled (i.e., $b_{\mathrm{hop}} < B_{\mathrm{SRS}}$), the frequency position indexes n_b are defined by

$$n_b = \begin{cases} \lfloor 4n_{\mathrm{RRC}} / m_{\mathrm{SRS},b} \rfloor \bmod N_b & b \leq b_{\mathrm{hop}} \\ \left\{F_b(n_{\mathrm{SRS}}) + \lfloor 4n_{\mathrm{RRC}} / m_{\mathrm{SRS},b} \rfloor\right\} \bmod N_b & \text{otherwise} \end{cases}$$

where N_b is given by Table 5.5.3.2-1 through Table 5.5.3.2-4 for each uplink bandwidth $N_{\mathrm{RB}}^{\mathrm{UL}}$,

$$F_b(n_{\mathrm{SRS}}) = \begin{cases} (N_b/2)\left\lfloor \dfrac{n_{\mathrm{SRS}} \bmod \Pi_{b'=b_{\mathrm{hop}}}^{b} N_{b'}}{\Pi_{b'=b_{\mathrm{hop}}}^{b-1} N_{b'}} \right\rfloor + \left\lfloor \dfrac{n_{\mathrm{SRS}} \bmod \Pi_{b'=b_{\mathrm{hop}}}^{b} N_{b'}}{2\Pi_{b'=b_{\mathrm{hop}}}^{b-1} N_{b'}} \right\rfloor & \text{if } N_b \text{ even} \\ \lfloor N_b/2 \rfloor \left\lfloor n_{\mathrm{SRS}} / \Pi_{b'=b_{\mathrm{hop}}}^{b-1} N_{b'} \right\rfloor & \text{if } N_b \text{ odd} \end{cases}$$

where $N_{b_{\mathrm{hop}}} = 1$ regardless of the N_b value on Table 5.5.3.2-1 through Table 5.5.3.2-4, and

$$n_{\mathrm{SRS}} = \begin{cases} 2N_{\mathrm{SP}} n_{\mathrm{f}} + 2(N_{\mathrm{SP}} - 1)\left\lfloor \dfrac{n_{\mathrm{s}}}{10} \right\rfloor + \left\lfloor \dfrac{T_{\mathrm{offset}}}{T_{\mathrm{offset\_max}}} \right\rfloor, & \text{for 2 ms SRS periodicity of frame structure type 2} \\ \left\lfloor (n_{\mathrm{f}} \times 10 + \lfloor n_{\mathrm{s}}/2 \rfloor)/T_{\mathrm{SRS}} \right\rfloor, & \text{otherwise} \end{cases}$$

counts the number of UE-specific SRS transmissions, where T_{SRS} is UE-specific periodicity of SRS transmission defined in clause 8.2 of 3GPP TS 36.213 [4], T_{offset} is SRS subframe offset defined in Table 8.2-2 of 3GPP TS 36.213 [4] and $T_{\mathrm{offset\_max}}$ is the maximum value of T_{offset} for a certain configuration of SRS subframe offset.

The sounding reference signal shall be transmitted in the last symbol of the uplink subframe.

Petitioners' Exhibit 1003, p. 1119
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.5.3.2-1: $m_{\mathrm{SRS},b}$ and N_b, $b = 0,1,2,3$, values for the uplink bandwidth of $6 \le N_{\mathrm{RB}}^{\mathrm{UL}} \le 40$

SRS bandwidth configuration C_{SRS}	SRS-Bandwidth $B_{\mathrm{SRS}} = 0$		SRS-Bandwidth $B_{\mathrm{SRS}} = 1$		SRS-Bandwidth $B_{\mathrm{SRS}} = 2$		SRS-Bandwidth $B_{\mathrm{SRS}} = 3$	
	$m_{\mathrm{SRS},0}$	N_0	$m_{\mathrm{SRS},1}$	N_1	$m_{\mathrm{SRS},2}$	N_2	$m_{\mathrm{SRS},3}$	N_3
0	36	1	12	3	4	3	4	1
1	32	1	16	2	8	2	4	2
2	24	1	4	6	4	1	4	1
3	20	1	4	5	4	1	4	1
4	16	1	4	4	4	1	4	1
5	12	1	4	3	4	1	4	1
6	8	1	4	2	4	1	4	1
7	4	1	4	1	4	1	4	1

Table 5.5.3.2-2: $m_{\mathrm{SRS},b}$ and N_b, $b = 0,1,2,3$, values for the uplink bandwidth of $40 < N_{\mathrm{RB}}^{\mathrm{UL}} \le 60$

SRS bandwidth configuration C_{SRS}	SRS-Bandwidth $B_{\mathrm{SRS}} = 0$		SRS-Bandwidth $B_{\mathrm{SRS}} = 1$		SRS-Bandwidth $B_{\mathrm{SRS}} = 2$		SRS-Bandwidth $B_{\mathrm{SRS}} = 3$	
	$m_{\mathrm{SRS},0}$	N_0	$m_{\mathrm{SRS},1}$	N_1	$m_{\mathrm{SRS},2}$	N_2	$m_{\mathrm{SRS},3}$	N_3
0	48	1	24	2	12	2	4	3
1	48	1	16	3	8	2	4	2
2	40	1	20	2	4	5	4	1
3	36	1	12	3	4	3	4	1
4	32	1	16	2	8	2	4	2
5	24	1	4	6	4	1	4	1
6	20	1	4	5	4	1	4	1
7	16	1	4	4	4	1	4	1

Table 5.5.3.2-3: $m_{\mathrm{SRS},b}$ and N_b, $b = 0,1,2,3$, values for the uplink bandwidth of $60 < N_{\mathrm{RB}}^{\mathrm{UL}} \le 80$

SRS bandwidth configuration C_{SRS}	SRS-Bandwidth $B_{\mathrm{SRS}} = 0$		SRS-Bandwidth $B_{\mathrm{SRS}} = 1$		SRS-Bandwidth $B_{\mathrm{SRS}} = 2$		SRS-Bandwidth $B_{\mathrm{SRS}} = 3$	
	$m_{\mathrm{SRS},0}$	N_0	$m_{\mathrm{SRS},1}$	N_1	$m_{\mathrm{SRS},2}$	N_2	$m_{\mathrm{SRS},3}$	N_3
0	72	1	24	3	12	2	4	3
1	64	1	32	2	16	2	4	4
2	60	1	20	3	4	5	4	1
3	48	1	24	2	12	2	4	3
4	48	1	16	3	8	2	4	2
5	40	1	20	2	4	5	4	1
6	36	1	12	3	4	3	4	1
7	32	1	16	2	8	2	4	2

Table 5.5.3.2-4: $m_{\mathrm{SRS},b}$ and N_b, $b = 0,1,2,3$, values for the uplink bandwidth of $80 < N_{\mathrm{RB}}^{\mathrm{UL}} \le 110$

SRS bandwidth configuration C_{SRS}	SRS-Bandwidth $B_{\mathrm{SRS}} = 0$		SRS-Bandwidth $B_{\mathrm{SRS}} = 1$		SRS-Bandwidth $B_{\mathrm{SRS}} = 2$		SRS-Bandwidth $B_{\mathrm{SRS}} = 3$	
	$m_{\mathrm{SRS},0}$	N_0	$m_{\mathrm{SRS},1}$	N_1	$m_{\mathrm{SRS},2}$	N_2	$m_{\mathrm{SRS},3}$	N_3
0	96	1	48	2	24	2	4	6
1	96	1	32	3	16	2	4	4
2	80	1	40	2	20	2	4	5
3	72	1	24	3	12	2	4	3
4	64	1	32	2	16	2	4	4
5	60	1	20	3	4	5	4	1
6	48	1	24	2	12	2	4	3
7	48	1	16	3	8	2	4	2

Petitioners' Exhibit 1003, p. 1120
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.5.3.3 Sounding reference signal subframe configuration

The cell-specific subframe configuration period T_{SFC} and the cell-specific subframe offset Δ_{SFC} for the transmission of sounding reference signals are listed in Tables 5.5.3.3-1 and 5.5.3.3-2, for frame structures type 1 and 2 respectively, where the parameter *srs-SubframeConfig* is provided by higher layers. Sounding reference signal subframes are the subframes satisfying $\lfloor n_s / 2 \rfloor \bmod T_{\mathrm{SFC}} \in \Delta_{\mathrm{SFC}}$. For frame structure type 2, a sounding reference signal is transmitted only in uplink subframes or UpPTS.

Table 5.5.3.3-1: Frame structure type 1 sounding reference signal subframe configuration

srs-SubframeConfig	Binary	Configuration Period T_{SFC} (subframes)	Transmission offset Δ_{SFC} (subframes)
0	0000	1	{0}
1	0001	2	{0}
2	0010	2	{1}
3	0011	5	{0}
4	0100	5	{1}
5	0101	5	{2}
6	0110	5	{3}
7	0111	5	{0,1}
8	1000	5	{2,3}
9	1001	10	{0}
10	1010	10	{1}
11	1011	10	{2}
12	1100	10	{3}
13	1101	10	{0,1,2,3,4,6,8}
14	1110	10	{0,1,2,3,4,5,6,8}
15	1111	reserved	reserved

Table 5.5.3.3-2: Frame structure type 2 sounding reference signal subframe configuration

srs-SubframeConfig	Binary	Configuration Period T_{SFC} (subframes)	Transmission offset Δ_{SFC} (subframes)
0	0000	5	{1}
1	0001	5	{1, 2}
2	0010	5	{1, 3}
3	0011	5	{1, 4}
4	0100	5	{1, 2, 3}
5	0101	5	{1, 2, 4}
6	0110	5	{1, 3, 4}
7	0111	5	{1, 2, 3, 4}
8	1000	10	{1, 2, 6}
9	1001	10	{1, 3, 6}
10	1010	10	{1, 6, 7}
11	1011	10	{1, 2, 6, 8}
12	1100	10	{1, 3, 6, 9}
13	1101	10	{1, 4, 6, 7}
14	1110	reserved	reserved
15	1111	reserved	reserved

Petitioners' Exhibit 1003, p. 1121
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.6 SC-FDMA baseband signal generation

This clause applies to all uplink physical signals and uplink physical channels except the physical random access channel.

The time-continuous signal $s_l^{(p)}(t)$ for antenna port p in SC-FDMA symbol l in an uplink slot is defined by

$$s_l^{(p)}(t) = \sum_{k=-\lfloor N_{\mathrm{RB}}^{\mathrm{UL}} N_{\mathrm{sc}}^{\mathrm{RB}}/2 \rfloor}^{\lceil N_{\mathrm{RB}}^{\mathrm{UL}} N_{\mathrm{sc}}^{\mathrm{RB}}/2 \rceil - 1} a_{k^{(-)},l}^{(p)} \cdot e^{j2\pi(k+1/2)\Delta f\left(t - N_{\mathrm{CP},l} T_{\mathrm{s}}\right)}$$

for $0 \le t < (N_{\mathrm{CP},l} + N) \times T_{\mathrm{s}}$ where $k^{(-)} = k + \lfloor N_{RB}^{UL} N_{sc}^{RB}/2 \rfloor$, $N = 2048$, $\Delta f = 15\,\mathrm{kHz}$ and $a_{k,l}^{(p)}$ is the content of resource element (k,l) on antenna port p.

The SC-FDMA symbols in a slot shall be transmitted in increasing order of l, starting with $l = 0$, where SC-FDMA symbol $l > 0$ starts at time $\sum_{l'=0}^{l-1} (N_{\mathrm{CP},l'} + N) T_{\mathrm{s}}$ within the slot.

Table 5.6-1 lists the values of $N_{\mathrm{CP},l}$ that shall be used.

Table 5.6-1: SC-FDMA parameters

Configuration	Cyclic prefix length $N_{\mathrm{CP},l}$
Normal cyclic prefix	160 for $l = 0$ 144 for $l = 1,2,\ldots,6$
Extended cyclic prefix	512 for $l = 0,1,\ldots,5$

Petitioners' Exhibit 1003, p. 1122
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.7 Physical random access channel

5.7.1 Time and frequency structure

The physical layer random access preamble, illustrated in Figure 5.7.1-1, consists of a cyclic prefix of length T_{CP} and a sequence part of length T_{SEQ}. The parameter values are listed in Table 5.7.1-1 and depend on the frame structure and the random access configuration. Higher layers control the preamble format.

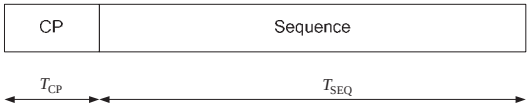


Figure 5.7.1-1: Random access preamble format

Table 5.7.1-1: Random access preamble parameters

Preamble format	T_{CP}	T_{SEQ}
0	$3168 \cdot T_s$	$24576 \cdot T_s$
1	$21024 \cdot T_s$	$24576 \cdot T_s$
2	$6240 \cdot T_s$	$2 \cdot 24576 \cdot T_s$
3	$21024 \cdot T_s$	$2 \cdot 24576 \cdot T_s$
4 (see Note)	$448 \cdot T_s$	$4096 \cdot T_s$
NOTE: Frame structure type 2 and special subframe configurations with UpPTS lengths $4384 \cdot T_s$ and $5120 \cdot T_s$ only.		

The transmission of a random access preamble, if triggered by the MAC layer, is restricted to certain time and frequency resources. These resources are enumerated in increasing order of the subframe number within the radio frame and the physical resource blocks in the frequency domain such that index 0 correspond to the lowest numbered physical resource block and subframe within the radio frame. PRACH resources within the radio frame are indicated by a PRACH configuration index, where the indexing is in the order of appearance in Table 5.7.1-2 and Table 5.7.1-4.

For non-BL/CE UEs there is a single PRACH configuration with $n_{\text{PRB offset}}^{\text{RA}}$ given by the higher-layer parameter *prach-FrequencyOffset.*

For BL/CE UEs, for each PRACH coverage enhancement level, there is a PRACH configuration configured by higher layers with a PRACH configuration index (*prach-ConfigurationIndex*), a PRACH frequency offset $\bar{n}_{\text{PRBoffset}}^{\text{RA}}$ (*prach-FrequencyOffset*), a number of PRACH repetitions per attempt $N_{\text{rep}}^{\text{PRACH}}$ (*numRepetitionPerPreambleAttempt*) and optionally a PRACH starting subframe periodicity $N_{\text{start}}^{\text{PRACH}}$ (*prach-StartingSubframe*). PRACH of preamble format 0-3 is transmitted $N_{\text{rep}}^{\text{PRACH}} \geq 1$ times, whereas PRACH of preamble format 4 is transmitted one time only.

For BL/CE UEs and for each PRACH coverage enhancement level, if frequency hopping is enabled for a PRACH configuration by the higher-layer parameter *prach-HoppingConfig*, the value of the parameter $n_{\text{PRB offset}}^{\text{RA}}$ depends on the SFN and the PRACH configuration index and is given by

- In case the PRACH configuration index is such that a PRACH resource occurs in every radio frame when calculated as below from Table 5.7.1-2 or Table 5.7.1-4,

$$n_{\text{PRB offset}}^{\text{RA}} = \begin{cases} \bar{n}_{\text{PRB offset}}^{\text{RA}} & \text{if } n_f \bmod 2 = 0 \\ \left(\bar{n}_{\text{PRB offset}}^{\text{RA}} + f_{\text{PRB,hop}}^{\text{PRACH}}\right) \bmod N_{\text{RB}}^{\text{UL}} & \text{if } n_f \bmod 2 = 1 \end{cases}$$

- otherwise

Petitioners' Exhibit 1003, p. 1123
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$n_{\mathrm{PRB\,offset}}^{\mathrm{RA}} = \begin{cases} \bar{n}_{\mathrm{PRB\,offset}}^{\mathrm{RA}} & \text{if } \left\lfloor \frac{n_f \bmod 4}{2} \right\rfloor = 0 \\ \left(\bar{n}_{\mathrm{PRB\,offset}}^{\mathrm{RA}} + f_{\mathrm{PRB,hop}}^{\mathrm{PRACH}}\right) \bmod N_{\mathrm{RB}}^{\mathrm{UL}} & \text{if } \left\lfloor \frac{n_f \bmod 4}{2} \right\rfloor = 1 \end{cases}$$

where n_f is the system frame number, $f_{\mathrm{PRB,hop}}^{\mathrm{PRACH}}$ corresponds to a cell-specific higher-layer parameter *prach-HoppingOffset*. If frequency hopping is not enabled for the PRACH configuration then $n_{\mathrm{PRB\,offset}}^{\mathrm{RA}} = \bar{n}_{\mathrm{PRB\,offset}}^{\mathrm{RA}}$.

For frame structure type 1 with preamble format 0-3, for each of the PRACH configurations there is at most one random access resource per subframe.
Table 5.7.1-2 lists the preamble formats according to Table 5.7.1-1 and the subframes in which random access preamble transmission is allowed for a given configuration in frame structure type 1. The start of the random access preamble shall be aligned with the start of the corresponding uplink subframe at the UE assuming $N_{\mathrm{TA}} = 0$, where N_{TA} is defined in clause 8.1. For PRACH configurations 0, 1, 2, 15, 16, 17, 18, 31, 32, 33, 34, 47, 48, 49, 50 and 63 the UE may for handover purposes assume an absolute value of the relative time difference between radio frame i in the current cell and the target cell of less than $153600 \cdot T_s$.

The first physical resource block $n_{\mathrm{PRB}}^{\mathrm{RA}}$ allocated to the PRACH opportunity considered for preamble formats 0, 1, 2 and 3 is defined as $n_{\mathrm{PRB}}^{\mathrm{RA}} = n_{\mathrm{PRB\,offset}}^{\mathrm{RA}}$.

Table 5.7.1-2: Frame structure type 1 random access configuration for preamble formats 0-3

PRACH Configuration Index	Preamble Format	System frame number	Subframe number	PRACH Configuration Index	Preamble Format	System frame number	Subframe number
0	0	Even	1	32	2	Even	1
1	0	Even	4	33	2	Even	4
2	0	Even	7	34	2	Even	7
3	0	Any	1	35	2	Any	1
4	0	Any	4	36	2	Any	4
5	0	Any	7	37	2	Any	7
6	0	Any	1, 6	38	2	Any	1, 6
7	0	Any	2 ,7	39	2	Any	2 ,7
8	0	Any	3, 8	40	2	Any	3, 8
9	0	Any	1, 4, 7	41	2	Any	1, 4, 7
10	0	Any	2, 5, 8	42	2	Any	2, 5, 8
11	0	Any	3, 6, 9	43	2	Any	3, 6, 9
12	0	Any	0, 2, 4, 6, 8	44	2	Any	0, 2, 4, 6, 8
13	0	Any	1, 3, 5, 7, 9	45	2	Any	1, 3, 5, 7, 9
14	0	Any	0, 1, 2, 3, 4, 5, 6, 7, 8, 9	46	N/A	N/A	N/A
15	0	Even	9	47	2	Even	9
16	1	Even	1	48	3	Even	1
17	1	Even	4	49	3	Even	4
18	1	Even	7	50	3	Even	7
19	1	Any	1	51	3	Any	1
20	1	Any	4	52	3	Any	4
21	1	Any	7	53	3	Any	7
22	1	Any	1, 6	54	3	Any	1, 6
23	1	Any	2 ,7	55	3	Any	2 ,7
24	1	Any	3, 8	56	3	Any	3, 8
25	1	Any	1, 4, 7	57	3	Any	1, 4, 7
26	1	Any	2, 5, 8	58	3	Any	2, 5, 8
27	1	Any	3, 6, 9	59	3	Any	3, 6, 9
28	1	Any	0, 2, 4, 6, 8	60	N/A	N/A	N/A
29	1	Any	1, 3, 5, 7, 9	61	N/A	N/A	N/A
30	N/A	N/A	N/A	62	N/A	N/A	N/A
31	1	Even	9	63	3	Even	9

For frame structure type 2 with preamble formats 0-4, for each of the PRACH configurations there might be multiple random access resources in an UL subframe (or UpPTS for preamble format 4) depending on the UL/DL configuration

Petitioners' Exhibit 1003, p. 1124
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

[see table 4.2-2]. Table 5.7.1-3 lists PRACH configurations allowed for frame structure type 2 where the configuration index corresponds to a certain combination of preamble format, PRACH density value, D_{RA} and version index, r_{RA}. For frame structure type 2 with PRACH configuration indices 0, 1, 2, 20, 21, 22, 30, 31, 32, 40, 41, 42, 48, 49, 50, or with PRACH configuration indices 51, 53, 54, 55, 56, 57 in UL/DL configuration 3, 4, 5, the UE may for handover purposes assume an absolute value of the relative time difference between radio frame i in the current cell and the target cell is less than $153600 \cdot T_s$.

Table 5.7.1-3: Frame structure type 2 random access configurations for preamble formats 0-4

PRACH configuration Index	Preamble Format	Density Per 10 ms D_{RA}	Version r_{RA}	PRACH configuration Index	Preamble Format	Density Per 10 ms D_{RA}	Version r_{RA}
0	0	0.5	0	32	2	0.5	2
1	0	0.5	1	33	2	1	0
2	0	0.5	2	34	2	1	1
3	0	1	0	35	2	2	0
4	0	1	1	36	2	3	0
5	0	1	2	37	2	4	0
6	0	2	0	38	2	5	0
7	0	2	1	39	2	6	0
8	0	2	2	40	3	0.5	0
9	0	3	0	41	3	0.5	1
10	0	3	1	42	3	0.5	2
11	0	3	2	43	3	1	0
12	0	4	0	44	3	1	1
13	0	4	1	45	3	2	0
14	0	4	2	46	3	3	0
15	0	5	0	47	3	4	0
16	0	5	1	48	4	0.5	0
17	0	5	2	49	4	0.5	1
18	0	6	0	50	4	0.5	2
19	0	6	1	51	4	1	0
20	1	0.5	0	52	4	1	1
21	1	0.5	1	53	4	2	0
22	1	0.5	2	54	4	3	0
23	1	1	0	55	4	4	0
24	1	1	1	56	4	5	0
25	1	2	0	57	4	6	0
26	1	3	0	58	N/A	N/A	N/A
27	1	4	0	59	N/A	N/A	N/A
28	1	5	0	60	N/A	N/A	N/A
29	1	6	0	61	N/A	N/A	N/A
30	2	0.5	0	62	N/A	N/A	N/A
31	2	0.5	1	63	N/A	N/A	N/A

Table 5.7.1-4 lists the mapping to physical resources for the different random access opportunities needed for a certain PRACH density value, D_{RA}. Each quadruple of the format $(f_{\mathrm{RA}}, t_{\mathrm{RA}}^{(0)}, t_{\mathrm{RA}}^{(1)}, t_{\mathrm{RA}}^{(2)})$ indicates the location of a specific random access resource, where f_{RA} is a frequency resource index within the considered time instance, $t_{\mathrm{RA}}^{(0)} = 0,1,2$ indicates whether the resource is reoccurring in all radio frames, in even radio frames, or in odd radio frames, respectively, $t_{\mathrm{RA}}^{(1)} = 0,1$ indicates whether the random access resource is located in first half frame or in second half frame, respectively, and where $t_{\mathrm{RA}}^{(2)}$ is the uplink subframe number where the preamble starts, counting from 0 at the first uplink subframe between 2 consecutive downlink-to-uplink switch points, with the exception of preamble format 4 where $t_{\mathrm{RA}}^{(2)}$ is denoted as (*). The start of the random access preamble formats 0-3 shall be aligned with the start of the corresponding uplink subframe at the UE assuming $N_{\mathrm{TA}} = 0$ and the random access preamble format 4 shall start $4832 \cdot T_s$ before the end of the UpPTS at the UE, where the UpPTS is referenced to the UE"s uplink frame timing assuming $N_{\mathrm{TA}} = 0$.

The random access opportunities for each PRACH configuration shall be allocated in time first and then in frequency if and only if time multiplexing is not sufficient to hold all opportunities of a PRACH configuration needed for a certain

Petitioners' Exhibit 1003, p. 1125
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

density value D_{RA} without overlap in time. For preamble format 0-3, the frequency multiplexing shall be done according to

$$n_{\text{PRB}}^{\text{RA}} = \begin{cases} n_{\text{PRB offset}}^{\text{RA}} + 6\left\lfloor \frac{f_{\text{RA}}}{2} \right\rfloor, & \text{if } f_{\text{RA}} \bmod 2 = 0 \\ N_{\text{RB}}^{\text{UL}} - 6 - n_{\text{PRB offset}}^{\text{RA}} - 6\left\lfloor \frac{f_{\text{RA}}}{2} \right\rfloor, & \text{otherwise} \end{cases}$$

where $N_{\text{RB}}^{\text{UL}}$ is the number of uplink resource blocks, $n_{\text{PRB}}^{\text{RA}}$ is the first physical resource block allocated to the PRACH opportunity considered and where $n_{\text{PRB offset}}^{\text{RA}}$ is the first physical resource block available for PRACH.

For preamble format 4, the frequency multiplexing shall be done according to

$$n_{\text{PRB}}^{\text{RA}} = \begin{cases} 6 f_{\text{RA}}, & \text{if } \left((n_{\text{f}} \bmod 2) \times (2 - N_{\text{SP}}) + t_{\text{RA}}^{(1)}\right) \bmod 2 = 0 \\ N_{\text{RB}}^{\text{UL}} - 6(f_{\text{RA}} + 1), & \text{otherwise} \end{cases}$$

where n_{f} is the system frame number and where N_{SP} is the number of DL to UL switch points within the radio frame.

For BL/CE UEs, only a subset of the subframes allowed for preamble transmission are allowed as starting subframes for the $N_{\text{rep}}^{\text{PRACH}}$ repetitions. The allowed starting subframes for a PRACH configuration are determined as follows:

- Enumerate the subframes that are allowed for preamble transmission for the PRACH configuration as $n_{\text{sf}}^{\text{RA}} = 0,...N_{\text{sf}}^{\text{RA}} - 1$ where $n_{\text{sf}}^{\text{RA}} = 0$ and $n_{\text{sf}}^{\text{RA}} = N_{\text{sf}}^{\text{RA}} - 1$ correspond to the two subframes allowed for preamble transmission with the smallest and the largest absolute subframe number $n_{\text{sf}}^{\text{abs}}$, respectively.

- If a PRACH starting subframe periodicity $N_{\text{start}}^{\text{PRACH}}$ is not provided by higher layers, the periodicity of the allowed starting subframes in terms of subframes allowed for preamble transmission is $N_{\text{rep}}^{\text{PRACH}}$. The allowed starting subframes defined over $n_{\text{sf}}^{\text{RA}} = 0,...N_{\text{sf}}^{\text{RA}} - 1$ are given by $jN_{\text{rep}}^{\text{PRACH}}$ where $j = 0, 1, 2, ...$

- If a PRACH starting subframe periodicity $N_{\text{start}}^{\text{PRACH}}$ is provided by higher layers, it indicates the periodicity of the allowed starting subframes in terms of subframes allowed for preamble transmission. The allowed starting subframes defined over $jN_{\text{start}}^{\text{PRACH}} + N_{\text{rep}}^{\text{PRACH}}$ where $j = 0, 1, 2, ...$

- No starting subframe with absolute subframe number $n_{\text{sf}}^{\text{abs}} > 10240 - N_{\text{rep}}^{\text{PRACH}}$ is allowed.

Each random access preamble occupies a bandwidth corresponding to 6 consecutive resource blocks for both frame structures.

Petitioners' Exhibit 1003, p. 1126
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.7.1-4: Frame structure type 2 random access preamble mapping in time and frequency

PRACH configuration Index (See Table 5.7.1-3)	UL/DL configuration (See Table 4.2-2)						
	0	1	2	3	4	5	6
0	(0,1,0,2)	(0,1,0,1)	(0,1,0,0)	(0,1,0,2)	(0,1,0,1)	(0,1,0,0)	(0,1,0,2)
1	(0,2,0,2)	(0,2,0,1)	(0,2,0,0)	(0,2,0,2)	(0,2,0,1)	(0,2,0,0)	(0,2,0,2)
2	(0,1,1,2)	(0,1,1,1)	(0,1,1,0)	(0,1,0,1)	(0,1,0,0)	N/A	(0,1,1,1)
3	(0,0,0,2)	(0,0,0,1)	(0,0,0,0)	(0,0,0,2)	(0,0,0,1)	(0,0,0,0)	(0,0,0,2)
4	(0,0,1,2)	(0,0,1,1)	(0,0,1,0)	(0,0,0,1)	(0,0,0,0)	N/A	(0,0,1,1)
5	(0,0,0,1)	(0,0,0,0)	N/A	(0,0,0,0)	N/A	N/A	(0,0,0,1)
6	(0,0,0,2) (0,0,1,2)	(0,0,0,1) (0,0,1,1)	(0,0,0,0) (0,0,1,0)	(0,0,0,1) (0,0,0,2)	(0,0,0,0) (0,0,0,1)	(0,0,0,0) (1,0,0,0)	(0,0,0,2) (0,0,1,1)
7	(0,0,0,1) (0,0,1,1)	(0,0,0,0) (0,0,1,0)	N/A	(0,0,0,0) (0,0,0,2)	N/A	N/A	(0,0,0,1) (0,0,1,0)
8	(0,0,0,0) (0,0,1,0)	N/A	N/A	(0,0,0,0) (0,0,0,1)	N/A	N/A	(0,0,0,0) (0,0,1,1)
9	(0,0,0,1) (0,0,0,2) (0,0,1,2)	(0,0,0,0) (0,0,0,1) (0,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2)	(0,0,0,0) (0,0,0,1) (1,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0)	(0,0,0,1) (0,0,0,2) (0,0,1,1)
10	(0,0,0,0) (0,0,1,0) (0,0,1,1)	(0,0,0,1) (0,0,1,0) (0,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,1,0)	N/A	(0,0,0,0) (0,0,0,1) (1,0,0,0)	N/A	(0,0,0,0) (0,0,0,2) (0,0,1,0)
11	N/A	(0,0,0,0) (0,0,0,1) (0,0,1,0)	N/A	N/A	N/A	N/A	(0,0,0,1) (0,0,1,0) (0,0,1,1)
12	(0,0,0,1) (0,0,0,2) (0,0,1,1) (0,0,1,2)	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,2)	(0,0,0,0) (0,0,0,1) (1,0,0,0) (1,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0)	(0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,1)
13	(0,0,0,0) (0,0,0,2) (0,0,1,0) (0,0,1,2)	N/A	N/A	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,1)	N/A	N/A	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,1)
14	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1)	N/A	N/A	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,0)	N/A	N/A	(0,0,0,0) (0,0,0,2) (0,0,1,0) (0,0,1,1)
15	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,1) (0,0,1,2)	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1) (1,0,0,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0) (2,0,0,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,1) (1,0,0,2)	(0,0,0,0) (0,0,0,1) (1,0,0,0) (1,0,0,1) (2,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0) (4,0,0,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,1)
16	(0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,1) (0,0,1,2)	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1) (1,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0) (2,0,1,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,0) (1,0,0,2)	(0,0,0,0) (0,0,0,1) (1,0,0,0) (1,0,0,1) (2,0,0,0)	N/A	N/A
17	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,2)	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1) (1,0,0,0)	N/A	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,0) (1,0,0,1)	N/A	N/A	N/A
18	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,1) (0,0,1,2)	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1) (1,0,0,1) (1,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0) (2,0,0,0) (2,0,1,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2) (1,0,0,0) (1,0,0,1) (1,0,0,2)	(0,0,0,0) (0,0,0,1) (1,0,0,0) (1,0,0,1) (2,0,0,0) (2,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0) (4,0,0,0) (5,0,0,0)	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,1) (1,0,0,2)
19	N/A	(0,0,0,0) (0,0,0,1) (0,0,1,0) (0,0,1,1) (1,0,0,0) (1,0,1,0)	N/A	N/A	N/A	N/A	(0,0,0,0) (0,0,0,1) (0,0,0,2) (0,0,1,0) (0,0,1,1) (1,0,1,1)
20 / 30	(0,1,0,1)	(0,1,0,0)	N/A	(0,1,0,1)	(0,1,0,0)	N/A	(0,1,0,1)
21 / 31	(0,2,0,1)	(0,2,0,0)	N/A	(0,2,0,1)	(0,2,0,0)	N/A	(0,2,0,1)
22 / 32	(0,1,1,1)	(0,1,1,0)	N/A	N/A	N/A	N/A	(0,1,1,0)
23 / 33	(0,0,0,1)	(0,0,0,0)	N/A	(0,0,0,1)	(0,0,0,0)	N/A	(0,0,0,1)
24 / 34	(0,0,1,1)	(0,0,1,0)	N/A	N/A	N/A	N/A	(0,0,1,0)
25 / 35	(0,0,0,1) (0,0,1,1)	(0,0,0,0) (0,0,1,0)	N/A	(0,0,0,1) (1,0,0,1)	(0,0,0,0) (1,0,0,0)	N/A	(0,0,0,1) (0,0,1,0)
26 / 36	(0,0,0,1) (0,0,1,1) (1,0,0,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0)	N/A	(0,0,0,1) (1,0,0,1) (2,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0)	N/A	(0,0,0,1) (0,0,1,0) (1,0,0,1)

Petitioners' Exhibit 1003, p. 1127
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

27 / 37	(0,0,0,1) (0,0,1,1) (1,0,0,1) (1,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0)	N/A	(0,0,0,1) (1,0,0,1) (2,0,0,1) (3,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0)	N/A	(0,0,0,1) (0,0,1,0) (1,0,0,1) (1,0,1,0)
28 / 38	(0,0,0,1) (0,0,1,1) (1,0,0,1) (1,0,1,1) (2,0,0,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0) (2,0,0,0)	N/A	(0,0,0,1) (1,0,0,1) (2,0,0,1) (3,0,0,1) (4,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0) (4,0,0,0)	N/A	(0,0,0,1) (0,0,1,0) (1,0,0,1) (1,0,1,0) (2,0,0,1)
29 /39	(0,0,0,1) (0,0,1,1) (1,0,0,1) (1,0,1,1) (2,0,0,1) (2,0,1,1)	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0) (2,0,0,0) (2,0,1,0)	N/A	(0,0,0,1) (1,0,0,1) (2,0,0,1) (3,0,0,1) (4,0,0,1) (5,0,0,1)	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0) (4,0,0,0) (5,0,0,0)	N/A	(0,0,0,1) (0,0,1,0) (1,0,0,1) (1,0,1,0) (2,0,0,1) (2,0,1,0)
40	(0,1,0,0)	N/A	N/A	(0,1,0,0)	N/A	N/A	(0,1,0,0)
41	(0,2,0,0)	N/A	N/A	(0,2,0,0)	N/A	N/A	(0,2,0,0)
42	(0,1,1,0)	N/A	N/A	N/A	N/A	N/A	N/A
43	(0,0,0,0)	N/A	N/A	(0,0,0,0)	N/A	N/A	(0,0,0,0)
44	(0,0,1,0)	N/A	N/A	N/A	N/A	N/A	N/A
45	(0,0,0,0) (0,0,1,0)	N/A	N/A	(0,0,0,0) (1,0,0,0)	N/A	N/A	(0,0,0,0) (1,0,0,0)
46	(0,0,0,0) (0,0,1,0) (1,0,0,0)	N/A	N/A	(0,0,0,0) (1,0,0,0) (2,0,0,0)	N/A	N/A	(0,0,0,0) (1,0,0,0) (2,0,0,0)
47	(0,0,0,0) (0,0,1,0) (1,0,0,0) (1,0,1,0)	N/A	N/A	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0)	N/A	N/A	(0,0,0,0) (1,0,0,0) (2,0,0,0) (3,0,0,0)
48	(0,1,0,*)	(0,1,0,*)	(0,1,0,*)	(0,1,0,*)	(0,1,0,*)	(0,1,0,*)	(0,1,0,*)
49	(0,2,0,*)	(0,2,0,*)	(0,2,0,*)	(0,2,0,*)	(0,2,0,*)	(0,2,0,*)	(0,2,0,*)
50	(0,1,1,*)	(0,1,1,*)	(0,1,1,*)	N/A	N/A	N/A	(0,1,1,*)
51	(0,0,0,*)	(0,0,0,*)	(0,0,0,*)	(0,0,0,*)	(0,0,0,*)	(0,0,0,*)	(0,0,0,*)
52	(0,0,1,*)	(0,0,1,*)	(0,0,1,*)	N/A	N/A	N/A	(0,0,1,*)
53	(0,0,0,*) (0,0,1,*)	(0,0,0,*) (0,0,1,*)	(0,0,0,*) (0,0,1,*)	(0,0,0,*) (1,0,0,*)	(0,0,0,*) (1,0,0,*)	(0,0,0,*) (1,0,0,*)	(0,0,0,*) (0,0,1,*)
54	(0,0,0,*) (0,0,1,*) (1,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*)
55	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*)
56	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*) (4,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*) (4,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*) (4,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*)
57	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*) (2,0,1,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*) (2,0,1,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*) (2,0,1,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*) (4,0,0,*) (5,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*) (4,0,0,*) (5,0,0,*)	(0,0,0,*) (1,0,0,*) (2,0,0,*) (3,0,0,*) (4,0,0,*) (5,0,0,*)	(0,0,0,*) (0,0,1,*) (1,0,0,*) (1,0,1,*) (2,0,0,*) (2,0,1,*)
58	N/A	N/A	N/A	N/A	N/A	N/A	N/A
59	N/A	N/A	N/A	N/A	N/A	N/A	N/A
60	N/A	N/A	N/A	N/A	N/A	N/A	N/A
61	N/A	N/A	N/A	N/A	N/A	N/A	N/A
62	N/A	N/A	N/A	N/A	N/A	N/A	N/A
63	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NOTE: * UpPTS							

Petitioners' Exhibit 1003, p. 1128
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.7.2 Preamble sequence generation

The random access preambles are generated from Zadoff-Chu sequences with zero correlation zone, generated from one or several root Zadoff-Chu sequences. The network configures the set of preamble sequences the UE is allowed to use.

There are 64 preambles available in each cell. The set of 64 preamble sequences in a cell is found by including first, in the order of increasing cyclic shift, all the available cyclic shifts of a root Zadoff-Chu sequence with the logical index RACH_ROOT_SEQUENCE, where RACH_ROOT_SEQUENCE is broadcasted as part of the System Information. Additional preamble sequences, in case 64 preambles cannot be generated from a single root Zadoff-Chu sequence, are obtained from the root sequences with the consecutive logical indexes until all the 64 sequences are found.
The logical root sequence order is cyclic: the logical index 0 is consecutive to 837. The relation between a logical root sequence index and physical root sequence index u is given by Tables 5.7.2-4 and 5.7.2-5 for preamble formats 0 – 3 and 4, respectively.

The uth root Zadoff-Chu sequence is defined by

$$x_u(n) = e^{-j\frac{\pi un(n+1)}{N_{\text{ZC}}}}, \quad 0 \le n \le N_{\text{ZC}} - 1$$

where the length N_{ZC} of the Zadoff-Chu sequence is given by Table 5.7.2-1. From the uth root Zadoff-Chu sequence, random access preambles with zero correlation zones of length $N_{\text{CS}} - 1$ are defined by cyclic shifts according to

$$x_{u,v}(n) = x_u((n + C_v) \bmod N_{\text{ZC}})$$

where the cyclic shift is given by

$$C_v = \begin{cases} vN_{\text{CS}} & v = 0,1,\ldots,\lfloor N_{\text{ZC}}/N_{\text{CS}} \rfloor - 1, N_{\text{CS}} \neq 0 \quad \text{for unrestricted sets} \\ 0 & N_{\text{CS}} = 0 \quad \text{for unrestricted sets} \\ d_{\text{start}} \lfloor v/n_{\text{shift}}^{\text{RA}} \rfloor + (v \bmod n_{\text{shift}}^{\text{RA}}) N_{\text{CS}} & v = 0,1,\ldots,n_{\text{shift}}^{\text{RA}} n_{\text{group}}^{\text{RA}} + \bar{n}_{\text{shift}}^{\text{RA}} - 1 \quad \text{for restricted sets} \end{cases}$$

and N_{CS} is given by Tables 5.7.2-2 and 5.7.2-3 for preamble formats 0-3 and 4, respectively, where the parameter *zeroCorrelationZoneConfig* is provided by higher layers. The parameter *High-speed-flag* provided by higher layers determines if unrestricted set or restricted set shall be used.

The variable d_u is the cyclic shift corresponding to a Doppler shift of magnitude $1/T_{\text{SEQ}}$ and is given by

$$d_u = \begin{cases} p & 0 \le p < N_{\text{ZC}}/2 \\ N_{\text{ZC}} - p & \text{otherwise} \end{cases}$$

where p is the smallest non-negative integer that fulfils $(pu) \bmod N_{\text{ZC}} = 1$. The parameters for restricted sets of cyclic shifts depend on d_u. For $N_{\text{CS}} \le d_u < N_{\text{ZC}}/3$, the parameters are given by

$$\begin{aligned} n_{\text{shift}}^{\text{RA}} &= \lfloor d_u / N_{\text{CS}} \rfloor \\ d_{\text{start}} &= 2d_u + n_{\text{shift}}^{\text{RA}} N_{\text{CS}} \\ n_{\text{group}}^{\text{RA}} &= \lfloor N_{\text{ZC}} / d_{\text{start}} \rfloor \\ \bar{n}_{\text{shift}}^{\text{RA}} &= \max\left(\left\lfloor (N_{\text{ZC}} - 2d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}}) / N_{\text{CS}} \right\rfloor, 0\right) \end{aligned}$$

For $N_{\text{ZC}}/3 \le d_u \le (N_{\text{ZC}} - N_{\text{CS}})/2$, the parameters are given by

$$\begin{aligned} n_{\text{shift}}^{\text{RA}} &= \lfloor (N_{\text{ZC}} - 2d_u)/N_{\text{CS}} \rfloor \\ d_{\text{start}} &= N_{\text{ZC}} - 2d_u + n_{\text{shift}}^{\text{RA}} N_{\text{CS}} \\ n_{\text{group}}^{\text{RA}} &= \lfloor d_u / d_{\text{start}} \rfloor \\ \bar{n}_{\text{shift}}^{\text{RA}} &= \min\left(\max\left(\left\lfloor (d_u - n_{\text{group}}^{\text{RA}} d_{\text{start}})/N_{\text{CS}} \right\rfloor, 0\right), n_{\text{shift}}^{\text{RA}}\right) \end{aligned}$$

Petitioners' Exhibit 1003, p. 1129
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

For all other values of d_u, there are no cyclic shifts in the restricted set.

Table 5.7.2-1: Random access preamble sequence length

Preamble format	N_{ZC}
0 – 3	839
4	139

Table 5.7.2-2: N_{CS} for preamble generation (preamble formats 0-3)

zeroCorrelationZoneConfig	N_{CS} value	
	Unrestricted set	Restricted set
0	0	15
1	13	18
2	15	22
3	18	26
4	22	32
5	26	38
6	32	46
7	38	55
8	46	68
9	59	82
10	76	100
11	93	128
12	119	158
13	167	202
14	279	237
15	419	-

Table 5.7.2-3: N_{CS} for preamble generation (preamble format 4)

zeroCorrelationZoneConfig	N_{CS} value
0	2
1	4
2	6
3	8
4	10
5	12
6	15
7	N/A
8	N/A
9	N/A
10	N/A
11	N/A
12	N/A
13	N/A
14	N/A
15	N/A

Petitioners' Exhibit 1003, p. 1130
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.7.2-4: Root Zadoff-Chu sequence order for preamble formats 0 – 3

Logical root sequence number	Physical root sequence number u (in increasing order of the corresponding logical sequence number)
0–23	129, 710, 140, 699, 120, 719, 210, 629, 168, 671, 84, 755, 105, 734, 93, 746, 70, 769, 60, 779 2, 837, 1, 838
24–29	56, 783, 112, 727, 148, 691
30–35	80, 759, 42, 797, 40, 799
36–41	35, 804, 73, 766, 146, 693
42–51	31, 808, 28, 811, 30, 809, 27, 812, 29, 810
52–63	24, 815, 48, 791, 68, 771, 74, 765, 178, 661, 136, 703
64–75	86, 753, 78, 761, 43, 796, 39, 800, 20, 819, 21, 818
76–89	95, 744, 202, 637, 190, 649, 181, 658, 137, 702, 125, 714, 151, 688
90–115	217, 622, 128, 711, 142, 697, 122, 717, 203, 636, 118, 721, 110, 729, 89, 750, 103, 736, 61, 778, 55, 784, 15, 824, 14, 825
116–135	12, 827, 23, 816, 34, 805, 37, 802, 46, 793, 207, 632, 179, 660, 145, 694, 130, 709, 223, 616
136–167	228, 611, 227, 612, 132, 707, 133, 706, 143, 696, 135, 704, 161, 678, 201, 638, 173, 666, 106, 733, 83, 756, 91, 748, 66, 773, 53, 786, 10, 829, 9, 830
168–203	7, 832, 8, 831, 16, 823, 47, 792, 64, 775, 57, 782, 104, 735, 101, 738, 108, 731, 208, 631, 184, 655, 197, 642, 191, 648, 121, 718, 141, 698, 149, 690, 216, 623, 218, 621
204–263	152, 687, 144, 695, 134, 705, 138, 701, 199, 640, 162, 677, 176, 663, 119, 720, 158, 681, 164, 675, 174, 665, 171, 668, 170, 669, 87, 752, 169, 670, 88, 751, 107, 732, 81, 758, 82, 757, 100, 739, 98, 741, 71, 768, 59, 780, 65, 774, 50, 789, 49, 790, 26, 813, 17, 822, 13, 826, 6, 833
264–327	5, 834, 33, 806, 51, 788, 75, 764, 99, 740, 96, 743, 97, 742, 166, 673, 172, 667, 175, 664, 187, 652, 163, 676, 185, 654, 200, 639, 114, 725, 189, 650, 115, 724, 194, 645, 195, 644, 192, 647, 182, 657, 157, 682, 156, 683, 211, 628, 154, 685, 123, 716, 139, 700, 212, 627, 153, 686, 213, 626, 215, 624, 150, 689
328–383	225, 614, 224, 615, 221, 618, 220, 619, 127, 712, 147, 692, 124, 715, 193, 646, 205, 634, 206, 633, 116, 723, 160, 679, 186, 653, 167, 672, 79, 760, 85, 754, 77, 762, 92, 747, 58, 781, 62, 777, 69, 770, 54, 785, 36, 803, 32, 807, 25, 814, 18, 821, 11, 828, 4, 835
384–455	3, 836, 19, 820, 22, 817, 41, 798, 38, 801, 44, 795, 52, 787, 45, 794, 63, 776, 67, 772, 72 767, 76, 763, 94, 745, 102, 737, 90, 749, 109, 730, 165, 674, 111, 728, 209, 630, 204, 635, 117, 722, 188, 651, 159, 680, 198, 641, 113, 726, 183, 656, 180, 659, 177, 662, 196, 643, 155, 684, 214, 625, 126, 713, 131, 708, 219, 620, 222, 617, 226, 613
456–513	230, 609, 232, 607, 262, 577, 252, 587, 418, 421, 416, 423, 413, 426, 411, 428, 376, 463, 395, 444, 283, 556, 285, 554, 379, 460, 390, 449, 363, 476, 384, 455, 388, 451, 386, 453, 361, 478, 387, 452, 360, 479, 310, 529, 354, 485, 328, 511, 315, 524, 337, 502, 349, 490, 335, 504, 324, 515
514–561	323, 516, 320, 519, 334, 505, 359, 480, 295, 544, 385, 454, 292, 547, 291, 548, 381, 458, 399, 440, 380, 459, 397, 442, 369, 470, 377, 462, 410, 429, 407, 432, 281, 558, 414, 425, 247, 592, 277, 562, 271, 568, 272, 567, 264, 575, 259, 580
562–629	237, 602, 239, 600, 244, 595, 243, 596, 275, 564, 278, 561, 250, 589, 246, 593, 417, 422, 248, 591, 394, 445, 393, 446, 370, 469, 365, 474, 300, 539, 299, 540, 364, 475, 362, 477, 298, 541, 312, 527, 313, 526, 314, 525, 353, 486, 352, 487, 343, 496, 327, 512, 350, 489, 326, 513, 319, 520, 332, 507, 333, 506, 348, 491, 347, 492, 322, 517
630–659	330, 509, 338, 501, 341, 498, 340, 499, 342, 497, 301, 538, 366, 473, 401, 438, 371, 468, 408, 431, 375, 464, 249, 590, 269, 570, 238, 601, 234, 605
660–707	257, 582, 273, 566, 255, 584, 254, 585, 245, 594, 251, 588, 412, 427, 372, 467, 282, 557, 403, 436, 396, 443, 392, 447, 391, 448, 382, 457, 389, 450, 294, 545, 297, 542, 311, 528, 344, 495, 345, 494, 318, 521, 331, 508, 325, 514, 321, 518
708–729	346, 493, 339, 500, 351, 488, 306, 533, 289, 550, 400, 439, 378, 461, 374, 465, 415, 424, 270, 569, 241, 598
730–751	231, 608, 260, 579, 268, 571, 276, 563, 409, 430, 398, 441, 290, 549, 304, 535, 308, 531, 358, 481, 316, 523
752–765	293, 546, 288, 551, 284, 555, 368, 471, 253, 586, 256, 583, 263, 576
766–777	242, 597, 274, 565, 402, 437, 383, 456, 357, 482, 329, 510
778–789	317, 522, 307, 532, 286, 553, 287, 552, 266, 573, 261, 578
790–795	236, 603, 303, 536, 356, 483
796–803	355, 484, 405, 434, 404, 435, 406, 433
804–809	235, 604, 267, 572, 302, 537
810–815	309, 530, 265, 574, 233, 606
816–819	367, 472, 296, 543
820–837	336, 503, 305, 534, 373, 466, 280, 559, 279, 560, 419, 420, 240, 599, 258, 581, 229, 610

Petitioners' Exhibit 1003, p. 1131
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.7.2-5: Root Zadoff-Chu sequence order for preamble format 4

Logical root sequence number	Physical root sequence number u (in increasing order of the corresponding logical sequence number)																			
0 – 19	1	138	2	137	3	136	4	135	5	134	6	133	7	132	8	131	9	130	10	129
20 – 39	11	128	12	127	13	126	14	125	15	124	16	123	17	122	18	121	19	120	20	119
40 – 59	21	118	22	117	23	116	24	115	25	114	26	113	27	112	28	111	29	110	30	109
60 – 79	31	108	32	107	33	106	34	105	35	104	36	103	37	102	38	101	39	100	40	99
80 – 99	41	98	42	97	43	96	44	95	45	94	46	93	47	92	48	91	49	90	50	89
100 – 119	51	88	52	87	53	86	54	85	55	84	56	83	57	82	58	81	59	80	60	79
120 – 137	61	78	62	77	63	76	64	75	65	74	66	73	67	72	68	71	69	70	-	-
138 – 837	N/A																			

5.7.3 Baseband signal generation

The time-continuous random access signal $s(t)$ is defined by

$$s(t) = \beta_{\text{PRACH}} \sum_{k=0}^{N_{\text{ZC}}-1} \sum_{n=0}^{N_{\text{ZC}}-1} x_{u,v}(n) \cdot e^{-j\frac{2\pi nk}{N_{\text{ZC}}}} \cdot e^{j2\pi\left(k+\varphi+K\left(k_0+\frac{1}{2}\right)\right)\Delta f_{\text{RA}}\left(t-T_{\text{CP}}\right)}$$

where $0 \le t < T_{\text{SEQ}} + T_{\text{CP}}$, β_{PRACH} is an amplitude scaling factor in order to conform to the transmit power P_{PRACH} specified in clause 6.1 in 3GPP TS 36.213 [4], and $k_0 = n_{\text{PRB}}^{\text{RA}} N_{\text{sc}}^{\text{RB}} - N_{\text{RB}}^{\text{UL}} N_{\text{sc}}^{\text{RB}} / 2$. The location in the frequency domain is controlled by the parameter $n_{\text{PRB}}^{\text{RA}}$ is derived from clause 5.7.1. The factor $K = \Delta f / \Delta f_{\text{RA}}$ accounts for the difference in subcarrier spacing between the random access preamble and uplink data transmission. The variable Δf_{RA}, the subcarrier spacing for the random access preamble, and the variable φ, a fixed offset determining the frequency-domain location of the random access preamble within the physical resource blocks, are both given by Table 5.7.3-1.

Table 5.7.3-1: Random access baseband parameters

Preamble format	Δf_{RA}	φ
0 – 3	1250 Hz	7
4	7500 Hz	2

Petitioners' Exhibit 1003, p. 1132
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.8 Modulation and upconversion

Modulation and upconversion to the carrier frequency of the complex-valued SC-FDMA baseband signal for each antenna port or the complex-valued PRACH baseband signal is shown in Figure 5.8-1. The filtering required prior to transmission is defined by the requirements in 3GPP TS 36.101 [7].

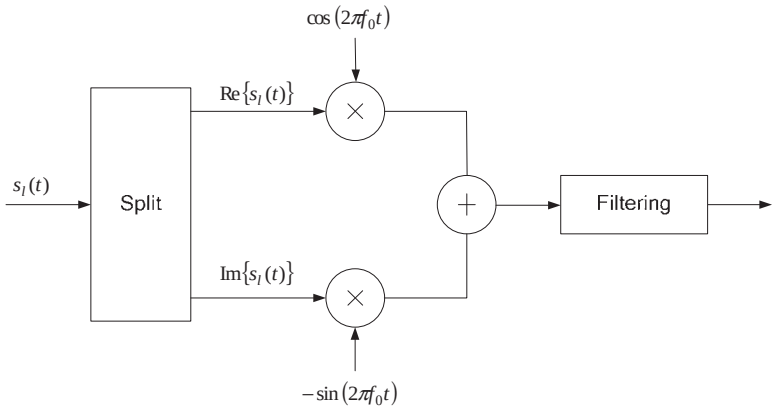


Figure 5.8-1: Uplink modulation

Petitioners' Exhibit 1003, p. 1133
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6 Downlink

6.1 Overview

The smallest time-frequency unit for downlink transmission is denoted a resource element and is defined in clause 6.2.2.

A subset of the downlink subframes in a radio frame on a carrier supporting PDSCH transmission can be configured as MBSFN subframes by higher layers. Each MBSFN subframe is divided into a non-MBSFN region and an MBSFN region.

- The non-MBSFN region spans the first one or two OFDM symbols in an MBSFN subframe where the length of the non-MBSFN region is given according to Subclause 6.7.
- The MBSFN region in an MBSFN subframe is defined as the OFDM symbols not used for the non-MBSFN region.

For frame structure type 3, MBSFN configuration shall not be applied to downlink subframes in which at least one OFDM symbol is not occupied or discovery signal is transmitted.

Unless otherwise specified, transmission in each downlink subframe shall use the same cyclic prefix length as used for downlink subframe #0.

6.1.1 Physical channels

A downlink physical channel corresponds to a set of resource elements carrying information originating from higher layers and is the interface defined between 3GPP TS 36.212 [3] and the present document 3GPP TS 36.211.
The following downlink physical channels are defined:

- Physical Downlink Shared Channel, PDSCH
- Physical Broadcast Channel, PBCH
- Physical Multicast Channel, PMCH
- Physical Control Format Indicator Channel, PCFICH
- Physical Downlink Control Channel, PDCCH
- Physical Hybrid ARQ Indicator Channel, PHICH
- Enhanced Physical Downlink Control Channel, EPDCCH
- MTC Physical Downlink Control Channel, MPDCCH

6.1.2 Physical signals

A downlink physical signal corresponds to a set of resource elements used by the physical layer but does not carry information originating from higher layers. The following downlink physical signals are defined:

- Reference signal
- Synchronization signal
- Discovery signal

Petitioners' Exhibit 1003, p. 1134
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.2 Slot structure and physical resource elements

6.2.1 Resource grid

The transmitted signal in each slot is described by one or several resource grids of $N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}$ subcarriers and $N_{\mathrm{symb}}^{\mathrm{DL}}$ OFDM symbols. The resource grid structure is illustrated in Figure 6.2.2-1. The quantity $N_{\mathrm{RB}}^{\mathrm{DL}}$ depends on the downlink transmission bandwidth configured in the cell and shall fulfil

$$N_{\mathrm{RB}}^{\mathrm{min,DL}} \le N_{\mathrm{RB}}^{\mathrm{DL}} \le N_{\mathrm{RB}}^{\mathrm{max,DL}}$$

where $N_{\mathrm{RB}}^{\mathrm{min,DL}} = 6$ and $N_{\mathrm{RB}}^{\mathrm{max,DL}} = 110$ are the smallest and largest downlink bandwidths, respectively, supported by the current version of this specification.

The set of allowed values for $N_{\mathrm{RB}}^{\mathrm{DL}}$ is given by 3GPP TS 36.104 [6]. The number of OFDM symbols in a slot depends on the cyclic prefix length and subcarrier spacing configured and is given in Table 6.2.3-1.

An antenna port is defined such that the channel over which a symbol on the antenna port is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed. For MBSFN reference signals, positioning reference signals, UE-specific reference signals associated with PDSCH and demodulation reference signals associated with EPDCCH, there are limits given below within which the channel can be inferred from one symbol to another symbol on the same antenna port. There is one resource grid per antenna port. The set of antenna ports supported depends on the reference signal configuration in the cell:

- Cell-specific reference signals support a configuration of one, two, or four antenna ports and are transmitted on antenna ports $p = 0$, $p \in \{0,1\}$, and $p \in \{0,1,2,3\}$, respectively.

- MBSFN reference signals are transmitted on antenna port $p = 4$. The channel over which a symbol on antenna port $p = 4$ is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed only if the two symbols correspond to subframes of the same MBSFN area.

- UE-specific reference signals associated with PDSCH are transmitted on antenna port(s) $p = 5$, $p = 7$, $p = 8$, or one or several of $p \in \{7,8,9,10,11,12,13,14\}$. The channel over which a symbol on one of these antenna ports is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed only if the two symbols are within the same subframe and in the same PRG when PRB bundling is used or in the same PRB pair when PRB bundling is not used.

- Demodulation reference signals associated with EPDCCH are transmitted on one or several of $p \in \{107,108,109,110\}$. The channel over which a symbol on one of these antenna ports is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed only if the two symbols are in the same PRB pair.

- Positioning reference signals are transmitted on antenna port $p = 6$. The channel over which a symbol on antenna port $p = 6$ is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed only within one positioning reference signal occasion consisting of N_{PRS} consecutive downlink subframes, where N_{PRS} is configured by higher layers.

- CSI reference signals support a configuration of one, two, four, eight, twelve, or sixteen antenna ports and are transmitted on antenna ports $p = 15$, $p = 15,16$, $p = 15,...,18$, $p = 15,...,22$, $p = 15,...,26$ and $p = 15,...,30$, respectively.

Two antenna ports are said to be quasi co-located if the large-scale properties of the channel over which a symbol on one antenna port is conveyed can be inferred from the channel over which a symbol on the other antenna port is conveyed. The large-scale properties include one or more of delay spread, Doppler spread, Doppler shift, average gain, and average delay.

Petitioners' Exhibit 1003, p. 1135
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.2.2 Resource elements

Each element in the resource grid for antenna port p is called a resource element and is uniquely identified by the index pair (k,l) in a slot where $k = 0,...,N_{\text{RB}}^{\text{DL}}N_{\text{sc}}^{\text{RB}} - 1$ and $l = 0,...,N_{\text{symb}}^{\text{DL}} - 1$ are the indices in the frequency and time domains, respectively. Resource element (k,l) on antenna port p corresponds to the complex value $a_{k,l}^{(p)}$. When there is no risk for confusion, or no particular antenna port is specified, the index p may be dropped.

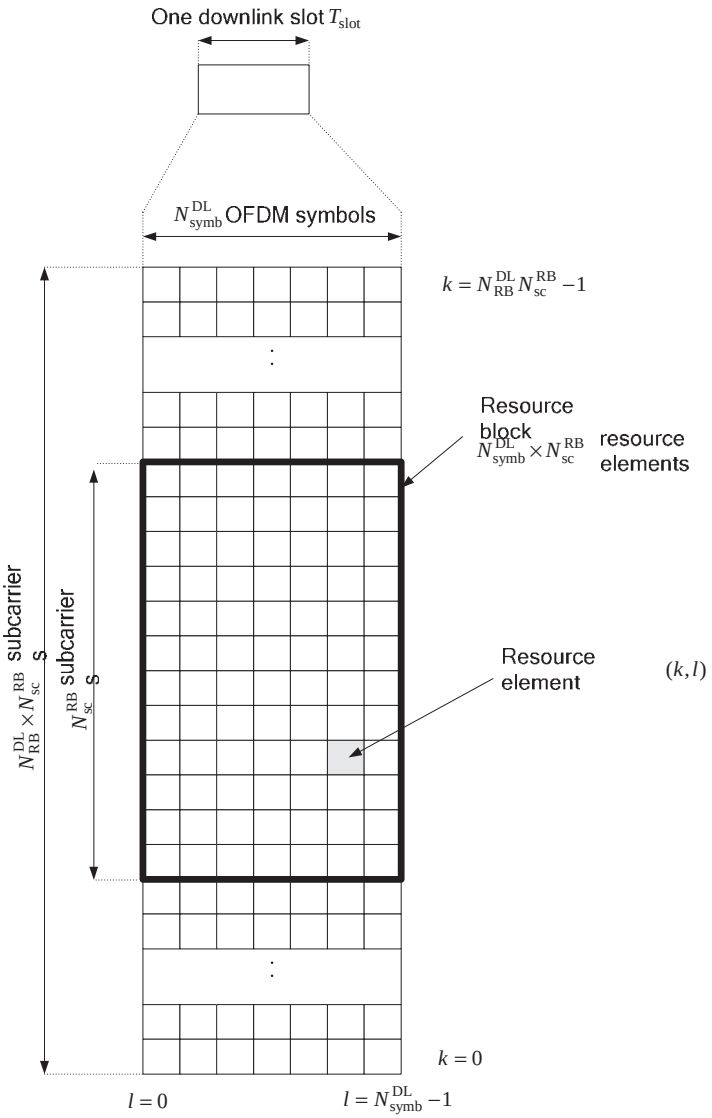


Figure 6.2.2-1: Downlink resource grid

Petitioners' Exhibit 1003, p. 1136
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.2.3 Resource blocks

Resource blocks are used to describe the mapping of certain physical channels to resource elements. Physical and virtual resource blocks are defined.

A physical resource block is defined as $N_{\text{symb}}^{\text{DL}}$ consecutive OFDM symbols in the time domain and $N_{\text{sc}}^{\text{RB}}$ consecutive subcarriers in the frequency domain, where $N_{\text{symb}}^{\text{DL}}$ and $N_{\text{sc}}^{\text{RB}}$ are given by Table 6.2.3-1. A physical resource block thus consists of $N_{\text{symb}}^{\text{DL}} \times N_{\text{sc}}^{\text{RB}}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.

Physical resource blocks are numbered from 0 to $N_{\text{RB}}^{\text{DL}} - 1$ in the frequency domain. The relation between the physical resource block number n_{PRB} in the frequency domain and resource elements (k, l) in a slot is given by

$$n_{\text{PRB}} = \left\lfloor \frac{k}{N_{\text{sc}}^{\text{RB}}} \right\rfloor$$

Table 6.2.3-1: Physical resource blocks parameters

Configuration		$N_{\text{sc}}^{\text{RB}}$	$N_{\text{symb}}^{\text{DL}}$
Normal cyclic prefix	$\Delta f = 15$ kHz	12	7
Extended cyclic prefix	$\Delta f = 15$ kHz		6
	$\Delta f = 7.5$ kHz	24	3

A physical resource-block pair is defined as the two physical resource blocks in one subframe having the same physical resource-block number n_{PRB}.

A virtual resource block is of the same size as a physical resource block. Two types of virtual resource blocks are defined:

- Virtual resource blocks of localized type
- Virtual resource blocks of distributed type

For each type of virtual resource blocks, a pair of virtual resource blocks over two slots in a subframe is assigned together by a single virtual resource block number, n_{VRB}.

6.2.3.1 Virtual resource blocks of localized type

Virtual resource blocks of localized type are mapped directly to physical resource blocks such that virtual resource block n_{VRB} corresponds to physical resource block $n_{\text{PRB}} = n_{\text{VRB}}$. Virtual resource blocks are numbered from 0 to $N_{\text{VRB}}^{\text{DL}} - 1$, where $N_{\text{VRB}}^{\text{DL}} = N_{\text{RB}}^{\text{DL}}$.

6.2.3.2 Virtual resource blocks of distributed type

Virtual resource blocks of distributed type are mapped to physical resource blocks as described below.

Petitioners' Exhibit 1003, p. 1137
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.2.3.2-1: RB gap values

System BW (N_{RB}^{DL})	Gap (N_{gap})	
	1st Gap ($N_{gap,1}$)	2nd Gap ($N_{gap,2}$)
6-10	$\lceil N_{RB}^{DL}/2 \rceil$	N/A
11	4	N/A
12-19	8	N/A
20-26	12	N/A
27-44	18	N/A
45-49	27	N/A
50-63	27	9
64-79	32	16
80-110	48	16

The parameter N_{gap} is given by Table 6.2.3.2-1. For $6 \le N_{RB}^{DL} \le 49$, only one gap value $N_{gap,1}$ is defined and $N_{gap} = N_{gap,1}$. For $50 \le N_{RB}^{DL} \le 110$, two gap values $N_{gap,1}$ and $N_{gap,2}$ are defined. Whether $N_{gap} = N_{gap,1}$ or $N_{gap} = N_{gap,2}$ is signaled as part of the downlink scheduling assignment as described in 3GPP TS 36.212 [3].

Virtual resource blocks of distributed type are numbered from 0 to $N_{VRB}^{DL} - 1$, where $N_{VRB}^{DL} = N_{VRB,gap1}^{DL} = 2 \cdot \min(N_{gap}, N_{RB}^{DL} - N_{gap})$ for $N_{gap} = N_{gap,1}$ and $N_{VRB}^{DL} = N_{VRB,gap2}^{DL} = \lfloor N_{RB}^{DL}/2N_{gap} \rfloor \cdot 2N_{gap}$ for $N_{gap} = N_{gap,2}$.

Consecutive $\tilde{N}_{VRB}^{DL}$ VRB numbers compose a unit of VRB number interleaving, where $\tilde{N}_{VRB}^{DL} = N_{VRB}^{DL}$ for $N_{gap} = N_{gap,1}$ and $\tilde{N}_{VRB}^{DL} = 2N_{gap}$ for $N_{gap} = N_{gap,2}$. Interleaving of VRB numbers of each interleaving unit is performed with 4 columns and N_{row} rows, where $N_{row} = \lceil \tilde{N}_{VRB}^{DL}/(4P) \rceil \cdot P$, and P is RBG size as described in 3GPP TS 36.213 [4]. VRB numbers are written row by row in the rectangular matrix, and read out column by column. N_{null} nulls are inserted in the last $N_{null}/2$ rows of the 2nd and 4th column, where $N_{null} = 4N_{row} - \tilde{N}_{VRB}^{DL}$. Nulls are ignored when reading out. The VRB numbers mapping to PRB numbers including interleaving is derived as follows:

For even slot number n_s;

$$\tilde{n}_{PRB}(n_s) = \begin{cases} \tilde{n}'_{PRB} - N_{row} & , N_{null} \neq 0 \text{ and } \tilde{n}_{VRB} \ge \tilde{N}_{VRB}^{DL} - N_{null} \text{ and } \tilde{n}_{VRB} \bmod 2 = 1 \\ \tilde{n}'_{PRB} - N_{row} + N_{null}/2 & , N_{null} \neq 0 \text{ and } \tilde{n}_{VRB} \ge \tilde{N}_{VRB}^{DL} - N_{null} \text{ and } \tilde{n}_{VRB} \bmod 2 = 0 \\ \tilde{n}''_{PRB} - N_{null}/2 & , N_{null} \neq 0 \text{ and } \tilde{n}_{VRB} < \tilde{N}_{VRB}^{DL} - N_{null} \text{ and } \tilde{n}_{VRB} \bmod 4 \ge 2 \\ \tilde{n}''_{PRB} & , \text{otherwise} \end{cases},$$

where $\tilde{n}'_{PRB} = 2N_{row} \cdot (\tilde{n}_{VRB} \bmod 2) + \lfloor \tilde{n}_{VRB}/2 \rfloor + \tilde{N}_{VRB}^{DL} \cdot \lfloor n_{VRB}/\tilde{N}_{VRB}^{DL} \rfloor$,

and $\tilde{n}''_{PRB} = N_{row} \cdot (\tilde{n}_{VRB} \bmod 4) + \lfloor \tilde{n}_{VRB}/4 \rfloor + \tilde{N}_{VRB}^{DL} \cdot \lfloor n_{VRB}/\tilde{N}_{VRB}^{DL} \rfloor$,

where $\tilde{n}_{VRB} = n_{VRB} \bmod \tilde{N}_{VRB}^{DL}$ and n_{VRB} is obtained from the downlink scheduling assignment as described in 3GPP TS 36.213 [4].

For odd slot number n_s;

$$\tilde{n}_{PRB}(n_s) = \left(\tilde{n}_{PRB}(n_s - 1) + \tilde{N}_{VRB}^{DL}/2\right) \bmod \tilde{N}_{VRB}^{DL} + \tilde{N}_{VRB}^{DL} \cdot \lfloor n_{VRB}/\tilde{N}_{VRB}^{DL} \rfloor$$

Then, for all n_s;

$$n_{PRB}(n_s) = \begin{cases} \tilde{n}_{PRB}(n_s), & \tilde{n}_{PRB}(n_s) < \tilde{N}_{VRB}^{DL}/2 \\ \tilde{n}_{PRB}(n_s) + N_{gap} - \tilde{N}_{VRB}^{DL}/2, & \tilde{n}_{PRB}(n_s) \ge \tilde{N}_{VRB}^{DL}/2 \end{cases}.$$

Petitioners' Exhibit 1003, p. 1138
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Virtual resource blocks of distributed type are not applicable to BL/CE UEs.

6.2.4 Resource-element groups

Resource-element groups are used for defining the mapping of control channels to resource elements.

A resource-element group is represented by the index pair (k',l') of the resource element with the lowest index k in the group with all resource elements in the group having the same value of l. The set of resource elements (k,l) in a resource-element group depends on the number of cell-specific reference signals configured as described below with $k_0 = n_{\text{PRB}} \cdot N_{\text{sc}}^{\text{RB}}$, $0 \le n_{\text{PRB}} < N_{\text{RB}}^{\text{DL}}$.

- In the first OFDM symbol of the first slot in a subframe the two resource-element groups in physical resource block n_{PRB} consist of resource elements $(k,l=0)$ with $k = k_0 + 0, k_0 + 1, ..., k_0 + 5$ and $k = k_0 + 6, k_0 + 7, ..., k_0 + 11$, respectively.

- In the second OFDM symbol of the first slot in a subframe in case of one or two cell-specific reference signals configured, the three resource-element groups in physical resource block n_{PRB} consist of resource elements $(k,l=1)$ with $k = k_0 + 0, k_0 + 1, ..., k_0 + 3$, $k = k_0 + 4, k_0 + 5, ..., k_0 + 7$ and $k = k_0 + 8, k_0 + 9, ..., k_0 + 11$, respectively.

- In the second OFDM symbol of the first slot in a subframe in case of four cell-specific reference signals configured, the two resource-element groups in physical resource block n_{PRB} consist of resource elements $(k,l=1)$ with $k = k_0 + 0, k_0 + 1, ..., k_0 + 5$ and $k = k_0 + 6, k_0 + 7, ..., k_0 + 11$, respectively.

- In the third OFDM symbol of the first slot in a subframe, the three resource-element groups in physical resource block n_{PRB} consist of resource elements $(k,l=2)$ with $k = k_0 + 0, k_0 + 1, ..., k_0 + 3$, $k = k_0 + 4, k_0 + 5, ..., k_0 + 7$ and $k = k_0 + 8, k_0 + 9, ..., k_0 + 11$, respectively.

- In the fourth OFDM symbol of the first slot in a subframe in case of normal cyclic prefix, the three resource-element groups in physical resource block n_{PRB} consist of resource elements $(k,l=3)$ with $k = k_0 + 0, k_0 + 1, ..., k_0 + 3$, $k = k_0 + 4, k_0 + 5, ..., k_0 + 7$ and $k = k_0 + 8, k_0 + 9, ..., k_0 + 11$, respectively.

- In the fourth OFDM symbol of the first slot in a subframe in case of extended cyclic prefix, the two resource-element groups in physical resource block n_{PRB} consist of resource elements $(k,l=3)$ with $k = k_0 + 0, k_0 + 1, ..., k_0 + 5$ and $k = k_0 + 6, k_0 + 7, ..., k_0 + 11$, respectively.

Mapping of a symbol-quadruplet $\langle z(i), z(i+1), z(i+2), z(i+3) \rangle$ onto a resource-element group represented by resource-element (k',l') is defined such that elements $z(i)$ are mapped to resource elements (k,l) of the resource-element group not used for cell-specific reference signals in increasing order of i and k. In case a single cell-specific reference signal is configured, cell-specific reference signals shall be assumed to be present on antenna ports 0 and 1 for the purpose of mapping a symbol-quadruplet to a resource-element group, otherwise the number of cell-specific reference signals shall be assumed equal to the actual number of antenna ports used for cell-specific reference signals. The UE shall not make any assumptions about resource elements assumed to be reserved for reference signals but not used for transmission of a reference signal.

For frame structure type 3, if the higher layer parameter *subframeStartPosition* indicates "s07" and the downlink transmission starts in the second slot of a subframe, the above definition applies to the second slot of that subframe instead of the first slot.

Petitioners' Exhibit 1003, p. 1139
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.2.4A Enhanced Resource-Element Groups (EREGs)

EREGs are used for defining the mapping of enhanced control channels to resource elements.

There are 16 EREGs, numbered from 0 to 15, per physical resource block pair. Number all resource elements, except resource elements carrying DM-RS for antenna ports $p = \{107,108,109,110\}$ for normal cyclic prefix or $p = \{107,108\}$ for extended cyclic prefix, in a physical resource-block pair cyclically from 0 to 15 in an increasing order of first frequency, then time. All resource elements with number i in that physical resource-block pair constitutes EREG number i.

For frame structure type 3, if the higher layer parameter *subframeStartPosition* indicates "s07" and the downlink transmission starts in the second slot of a subframe, the above definition applies to the second slot of that subframe instead of the first slot.

6.2.5 Guard period for half-duplex FDD operation

For type A half-duplex FDD operation, a guard period is created by the UE by

- not receiving the last part of a downlink subframe immediately preceding an uplink subframe from the same UE.

For type B half-duplex FDD operation, guard periods, each referred to as a half-duplex guard subframe, are created by the UE by

- not receiving a downlink subframe immediately preceding an uplink subframe from the same UE, and
- not receiving a downlink subframe immediately following an uplink subframe from the same UE.

6.2.6 Guard Period for TDD Operation

For frame structure type 2, the GP field in Figure 4.2-1 serves as a guard period.

6.2.7 Narrowbands

A narrowband is defined as six non-overlapping consecutive physical resource blocks in the frequency domain. The total number of downlink narrowbands in the downlink transmission bandwidth configured in the cell is given by

$$N_{\mathrm{NB}}^{\mathrm{DL}} = \left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}}{6} \right\rfloor$$

The narrowbands are numbered $n_{\mathrm{NB}} = 0,\ldots,N_{\mathrm{NB}}^{\mathrm{DL}} - 1$ in order of increasing physical resource-block number where narrowband n_{NB} is composed of physical resorce-block indices

$$\begin{cases} 6n_{\mathrm{NB}} + i_0 + i & \text{if } N_{\mathrm{RB}}^{\mathrm{DL}} \bmod 2 = 0 \\ 6n_{\mathrm{NB}} + i_0 + i & \text{if } N_{\mathrm{RB}}^{\mathrm{DL}} \bmod 2 = 1 \text{ and } n_{\mathrm{NB}} < N_{\mathrm{NB}}^{\mathrm{DL}}/2 \\ 6n_{\mathrm{NB}} + i_0 + i + 1 & \text{if } N_{\mathrm{RB}}^{\mathrm{DL}} \bmod 2 = 1 \text{ and } n_{\mathrm{NB}} \geq N_{\mathrm{NB}}^{\mathrm{DL}}/2 \end{cases}$$

where

$$i = 0,1,\ldots,5$$
$$i_0 = \left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}}{2} \right\rfloor - \frac{6N_{\mathrm{NB}}^{\mathrm{DL}}}{2}$$

6.2.8 Guard period for narrowband retuning

For BL/CE UEs, a guard period is created by the UE not receiving at most the first two OFDM symbols in the second narrowband when

Petitioners' Exhibit 1003, p. 1140
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- the UE retunes from a first downlink narrowband to a second downlink narrowband with a different center frequency, or
- the UE retunes from a first uplink narrowband to a second downlink narrowband with a different center frequency for frame structure type 2.

Petitioners' Exhibit 1003, p. 1141
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.3 General structure for downlink physical channels

This clause describes a general structure, applicable to more than one physical channel.

The baseband signal representing a downlink physical channel is defined in terms of the following steps:

- scrambling of coded bits in each of the codewords to be transmitted on a physical channel
- modulation of scrambled bits to generate complex-valued modulation symbols
- mapping of the complex-valued modulation symbols onto one or several transmission layers
- precoding of the complex-valued modulation symbols on each layer for transmission on the antenna ports
- mapping of complex-valued modulation symbols for each antenna port to resource elements
- generation of complex-valued time-domain OFDM signal for each antenna port

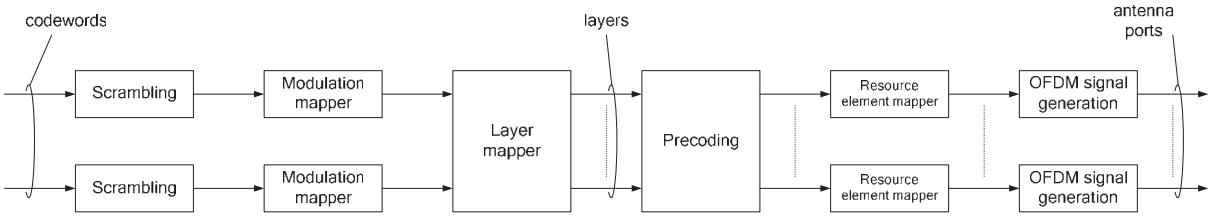


Figure 6.3-1: Overview of physical channel processing

6.3.1 Scrambling

For each codeword q, the block of bits $b^{(q)}(0),...,b^{(q)}(M_{\text{bit}}^{(q)}-1)$, where $M_{\text{bit}}^{(q)}$ is the number of bits in codeword q transmitted on the physical channel in one subframe, shall be scrambled prior to modulation, resulting in a block of scrambled bits $\tilde{b}^{(q)}(0),...,\tilde{b}^{(q)}(M_{\text{bit}}^{(q)}-1)$ according to

$$\tilde{b}^{(q)}(i) = \left(b^{(q)}(i) + c^{(q)}(i)\right) \bmod 2$$

where the scrambling sequence $c^{(q)}(i)$ is given by clause 7.2. The scrambling sequence generator shall be initialised at the start of each subframe, where the initialisation value of c_{init} depends on the transport channel type according to

$$c_{\text{init}} = \begin{cases} n_{\text{RNTI}} \cdot 2^{14} + q \cdot 2^{13} + \lfloor n_s/2 \rfloor \cdot 2^9 + N_{\text{ID}}^{\text{cell}} & \text{for PDSCH} \\ \lfloor n_s/2 \rfloor \cdot 2^9 + N_{\text{ID}}^{\text{MBSFN}} & \text{for PMCH} \end{cases}$$

where n_{RNTI} corresponds to the RNTI associated with the PDSCH transmission as described in clause 7.1 3GPP TS 36.213 [4].

For BL/CE UEs, the same scrambling sequence is applied per subframe to PDSCH for a given block of N_{acc} subframes. For the jth block of N_{acc} subframes, the scrambling sequence generator shall be initialised with

$$c_{\text{init}} = n_{\text{RNTI}} \cdot 2^{14} + q \cdot 2^{13} + \left[(j_0 + j) N_{\text{acc}} \bmod 10\right] \cdot 2^9 + N_{\text{ID}}^{\text{cell}}$$

where

Petitioners' Exhibit 1003, p. 1142
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$j = 0,1,\ldots,\left\lfloor \frac{i_0 + N_{\text{abs}}^{\text{PDSCH}} + i_\Delta - 1}{N_{\text{acc}}} \right\rfloor - j_0$$

$$j_0 = \left\lfloor (i_0 + i_\Delta)/N_{\text{acc}} \right\rfloor$$

$$i_\Delta = \begin{cases} 0, & \text{for frame structure type 1} \\ N_{\text{acc}} - 2, & \text{for frame structure type 2} \end{cases}$$

and i_0 is the absolute subframe number of the first downlink subframe intended for PDSCH. The PDSCH transmission spans $N_{\text{abs}}^{\text{PDSCH}}$ consecutive subframes including invalid subframes where the PDSCH transmission is postponed. For a BL/CE UE configured in CEModeA, $N_{\text{acc}} = 1$. For a BL/CE UE configured with CEModeB, $N_{\text{acc}} = 4$ for frame structure type 1 and $N_{\text{acc}} = 10$ for frame structure type 2.

Up to two codewords can be transmitted in one subframe, i.e., $q \in \{0,1\}$. In the case of single codeword transmission, q is equal to zero.

6.3.2 Modulation

For each codeword q, the block of scrambled bits $\tilde{b}^{(q)}(0),\ldots,\tilde{b}^{(q)}(M_{\text{bit}}^{(q)} - 1)$ shall be modulated as described in clause 7.1 using one of the modulation schemes in Table 6.3.2-1, resulting in a block of complex-valued modulation symbols $d^{(q)}(0),\ldots,d^{(q)}(M_{\text{symb}}^{(q)} - 1)$.

Table 6.3.2-1: Modulation schemes

Physical channel	Modulation schemes
PDSCH	QPSK, 16QAM, 64QAM, 256QAM
PMCH	QPSK, 16QAM, 64QAM, 256QAM

6.3.3 Layer mapping

The complex-valued modulation symbols for each of the codewords to be transmitted are mapped onto one or several layers. Complex-valued modulation symbols $d^{(q)}(0),\ldots,d^{(q)}(M_{\text{symb}}^{(q)} - 1)$ for codeword q shall be mapped onto the layers $x(i) = \left[x^{(0)}(i) \quad \ldots \quad x^{(\upsilon-1)}(i)\right]^T$, $i = 0,1,\ldots,M_{\text{symb}}^{\text{layer}} - 1$ where υ is the number of layers and $M_{\text{symb}}^{\text{layer}}$ is the number of modulation symbols per layer.

6.3.3.1 Layer mapping for transmission on a single antenna port

For transmission on a single antenna port, a single layer is used, $\upsilon = 1$, and the mapping is defined by

$$x^{(0)}(i) = d^{(0)}(i)$$

with $M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$.

Petitioners' Exhibit 1003, p. 1143
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.3.3.2 Layer mapping for spatial multiplexing

For spatial multiplexing, the layer mapping shall be done according to Table 6.3.3.2-1. The number of layers υ is less than or equal to the number of antenna ports P used for transmission of the physical channel. The case of a single codeword mapped to multiple layers is only applicable when the number of cell-specific reference signals is four or when the number of UE-specific reference signals is two or larger.

Table 6.3.3.2-1: Codeword-to-layer mapping for spatial multiplexing

Number of layers	Number of codewords	Codeword-to-layer mapping $i = 0,1,\ldots,M_{\text{symb}}^{\text{layer}}-1$	
1	1	$x^{(0)}(i) = d^{(0)}(i)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}$
2	1	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/2$
2	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(i)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}$
3	1	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i+1)$ $x^{(2)}(i) = d^{(0)}(3i+2)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/3$
3	2	$x^{(0)}(i) = d^{(0)}(i)$ $x^{(1)}(i) = d^{(1)}(2i)$ $x^{(2)}(i) = d^{(1)}(2i+1)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} = M_{\text{symb}}^{(1)}/2$
4	1	$x^{(0)}(i) = d^{(0)}(4i)$ $x^{(1)}(i) = d^{(0)}(4i+1)$ $x^{(2)}(i) = d^{(0)}(4i+2)$ $x^{(3)}(i) = d^{(0)}(4i+3)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/4$
4	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $x^{(2)}(i) = d^{(1)}(2i)$ $x^{(3)}(i) = d^{(1)}(2i+1)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/2 = M_{\text{symb}}^{(1)}/2$
5	2	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$ $x^{(2)}(i) = d^{(1)}(3i)$ $x^{(3)}(i) = d^{(1)}(3i+1)$ $x^{(4)}(i) = d^{(1)}(3i+2)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/2 = M_{\text{symb}}^{(1)}/3$
6	2	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i+1)$ $x^{(2)}(i) = d^{(0)}(3i+2)$ $x^{(3)}(i) = d^{(1)}(3i)$ $x^{(4)}(i) = d^{(1)}(3i+1)$ $x^{(5)}(i) = d^{(1)}(3i+2)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/3 = M_{\text{symb}}^{(1)}/3$
7	2	$x^{(0)}(i) = d^{(0)}(3i)$ $x^{(1)}(i) = d^{(0)}(3i+1)$ $x^{(2)}(i) = d^{(0)}(3i+2)$ $x^{(3)}(i) = d^{(1)}(4i)$ $x^{(4)}(i) = d^{(1)}(4i+1)$ $x^{(5)}(i) = d^{(1)}(4i+2)$ $x^{(6)}(i) = d^{(1)}(4i+3)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)}/3 = M_{\text{symb}}^{(1)}/4$

Petitioners' Exhibit 1003, p. 1144
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

8	2	$x^{(0)}(i) = d^{(0)}(4i)$ $x^{(1)}(i) = d^{(0)}(4i+1)$ $x^{(2)}(i) = d^{(0)}(4i+2)$ $x^{(3)}(i) = d^{(0)}(4i+3)$ $x^{(4)}(i) = d^{(1)}(4i)$ $x^{(5)}(i) = d^{(1)}(4i+1)$ $x^{(6)}(i) = d^{(1)}(4i+2)$ $x^{(7)}(i) = d^{(1)}(4i+3)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 4 = M_{\text{symb}}^{(1)} / 4$

6.3.3.3 Layer mapping for transmit diversity

For transmit diversity, the layer mapping shall be done according to Table 6.3.3.3-1. There is only one codeword and the number of layers υ is equal to the number of antenna ports P used for transmission of the physical channel.

Table 6.3.3.3-1: Codeword-to-layer mapping for transmit diversity

Number of layers	Number of codewords	Codeword-to-layer mapping $i = 0,1,...,M_{\text{symb}}^{\text{layer}} - 1$	
2	1	$x^{(0)}(i) = d^{(0)}(2i)$ $x^{(1)}(i) = d^{(0)}(2i+1)$	$M_{\text{symb}}^{\text{layer}} = M_{\text{symb}}^{(0)} / 2$
4	1	$x^{(0)}(i) = d^{(0)}(4i)$ $x^{(1)}(i) = d^{(0)}(4i+1)$ $x^{(2)}(i) = d^{(0)}(4i+2)$ $x^{(3)}(i) = d^{(0)}(4i+3)$	$M_{\text{symb}}^{\text{layer}} = \begin{cases} M_{\text{symb}}^{(0)} / 4 & \text{if } M_{\text{symb}}^{(0)} \bmod 4 = 0 \\ (M_{\text{symb}}^{(0)} + 2) / 4 & \text{if } M_{\text{symb}}^{(0)} \bmod 4 \neq 0 \end{cases}$ If $M_{\text{symb}}^{(0)} \bmod 4 \neq 0$ two null symbols shall be appended to $d^{(0)}(M_{\text{symb}}^{(0)} - 1)$

6.3.4 Precoding

The precoder takes as input a block of vectors $x(i) = \left[x^{(0)}(i) \quad ... \quad x^{(\upsilon-1)}(i)\right]^T$, $i = 0,1,...,M_{\text{symb}}^{\text{layer}} - 1$ from the layer mapping and generates a block of vectors $y(i) = \left[... \quad y^{(p)}(i) \quad ...\right]^T$, $i = 0,1,...,M_{\text{symb}}^{\text{ap}} - 1$ to be mapped onto resources on each of the antenna ports, where $y^{(p)}(i)$ represents the signal for antenna port p.

6.3.4.1 Precoding for transmission on a single antenna port

For transmission on a single antenna port, precoding is defined by

$$y^{(p)}(i) = x^{(0)}(i)$$

where $p \in \{0,4,5,7,8,11,13\}$ is the number of the single antenna port used for transmission of the physical channel and $i = 0,1,...,M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

6.3.4.2 Precoding for spatial multiplexing using antenna ports with cell-specific reference signals

Precoding for spatial multiplexing using antenna ports with cell-specific reference signals is only used in combination with layer mapping for spatial multiplexing as described in clause 6.3.3.2. Spatial multiplexing supports two or four antenna ports and the set of antenna ports used is $p \in \{0,1\}$ or $p \in \{0,1,2,3\}$, respectively.

Petitioners' Exhibit 1003, p. 1145
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.3.4.2.1 Precoding without CDD

Without Cyclic Delay Diversity (CDD), precoding for spatial multiplexing is defined by

$$\begin{bmatrix} y^{(0)}(i) \\ \vdots \\ y^{(P-1)}(i) \end{bmatrix} = W(i) \begin{bmatrix} x^{(0)}(i) \\ \vdots \\ x^{(\upsilon-1)}(i) \end{bmatrix}$$

where the precoding matrix $W(i)$ is of size $P \times \upsilon$ and $i = 0,1,...,M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

For spatial multiplexing, the values of $W(i)$ shall be selected among the precoder elements in the codebook configured in the eNodeB and the UE. The eNodeB can further confine the precoder selection in the UE to a subset of the elements in the codebook using codebook subset restrictions. The configured codebook shall be selected from Table 6.3.4.2.3-1 or 6.3.4.2.3-2.

6.3.4.2.2 Precoding for large delay CDD

For large-delay CDD, precoding for spatial multiplexing is defined by

$$\begin{bmatrix} y^{(0)}(i) \\ \vdots \\ y^{(P-1)}(i) \end{bmatrix} = W(i)D(i)U \begin{bmatrix} x^{(0)}(i) \\ \vdots \\ x^{(\upsilon-1)}(i) \end{bmatrix}$$

where the precoding matrix $W(i)$ is of size $P \times \upsilon$ and $i = 0,1,...,M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$. The diagonal size-$\upsilon \times \upsilon$ matrix $D(i)$ supporting cyclic delay diversity and the size-$\upsilon \times \upsilon$ matrix U are both given by Table 6.3.4.2.2-1 for different numbers of layers υ.

The values of the precoding matrix $W(i)$ shall be selected among the precoder elements in the codebook configured in the eNodeB and the UE. The eNodeB can further confine the precoder selection in the UE to a subset of the elements in the codebook using codebook subset restriction. The configured codebook shall be selected from Table 6.3.4.2.3-1 or 6.3.4.2.3-2.

For 2 antenna ports, the precoder is selected according to $W(i) = C_1$ where C_1 denotes the precoding matrix corresponding to precoder index 0 in Table 6.3.4.2.3-1.

For 4 antenna ports, the UE may assume that the eNodeB cyclically assigns different precoders to different vectors $\left[x^{(0)}(i) \quad ... \quad x^{(\upsilon-1)}(i)\right]^T$ on the physical downlink shared channel as follows. A different precoder is used every υ vectors, where υ denotes the number of transmission layers in the case of spatial multiplexing. In particular, the precoder is selected according to $W(i) = C_k$, where k is the precoder index given by $k = \left(\left\lfloor \frac{i}{\upsilon} \right\rfloor \bmod 4\right) + 1 \in \{1,2,3,4\}$ and C_1, C_2, C_3, C_4 denote precoder matrices corresponding to precoder indices 12,13,14 and 15, respectively, in Table 6.3.4.2.3-2.

Petitioners' Exhibit 1003, p. 1146
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.3.4.2.2-1: Large-delay cyclic delay diversity

Number of layers υ	U	$D(i)$
2	$\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\ 1 & e^{-j2\pi/2}\end{bmatrix}$	$\begin{bmatrix}1 & 0\\ 0 & e^{-j2\pi i/2}\end{bmatrix}$
3	$\frac{1}{\sqrt{3}}\begin{bmatrix}1 & 1 & 1\\ 1 & e^{-j2\pi/3} & e^{-j4\pi/3}\\ 1 & e^{-j4\pi/3} & e^{-j8\pi/3}\end{bmatrix}$	$\begin{bmatrix}1 & 0 & 0\\ 0 & e^{-j2\pi i/3} & 0\\ 0 & 0 & e^{-j4\pi i/3}\end{bmatrix}$
4	$\frac{1}{2}\begin{bmatrix}1 & 1 & 1 & 1\\ 1 & e^{-j2\pi/4} & e^{-j4\pi/4} & e^{-j6\pi/4}\\ 1 & e^{-j4\pi/4} & e^{-j8\pi/4} & e^{-j12\pi/4}\\ 1 & e^{-j6\pi/4} & e^{-j12\pi/4} & e^{-j18\pi/4}\end{bmatrix}$	$\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & e^{-j2\pi i/4} & 0 & 0\\ 0 & 0 & e^{-j4\pi i/4} & 0\\ 0 & 0 & 0 & e^{-j6\pi i/4}\end{bmatrix}$

6.3.4.2.3 Codebook for precoding and CSI reporting

For transmission on two antenna ports, $p \in \{0,1\}$, and for the purpose of CSI reporting based on two antenna ports $p \in \{0,1\}$ or $p \in \{15,16\}$, the precoding matrix $W(i)$ shall be selected from Table 6.3.4.2.3-1 or a subset thereof. For the closed-loop spatial multiplexing transmission mode defined in 3GPP TS 36.213 [4], the codebook index 0 is not used when the number of layers is $\upsilon = 2$.

Table 6.3.4.2.3-1: Codebook for transmission on antenna ports $\{0,1\}$ and for CSI reporting based on antenna ports $\{0,1\}$ or $\{15,16\}$

Codebook index	Number of layers υ	
	1	2
0	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\ 1\end{bmatrix}$	$\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 0\\ 0 & 1\end{bmatrix}$
1	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\ -1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix}$
2	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\ j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 1\\ j & -j\end{bmatrix}$
3	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\ -j\end{bmatrix}$	-

For transmission on four antenna ports, $p \in \{0,1,2,3\}$, the precoding matrix W shall be selected from Table 6.3.4.2.3-2 or a subset thereof. For the purpose of CSI reporting based on four antenna ports $p \in \{0,1,2,3\}$ or $p \in \{15,16,17,18\}$, the precoding matrix W shall be selected from Table 6.3.4.2.3-2 or a subset thereof except for *alternativeCodeBookEnabledFor4TX -r12 =TRUE* in which case the precoding matrix W shall be selected from Tables 7.2.4-0A, 7.2.4-0B, 7.2.4-0C, 7.2.4-0D in [4] or a subset thereof. The quantity $W_n^{\{s\}}$ denotes the matrix defined by the columns given by the set $\{s\}$ from the expression $W_n = I - 2u_n u_n^H / u_n^H u_n$ where I is the 4×4 identity matrix and the vector u_n is given by Table 6.3.4.2.3-2.

Petitioners' Exhibit 1003, p. 1147
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.3.4.2.3-2: Codebook for transmission on antenna ports $\{0,1,2,3\}$ and for CSI reporting based on antenna ports $\{0,1,2,3\}$ or $\{15,16,17,18\}$

Codebook index	u_n	Number of layers υ			
		1	2	3	4
0	$u_0 = \begin{bmatrix} 1 & -1 & -1 & -1 \end{bmatrix}^T$	$W_0^{\{1\}}$	$W_0^{\{14\}}/\sqrt{2}$	$W_0^{\{124\}}/\sqrt{3}$	$W_0^{\{1234\}}/2$
1	$u_1 = \begin{bmatrix} 1 & -j & 1 & j \end{bmatrix}^T$	$W_1^{\{1\}}$	$W_1^{\{12\}}/\sqrt{2}$	$W_1^{\{123\}}/\sqrt{3}$	$W_1^{\{1234\}}/2$
2	$u_2 = \begin{bmatrix} 1 & 1 & -1 & 1 \end{bmatrix}^T$	$W_2^{\{1\}}$	$W_2^{\{12\}}/\sqrt{2}$	$W_2^{\{123\}}/\sqrt{3}$	$W_2^{\{3214\}}/2$
3	$u_3 = \begin{bmatrix} 1 & j & 1 & -j \end{bmatrix}^T$	$W_3^{\{1\}}$	$W_3^{\{12\}}/\sqrt{2}$	$W_3^{\{123\}}/\sqrt{3}$	$W_3^{\{3214\}}/2$
4	$u_4 = \begin{bmatrix} 1 & (-1-j)/\sqrt{2} & -j & (1-j)/\sqrt{2} \end{bmatrix}^T$	$W_4^{\{1\}}$	$W_4^{\{14\}}/\sqrt{2}$	$W_4^{\{124\}}/\sqrt{3}$	$W_4^{\{1234\}}/2$
5	$u_5 = \begin{bmatrix} 1 & (1-j)/\sqrt{2} & j & (-1-j)/\sqrt{2} \end{bmatrix}^T$	$W_5^{\{1\}}$	$W_5^{\{14\}}/\sqrt{2}$	$W_5^{\{124\}}/\sqrt{3}$	$W_5^{\{1234\}}/2$
6	$u_6 = \begin{bmatrix} 1 & (1+j)/\sqrt{2} & -j & (-1+j)/\sqrt{2} \end{bmatrix}^T$	$W_6^{\{1\}}$	$W_6^{\{13\}}/\sqrt{2}$	$W_6^{\{134\}}/\sqrt{3}$	$W_6^{\{1324\}}/2$
7	$u_7 = \begin{bmatrix} 1 & (-1+j)/\sqrt{2} & j & (1+j)/\sqrt{2} \end{bmatrix}^T$	$W_7^{\{1\}}$	$W_7^{\{13\}}/\sqrt{2}$	$W_7^{\{134\}}/\sqrt{3}$	$W_7^{\{1324\}}/2$
8	$u_8 = \begin{bmatrix} 1 & -1 & 1 & 1 \end{bmatrix}^T$	$W_8^{\{1\}}$	$W_8^{\{12\}}/\sqrt{2}$	$W_8^{\{124\}}/\sqrt{3}$	$W_8^{\{1234\}}/2$
9	$u_9 = \begin{bmatrix} 1 & -j & -1 & -j \end{bmatrix}^T$	$W_9^{\{1\}}$	$W_9^{\{14\}}/\sqrt{2}$	$W_9^{\{134\}}/\sqrt{3}$	$W_9^{\{1234\}}/2$
10	$u_{10} = \begin{bmatrix} 1 & 1 & 1 & -1 \end{bmatrix}^T$	$W_{10}^{\{1\}}$	$W_{10}^{\{13\}}/\sqrt{2}$	$W_{10}^{\{123\}}/\sqrt{3}$	$W_{10}^{\{1324\}}/2$
11	$u_{11} = \begin{bmatrix} 1 & j & -1 & j \end{bmatrix}^T$	$W_{11}^{\{1\}}$	$W_{11}^{\{13\}}/\sqrt{2}$	$W_{11}^{\{134\}}/\sqrt{3}$	$W_{11}^{\{1324\}}/2$
12	$u_{12} = \begin{bmatrix} 1 & -1 & -1 & 1 \end{bmatrix}^T$	$W_{12}^{\{1\}}$	$W_{12}^{\{12\}}/\sqrt{2}$	$W_{12}^{\{123\}}/\sqrt{3}$	$W_{12}^{\{1234\}}/2$
13	$u_{13} = \begin{bmatrix} 1 & -1 & 1 & -1 \end{bmatrix}^T$	$W_{13}^{\{1\}}$	$W_{13}^{\{13\}}/\sqrt{2}$	$W_{13}^{\{123\}}/\sqrt{3}$	$W_{13}^{\{1324\}}/2$
14	$u_{14} = \begin{bmatrix} 1 & 1 & -1 & -1 \end{bmatrix}^T$	$W_{14}^{\{1\}}$	$W_{14}^{\{13\}}/\sqrt{2}$	$W_{14}^{\{123\}}/\sqrt{3}$	$W_{14}^{\{3214\}}/2$
15	$u_{15} = \begin{bmatrix} 1 & 1 & 1 & 1 \end{bmatrix}^T$	$W_{15}^{\{1\}}$	$W_{15}^{\{12\}}/\sqrt{2}$	$W_{15}^{\{123\}}/\sqrt{3}$	$W_{15}^{\{1234\}}/2$

For the purpose of CSI reporting for eight CSI reference signals the codebooks are given in clause 7.2.4 of 3GPP TS 36.213 [4].

6.3.4.3 Precoding for transmit diversity

Precoding for transmit diversity is only used in combination with layer mapping for transmit diversity as described in clause 6.3.3.3. The precoding operation for transmit diversity is defined for two and four antenna ports.

For transmission on two antenna ports, $p \in \{0,1\}$, the output $y(i) = \begin{bmatrix} y^{(0)}(i) & y^{(1)}(i) \end{bmatrix}^T$, $i = 0,1,\ldots,M_{\text{symb}}^{\text{ap}} - 1$ of the precoding operation is defined by

$$\begin{bmatrix} y^{(0)}(2i) \\ y^{(1)}(2i) \\ y^{(0)}(2i+1) \\ y^{(1)}(2i+1) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 & j & 0 \\ 0 & -1 & 0 & j \\ 0 & 1 & 0 & j \\ 1 & 0 & -j & 0 \end{bmatrix} \begin{bmatrix} \text{Re}\left(x^{(0)}(i)\right) \\ \text{Re}\left(x^{(1)}(i)\right) \\ \text{Im}\left(x^{(0)}(i)\right) \\ \text{Im}\left(x^{(1)}(i)\right) \end{bmatrix}$$

for $i = 0,1,\ldots,M_{\text{symb}}^{\text{layer}} - 1$ with $M_{\text{symb}}^{\text{ap}} = 2M_{\text{symb}}^{\text{layer}}$.

For transmission on four antenna ports, $p \in \{0,1,2,3\}$, the output $y(i) = \begin{bmatrix} y^{(0)}(i) & y^{(1)}(i) & y^{(2)}(i) & y^{(3)}(i) \end{bmatrix}^T$, $i = 0,1,\ldots,M_{\text{symb}}^{\text{ap}} - 1$ of the precoding operation is defined by

Petitioners' Exhibit 1003, p. 1148
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$\begin{bmatrix} y^{(0)}(4i) \\ y^{(1)}(4i) \\ y^{(2)}(4i) \\ y^{(3)}(4i) \\ y^{(0)}(4i+1) \\ y^{(1)}(4i+1) \\ y^{(2)}(4i+1) \\ y^{(3)}(4i+1) \\ y^{(0)}(4i+2) \\ y^{(1)}(4i+2) \\ y^{(2)}(4i+2) \\ y^{(3)}(4i+2) \\ y^{(0)}(4i+3) \\ y^{(1)}(4i+3) \\ y^{(2)}(4i+3) \\ y^{(3)}(4i+3) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 & 0 & 0 & j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & -j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & j & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & -j & 0 \end{bmatrix} \begin{bmatrix} \mathrm{Re}\left(x^{(0)}(i)\right) \\ \mathrm{Re}\left(x^{(1)}(i)\right) \\ \mathrm{Re}\left(x^{(2)}(i)\right) \\ \mathrm{Re}\left(x^{(3)}(i)\right) \\ \mathrm{Im}\left(x^{(0)}(i)\right) \\ \mathrm{Im}\left(x^{(1)}(i)\right) \\ \mathrm{Im}\left(x^{(2)}(i)\right) \\ \mathrm{Im}\left(x^{(3)}(i)\right) \end{bmatrix}$$

for $i = 0,1,\ldots,M_{\text{symb}}^{\text{layer}} - 1$ with $M_{\text{symb}}^{\text{ap}} = \begin{cases} 4M_{\text{symb}}^{\text{layer}} & \text{if } M_{\text{symb}}^{(0)} \bmod 4 = 0 \\ \left(4M_{\text{symb}}^{\text{layer}}\right) - 2 & \text{if } M_{\text{symb}}^{(0)} \bmod 4 \neq 0 \end{cases}$.

6.3.4.4 Precoding for spatial multiplexing using antenna ports with UE-specific reference signals

Precoding for spatial multiplexing using antenna ports with UE-specific reference signals is only used in combination with layer mapping for spatial multiplexing as described in clause 6.3.3.2. Spatial multiplexing using antenna ports with UE-specific reference signals supports up to eight antenna ports.

If the higher-layer parameter *dmrs-tableAlt* is set to 1, the precoding operation for two layers transmission using the set of antenna ports $p = \{11,13\}$ is defined by

$$\begin{bmatrix} y^{(11)}(i) \\ y^{(13)}(i) \end{bmatrix} = \begin{bmatrix} x^{(0)}(i) \\ x^{(1)}(i) \end{bmatrix}$$

where $i = 0,1,\ldots,M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$. Otherwise, the set of antenna ports used is $p = 7,8,\ldots,\upsilon+6$ and the precoding operation for transmission on υ antenna ports is defined by

$$\begin{bmatrix} y^{(7)}(i) \\ y^{(8)}(i) \\ \vdots \\ y^{(6+\upsilon)}(i) \end{bmatrix} = \begin{bmatrix} x^{(0)}(i) \\ x^{(1)}(i) \\ \vdots \\ x^{(\upsilon-1)}(i) \end{bmatrix}$$

where $i = 0,1,\ldots,M_{\text{symb}}^{\text{ap}} - 1$, $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$.

Petitioners' Exhibit 1003, p. 1149
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.3.5 Mapping to resource elements

For each of the antenna ports used for transmission of the physical channel, the block of complex-valued symbols $y^{(p)}(0),...,y^{(p)}(M_{\text{symb}}^{\text{ap}}-1)$ shall conform to the downlink power allocation specified in clause 5.2 in

3GPP TS 36.213 [4] and be mapped in sequence starting with $y^{(p)}(0)$ to resource elements (k,l) which meet all of the following criteria in the current subframe:

- they are in the physical resource blocks corresponding to the virtual resource blocks assigned for transmission, and
- they are not used for transmission of the core part of PBCH, synchronization signals, and
- they are assumed by the UE not to be used for cell-specific reference signals, where the positions of the cell-specific reference signals are given by clause 6.10.1.2 with the number of antenna ports for and the frequency shift of cell-specific reference signals derived as described in clause 6.10.1.2 4, and

The mapping to resource elements (k,l) on antenna port p not reserved for other purposes shall be in increasing order of first the index k over the assigned physical resource blocks and then the index l, starting with the first slot in a subframe.

Petitioners' Exhibit 1003, p. 1150
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.4 Physical downlink shared channel

The physical downlink shared channel shall be processed and mapped to resource elements as described in clause 6.3 with the following additions and exceptions:

- In resource blocks in which UE-specific reference signals are not transmitted, the PDSCH shall be transmitted on the same set of antenna ports as the PBCH, which is one of $\{0\}$, $\{0,1\}$, or $\{0,1,2,3\}$.
- In resource blocks in which UE-specific reference signals are transmitted, the PDSCH shall be transmitted on antenna port(s) $\{5\}, \{7\}, \{8\}$, or $p \in \{7,8,...,\upsilon+6\}$, where υ is the number of layers used for transmission of the PDSCH.
- If PDSCH is transmitted in MBSFN subframes as defined in 3GPP TS 36.213 [4], the PDSCH shall be transmitted on one or several of antenna port(s) $p \in \{7,8,...,\upsilon+6\}$, where υ is the number of layers used for transmission of the PDSCH.
- PDSCH is not mapped to resource elements used for UE-specific reference signals associated with PDSCH
- In mapping to resource elements, the positions of the cell-specific reference signals are given by clause 6.10.1.2 with the number of antenna ports and the frequency shift of the cell-specific reference signals derived as described in clause 6.10.1.2, unless other values for these parameters are provided by clause 7.1.9 in 3GPP TS 36.213 [4], in which case these values are used in the resource blocks indicated by the relevant DCI.
- If the DCI associated with the PDSCH uses the C-RNTI or semi-persistent C-RNTI, the PDSCH is not mapped to resource elements assumed by the UE to be used for transmission of:
  - zero-power CSI reference signals, where the positions of the CSI reference signals are given by clause 6.10.5.2.The configuration for zero power CSI reference signals is
    - obtained as described in clause 6.10.5.2, unless other values for these parameters are provided by clause 7.1.9 in 3GPP TS 36.213 [4], in which case these values are used in the resource blocks indicated by the relevant DCI, and
    - obtained by higher-layer configuration of up to five reserved CSI-RS resources as part of the discovery signal configuration following the procedure for zero-power CSI-RS in clause 6.10.5.2.
  - non-zero-power CSI reference signals for CSI reporting, where the positions of the non-zero-power CSI reference signals for CSI reporting are given by clause 6.10.5.2. The configuration for non-zero power CSI reference signals is obtained as described in clause 6.10.5.2.
- PDSCH is not mapped to any physical resource-block pair(s) carrying an EPDCCH associated with the PDSCH.
- PDSCH on antenna port 5, 7, 8, 9, 10, 11, 12, 13 or 14 is not mapped to any physical resource-block pair(s) carrying PBCH or synchronization signals.
- For frame structure type 1 and 2, the index l in the first slot in a subframe fulfils $l \geq l_{\text{DataStart}}$ where $l_{\text{DataStart}}$ is given by clause 7.1.6.4 of 3GPP TS 36.213 [4].
- For frame structure type 3,
  - if the higher layer parameter *subframeStartPosition* indicates "s07" and the downlink transmission starts in the second slot of a subframe
    - the index l in the second slot in a subframe fulfils $l \geq l_{\text{DataStart}}$ where $l_{\text{DataStart}}$ is given by clause 7.1.6.4 of 3GPP TS 36.213 [4],
  - otherwise
    - the index l in the first slot in a subframe fulfils $l \geq l_{\text{DataStart}}$ where $l_{\text{DataStart}}$ is given by clause 7.6.1.4 of 3GPP TS 36.213 [4],

Petitioners' Exhibit 1003, p. 1151
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- In mapping to resource elements, if the DCI associated with the PDSCH uses the C-RNTI or semi-persistent C-RNTI and transmit diversity according to clause 6.3.4.3 is used, resource elements in an OFDM symbol assumed by the UE to contain CSI-RS shall be used in the mapping if and only if all of the following criteria are fulfilled:
  - there is an even number of resource elements for the OFDM symbol in each resource block assigned for transmission, and
  - the complex-valued symbols $y^{(p)}(i)$ and $y^{(p)}(i+1)$, where i is an even number, can be mapped to resource elements (k,l) and $(k+n,l)$ in the same OFDM symbol with $n<3$.

6.4.1 Physical downlink shared channel for BL/CE UEs

For BL/CE UEs, the following additions and exceptions hold in addition to those in clause 6.4:

- For BL/CE UEs resource elements occupied by CSI reference signals shall be counted in the PDCSH mapping but not used for transmission of the PDSCH.
- For BL/CE UEs resource elements within PRBs containing PBCH repetitions shall be counted in the PDSCH mapping but not used for transmission of the PDSCH.

For BL/CE UEs, if the PDSCH is not carrying SIB1-BR the PRB resources within the narrowband $n_{\mathrm{NB}}^{(i_0)}$ for PDSCH transmission in the first subframe are obtained from the DCI as described in clauses 5.3.3.1.12, 5.3.3.1.13, and 5.5.1.3.14 in [3], or provided by higher layers. The PDSCH is transmitted with $N_{\mathrm{rep}}^{\mathrm{PDSCH}} \geq 1$ repetitions, spanning $N_{\mathrm{abs}}^{\mathrm{PDSCH}} \geq N_{\mathrm{rep}}^{\mathrm{PDSCH}}$ consecutive subframes, including invalid subframes where the the PDSCH transmission is postponed.

- If frequency hopping is not enabled for PDSCH, the PDSCH repetitions are located at the same PRB resources in the same narrowband $n_{\mathrm{NB}}^{(i_0)}$, and
- if frequency hopping is enabled for PDSCH, the PDSCH shall be transmitted in subframe i within the $N_{\mathrm{abs}}^{\mathrm{PDSCH}}$ consecutive downlink subframes using the same PRB resources within each narrowband

$$n_{\mathrm{NB}}^{(i)} = \left(n_{\mathrm{NB}}^{(i_0)} + \left(\left\lfloor \frac{i+i_\Delta}{N_{\mathrm{NB}}^{\mathrm{ch,DL}}} - j_0 \right\rfloor \bmod N_{\mathrm{NB,hop}}^{\mathrm{ch,DL}} \right) \cdot f_{\mathrm{NB,hop}}^{\mathrm{DL}} \right) \bmod N_{\mathrm{NB}}^{\mathrm{DL}}$$

$$j_0 = \left\lfloor (i_0 + i_\Delta) / N_{\mathrm{NB}}^{\mathrm{ch,DL}} \right\rfloor$$

$$i_0 \leq i \leq i_0 + N_{\mathrm{abs}}^{\mathrm{PDSCH}} - 1$$

$$i_\Delta = \begin{cases} 0, & \text{for frame structure type 1} \\ N_{\mathrm{NB}}^{\mathrm{ch,DL}} - 2, & \text{for frame structure type 2} \end{cases}$$

where i_0 is the absolute subframe number of the first downlink subframe intended for PDSCH and $N_{\mathrm{NB}}^{\mathrm{ch,DL}}$, $N_{\mathrm{NB,hop}}^{\mathrm{ch,DL}}$ and $f_{\mathrm{NB,hop}}^{\mathrm{DL}}$ are a cell-specific higher-layer parameters. For PDSCH carrying SI other than SIB1-BR, If *interval-DlHoppingConfigCommonModeB* is signalled in SIB1-BR, then the frequency hopping granularity $N_{\mathrm{NB}}^{\mathrm{ch,DL}}$ is set to *interval-DlHoppingConfigCommonModeB*; Otherwise, $N_{\mathrm{NB}}^{\mathrm{ch,DL}}$ is set to *interval-DlHoppingConfigCommonModeA* signalled in SIB1-BR.

For BL/CE UE in CEModeA, frequency hopping of PDSCH associated with C-RNTI or SPS-RNTI is enabled when higher layer parameter *mpdcch-pdsch-HoppingConfig* is set and the frequency hopping flag in DCI format 6-1A indicates frequency hopping, otherwise, frequency hopping of is not enabled.

The UE shall not expect PDSCH in subframe i if it is not a valid downlink subframe.

For BL/CE UEs, if the PDSCH carries SIB1-BR, the PDSCH transmission is repeated periodically in every period of 8 radio frames, where a period starts with a radio frame with $n_{\mathrm{f}} \bmod 8 = 0$ where n_{f} is the system frame number. The PDSCH is transmitted $N_{\mathrm{PDSCH}}^{\mathrm{SIB1\text{-}BR}}$ times in each period of 8 frames, Let $\{s_j\}$ be the set of narrowbands, excluding

Petitioners' Exhibit 1003, p. 1152
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

narrowbands overlapping with the 72 center subcarriers for $N_{\mathrm{RB}}^{\mathrm{DL}} > 15$, and ordered in increasing order of narrowband index. The PDSCH transmission cycles through the set $\{s_i\}$ of narrowbands in increasing order of i, starting with $i = 0$ for the first subframe, according to

$$
\begin{aligned}
n_{\mathrm{NB}} &= s_j \\
j &= \left(N_{\mathrm{ID}}^{\mathrm{cell}} \bmod N_{\mathrm{NB}}^{\mathrm{S}} + i \cdot \left\lfloor N_{\mathrm{NB}}^{\mathrm{S}} / m \right\rfloor\right) \bmod N_{\mathrm{NB}}^{\mathrm{S}} \\
i &= 0,1,\ldots,m-1 \\
m &= \begin{cases} 1 & N_{\mathrm{RB}}^{\mathrm{DL}} < 12 \\ 2 & 12 \le N_{\mathrm{RB}}^{\mathrm{DL}} \le 50 \\ 4 & 50 < N_{\mathrm{RB}}^{\mathrm{DL}} \end{cases}
\end{aligned}
$$

where $N_{\mathrm{NB}}^{\mathrm{S}}$ is the number of narrowbands in the set $\{s_j\}$.

The set of frames and subframes used for SIB1-BR transmission in each period are given by Tables 6.4.1-1 and 6.4.1-2.

Table 6.4.1-1: The set of frames and subframes for SIB1-BR for $N_{\mathrm{RB}}^{\mathrm{DL}} \le 15$.

$N_{\mathrm{PDSCH}}^{\mathrm{SIB1bis}}$	$N_{\mathrm{ID}}^{\mathrm{cell}} \bmod 2$	Frame structure type 1		Frame structure type 2	
		$n_{\mathrm{f}} \bmod 2$	n_{sf}	$n_{\mathrm{f}} \bmod 2$	n_{sf}
4	0	0	4	1	5
	1	1	4	1	5

Table 6.4.1-2: The set of frames and subframes for SIB1-BR for $N_{\mathrm{RB}}^{\mathrm{DL}} > 15$.

$N_{\mathrm{PDSCH}}^{\mathrm{SIB1bis}}$	$N_{\mathrm{ID}}^{\mathrm{cell}} \bmod 2$	Frame structure type 1		Frame structure type 2	
		$n_{\mathrm{f}} \bmod 2$	n_{sf}	$n_{\mathrm{f}} \bmod 2$	n_{sf}
4	0	0	4	1	5
	1	1	4	1	0
8	0	0, 1	4	0, 1	5
	1	0, 1	9	0, 1	0
16	0	0, 1	4, 9	0, 1	0, 5
	1	0, 1	0, 9	0, 1	0, 5

BL/CE UEs may assume the same precoding matrix being used for a PRB across a block of $N_{\mathrm{NB}}^{\mathrm{ch,DL}}$ consecutive subframes when UE-specific reference signals are transmitted together with the PDSCH.

For PDSCH transmission associated with RA-RNTI or temporary C-RNTI to BL/CE UEs, frequency hopping of the PDSCH is enabled when higher layer parameter *rar-HoppingConfig* is set. Further

- if PRACH CE level 0 or 1 is used for the last PRACH attempt, $N_{\mathrm{NB}}^{\mathrm{ch,DL}}$ is set to the higher layer parameter *interval-DlHoppingConfigCommonModeA*;
- if PRACH CE level 2 or 3 is used for the last PRACH attempt, $N_{\mathrm{NB}}^{\mathrm{ch,DL}}$ is set to the higher layer parameter *interval-DlHoppingConfigCommonModeB*.

6.5 Physical multicast channel

The physical multicast channel shall be processed and mapped to resource elements as described in clause 6.3 with the following exceptions:

- No transmit diversity scheme is specified.
- Layer mapping and precoding shall be done assuming a single antenna port and the transmission shall use antenna port 4.

Petitioners' Exhibit 1003, p. 1153
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- The PMCH can only be transmitted in the MBSFN region of an MBSFN subframe. The index l in the first slot in the MBSFN subframe fulfils $l \geq l_{\text{PMCHStart}}$ where $l_{\text{PMCHStart}}$ is equal to the value given by the higher layer parameter *non-MBSFNregionLength* [9].
- The PMCH shall use extended cyclic prefix.
- The PMCH is not mapped to resource elements used for transmission of MBSFN reference signals.

6.6 Physical broadcast channel

The PBCH is not transmitted for frame structure type 3.

6.6.1 Scrambling

The block of bits $b(0),...,b(M_{\text{bit}}-1)$, where M_{bit}, the number of bits transmitted on the physical broadcast channel, equals 1920 for normal cyclic prefix and 1728 for extended cyclic prefix, shall be scrambled with a cell-specific sequence prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{bit}}-1)$ according to

$$\tilde{b}(i) = \left(b(i) + c(i)\right) \bmod 2$$

where the scrambling sequence $c(i)$ is given by clause 7.2. The scrambling sequence shall be initialised with $c_{\text{init}} = N_{\text{ID}}^{\text{cell}}$ in each radio frame fulfilling $n_{\text{f}} \bmod 4 = 0$.

6.6.2 Modulation

The block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{bit}}-1)$ shall be modulated as described in clause 7.1, resulting in a block of complex-valued modulation symbols $d(0),...,d(M_{\text{symb}}-1)$. Table 6.6.2-1 specifies the modulation mappings applicable for the physical broadcast channel.

Table 6.6.2-1: PBCH modulation schemes.

Physical channel	Modulation schemes
PBCH	QPSK

6.6.3 Layer mapping and precoding

The block of modulation symbols $d(0),...,d(M_{\text{symb}}-1)$ shall be mapped to layers according to one of clauses 6.3.3.1 or 6.3.3.3 with $M_{\text{symb}}^{(0)} = M_{\text{symb}}$ and precoded according to one of clauses 6.3.4.1 or 6.3.4.3, resulting in a block of vectors $y(i) = \left[y^{(0)}(i) \quad ... \quad y^{(P-1)}(i)\right]^T$, $i = 0,...,M_{\text{symb}}-1$, where $y^{(p)}(i)$ represents the signal for antenna port p and where $p = 0,...,P-1$ and the number of antenna ports for cell-specific reference signals $P \in \{1,2,4\}$.

6.6.4 Mapping to resource elements

The block of complex-valued symbols $y^{(p)}(0),...,y^{(p)}(M_{\text{symb}}-1)$ for each antenna port is transmitted during 4 consecutive radio frames starting in each radio frame fulfilling $n_{\text{f}} \bmod 4 = 0$ and shall be mapped in sequence starting with $y(0)$ to resource elements (k,l) constituting the core set of PBCH resource elements. The mapping to resource elements (k,l) not reserved for transmission of reference signals shall be in increasing order of first the index k, then the index l in slot 1 in subframe 0 and finally the radio frame number. The resource-element indices are given by

Petitioners' Exhibit 1003, p. 1154
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$k = \frac{N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}}{2} - 36 + k', \quad k' = 0,1,...,71$$
$$l = 0,1,...,3$$

where resource elements reserved for reference signals shall be excluded. The mapping operation shall assume cell-specific reference signals for antenna ports 0-3 being present irrespective of the actual configuration. The UE shall assume that the resource elements assumed to be reserved for reference signals in the mapping operation above but not used for transmission of reference signal are not available for PDSCH transmission. The UE shall not make any other assumptions about these resource elements.

If a cell is configured with repetition of the physical broadcast channel

- symbols mapped to core resource element (k,l) in slot 1 in subframe 0 within a radio frame n_{f} according to the mapping operation above, and
- cell-specific reference signals in OFDM symbols l in slot 1 in subframe 0 within a radio frame n_{f} with l according to the mapping operation above

shall additionally be mapped to resource elements (k,l') in slot number n_{s}' within radio frame $n_{\mathrm{f}} - i$ unless resource element (k,l') is used by CSI reference signals.

For frame structure type 1, l', n_{s}', and i are given by Table 6.6.4-1.

For frame structure type 2,

- if $N_{\mathrm{RB}}^{\mathrm{DL}} > 15$, l' and n_{s}' are given by Table 6.6.4-2 and $i = 0$;
- if $7 \le N_{\mathrm{RB}}^{\mathrm{DL}} \le 15$, l' and n_{s}' are given by Table 6.6.4-2 and $i = 0$, except that repetitions with $n_{\mathrm{s}}' = 10$ and $n_{\mathrm{s}}' = 11$ are not applied.

For both frame structure type 1 and frame structure type 2, repetition of the physical broadcast channel is not applicable if $N_{\mathrm{RB}}^{\mathrm{DL}} = 6$.

Resource elements already used for transmission of cell-specific reference signals in absence of repetition shall not be used for additional mapping of cell-specific reference signals.

Table 6.6.4-1: Frame offset, slot and symbol number triplets for repetition of PBCH for frame structure type 1.

l	Frame offset, slot and symbol number triplets (i, n_{s}', l')	
	Normal cyclic prefix	Extended cyclic prefix
0	(1,18,3), (1,19,0), (1,19,4), (0,0,4)	(1,18,3), (1,19,0), (1,19,5)
1	(1,18,4), (1,19,1). (1,19,5), (0,1,4)	(1,18,4), (1,19,1). (0,0,3)
2	(1,18,5), (1,19,2), (1,19,6), (0,1,5)	(1,18,5), (1,19,2), (0,1,4)
3	(1,18,6), (1,19,3), (0,0,3), (0,1,6)	(1,19,3), (1,19,4), (0,1,5)

Table 6.6.4-2: Slot and symbol number pairs for repetition of PBCH for frame structure type 2.

l	Slot and symbol number pairs (n_{s}', l')	
	Normal cyclic prefix	Extended cyclic prefix
0	(0,3), (1,4), (10,3), (11,0), (11,4)	(0,3), (10,3), (11,0)
1	(0,4), (1,5), (10,4), (11,1), (11,5)	(0,4), (10,4), (11,1)
2	(0,5), (10,5), (11.2)	(0,5), (10,5), (11.2)
3	(0,6), (10,6), (11.3)	(1,4), (11,3), (11.4)

Petitioners' Exhibit 1003, p. 1155
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.7 Physical control format indicator channel

The physical control format indicator channel carries information about the number of OFDM symbols used for transmission of PDCCHs in a subframe. The set of OFDM symbols possible to use for PDCCH in a subframe is given by Table 6.7-1.

Table 6.7-1: Number of OFDM symbols used for PDCCH

Subframe	Number of OFDM symbols for PDCCH when $N_{RB}^{DL} > 10$	Number of OFDM symbols for PDCCH when $N_{RB}^{DL} \leq 10$
Subframe 1 and 6 for frame structure type 2	1, 2	2
MBSFN subframes on a carrier supporting PDSCH, configured with 1 or 2 cell-specific antenna ports	1, 2	2
MBSFN subframes on a carrier supporting PDSCH, configured with 4 cell-specific antenna ports	2	2
Subframes on a carrier not supporting PDSCH	0	0
Non-MBSFN subframes (except subframe 6 for frame structure type 2) configured with positioning reference signals	1, 2, 3	2, 3
All other cases	1, 2, 3	2, 3, 4

The UE may assume the PCFICH is transmitted when the number of OFDM symbols for PDCCH is greater than zero unless stated otherwise in [4, clause 12].

6.7.1 Scrambling

The block of bits $b(0),...,b(31)$ transmitted in one subframe shall be scrambled with a cell-specific sequence prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0),...,\tilde{b}(31)$ according to

$$\tilde{b}(i) = (b(i) + c(i)) \bmod 2$$

where the scrambling sequence $c(i)$ is given by clause 7.2. The scrambling sequence generator shall be initialised with $c_{init} = (\lfloor n_s/2 \rfloor + 1) \cdot (2N_{ID}^{cell} + 1) \cdot 2^9 + N_{ID}^{cell}$ at the start of each subframe.

6.7.2 Modulation

The block of scrambled bits $\tilde{b}(0),...,\tilde{b}(31)$ shall be modulated as described in clause 7.1, resulting in a block of complex-valued modulation symbols $d(0),...,d(15)$. Table 6.7.2-1 specifies the modulation mappings applicable for the physical control format indicator channel.

Table 6.7.2-1: PCFICH modulation schemes

Physical channel	Modulation schemes
PCFICH	QPSK

6.7.3 Layer mapping and precoding

The block of modulation symbols $d(0),...,d(15)$ shall be mapped to layers according to one of clauses 6.3.3.1 or 6.3.3.3 with $M_{symb}^{(0)} = 16$ and precoded according to one of clauses 6.3.4.1 or 6.3.4.3, resulting in a block of vectors $y(i) = \left[y^{(0)}(i) \quad ... \quad y^{(P-1)}(i) \right]^T$, $i = 0,...,15$, where $y^{(p)}(i)$ represents the signal for antenna port p and where $p = 0,...,P-1$ and the number of antenna ports for cell-specific reference signals $P \in \{1,2,4\}$. The PCFICH shall be transmitted on the same set of antenna ports as the PBCH.

Petitioners' Exhibit 1003, p. 1156
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.7.4 Mapping to resource elements

The mapping to resource elements is defined in terms of quadruplets of complex-valued symbols. Let $z^{(p)}(i) = \left\langle y^{(p)}(4i), y^{(p)}(4i+1), y^{(p)}(4i+2), y^{(p)}(4i+3) \right\rangle$ denote symbol quadruplet i for antenna port p. For each of the antenna ports, symbol quadruplets shall be mapped in increasing order of i to the four resource-element groups in the first OFDM symbol in a downlink subframe or DwPTS with the representative resource-element as defined in clause 6.2.4 given by

$z^{(p)}(0)$ is mapped to the resource-element group represented by $k = \bar{k}$

$z^{(p)}(1)$ is mapped to the resource-element group represented by $k = \bar{k} + \left\lfloor N_{\mathrm{RB}}^{\mathrm{DL}}/2 \right\rfloor \cdot N_{\mathrm{sc}}^{\mathrm{RB}}/2$

$z^{(p)}(2)$ is mapped to the resource-element group represented by $k = \bar{k} + \left\lfloor 2N_{\mathrm{RB}}^{\mathrm{DL}}/2 \right\rfloor \cdot N_{\mathrm{sc}}^{\mathrm{RB}}/2$

$z^{(p)}(3)$ is mapped to the resource-element group represented by $k = \bar{k} + \left\lfloor 3N_{\mathrm{RB}}^{\mathrm{DL}}/2 \right\rfloor \cdot N_{\mathrm{sc}}^{\mathrm{RB}}/2$

where the additions are modulo $N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}$,

$$\bar{k} = \left(N_{\mathrm{sc}}^{\mathrm{RB}}/2\right) \cdot \left(N_{\mathrm{ID}}^{\mathrm{cell}} \bmod 2N_{\mathrm{RB}}^{\mathrm{DL}}\right)$$

and $N_{\mathrm{ID}}^{\mathrm{cell}}$ is the physical-layer cell identity as given by clause 6.11.

Petitioners' Exhibit 1003, p. 1157
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.8 Physical downlink control channel

6.8.1 PDCCH formats

The physical downlink control channel carries scheduling assignments and other control information. A physical control channel is transmitted on an aggregation of one or several consecutive control channel elements (CCEs), where a control channel element corresponds to 9 resource element groups. The number of resource-element groups not assigned to PCFICH or PHICH is N_{REG}. The CCEs available in the system are numbered from 0 to $N_{\mathrm{CCE}}-1$, where $N_{\mathrm{CCE}}=\lfloor N_{\mathrm{REG}}/9\rfloor$. The PDCCH supports multiple formats as listed in Table 6.8.1-1. A PDCCH consisting of n consecutive CCEs may only start on a CCE fulfilling $i \bmod n = 0$, where i is the CCE number.

Multiple PDCCHs can be transmitted in a subframe.

Table 6.8.1-1: Supported PDCCH formats

PDCCH format	Number of CCEs	Number of resource-element groups	Number of PDCCH bits
0	1	9	72
1	2	18	144
2	4	36	288
3	8	72	576

6.8.2 PDCCH multiplexing and scrambling

The block of bits $b^{(i)}(0),\ldots,b^{(i)}(M_{\mathrm{bit}}^{(i)}-1)$ on each of the control channels to be transmitted in a subframe, where $M_{\mathrm{bit}}^{(i)}$ is the number of bits in one subframe to be transmitted on physical downlink control channel number i, shall be multiplexed, resulting in a block of bits $b^{(0)}(0),\ldots,b^{(0)}(M_{\mathrm{bit}}^{(0)}-1),b^{(1)}(0),\ldots,b^{(1)}(M_{\mathrm{bit}}^{(1)}-1),\ldots,b^{(n_{\mathrm{PDCCH}}-1)}(0),\ldots,b^{(n_{\mathrm{PDCCH}}-1)}(M_{\mathrm{bit}}^{(n_{\mathrm{PDCCH}}-1)}-1)$, where n_{PDCCH} is the number of PDCCHs transmitted in the subframe.

The block of bits $b^{(0)}(0),\ldots,b^{(0)}(M_{\mathrm{bit}}^{(0)}-1),b^{(1)}(0),\ldots,b^{(1)}(M_{\mathrm{bit}}^{(1)}-1),\ldots,b^{(n_{\mathrm{PDCCH}}-1)}(0),\ldots,b^{(n_{\mathrm{PDCCH}}-1)}(M_{\mathrm{bit}}^{(n_{\mathrm{PDCCH}}-1)}-1)$ shall be scrambled with a cell-specific sequence prior to modulation, resulting in a block of scrambled bits $\tilde{b}(0),\ldots,\tilde{b}(M_{\mathrm{tot}}-1)$ according to

$$\tilde{b}(i)=\left(b(i)+c(i)\right)\bmod 2$$

where the scrambling sequence $c(i)$ is given by clause 7.2. The scrambling sequence generator shall be initialised with $c_{\mathrm{init}}=\lfloor n_s/2\rfloor 2^9+N_{\mathrm{ID}}^{\mathrm{cell}}$ at the start of each subframe.

CCE number n corresponds to bits $b(72n),b(72n+1),\ldots,b(72n+71)$. If necessary, <NIL> elements shall be inserted in the block of bits prior to scrambling to ensure that the PDCCHs starts at the CCE positions as described in 3GPP TS 36.213 [4] and to ensure that the length $M_{\mathrm{tot}}=8N_{\mathrm{REG}}\geq\sum_{i=0}^{n_{\mathrm{PDCCH}}-1}M_{\mathrm{bit}}^{(i)}$ of the scrambled block of bits matches the amount of resource-element groups not assigned to PCFICH or PHICH.

6.8.3 Modulation

The block of scrambled bits $\tilde{b}(0),\ldots,\tilde{b}(M_{\mathrm{tot}}-1)$ shall be modulated as described in clause 7.1, resulting in a block of complex-valued modulation symbols $d(0),\ldots,d(M_{\mathrm{symb}}-1)$. Table 6.8.3-1 specifies the modulation mappings applicable for the physical downlink control channel.

Petitioners' Exhibit 1003, p. 1158
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.8.3-1: PDCCH modulation schemes

Physical channel	Modulation schemes
PDCCH	QPSK

6.8.4 Layer mapping and precoding

The block of modulation symbols $d(0),...,d(M_{\text{symb}}-1)$ shall be mapped to layers according to one of clauses 6.3.3.1 or 6.3.3.3 with $M_{\text{symb}}^{(0)} = M_{\text{symb}}$ and precoded according to one of clauses 6.3.4.1 or 6.3.4.3, resulting in a block of vectors $y(i) = \left[y^{(0)}(i) \quad ... \quad y^{(P-1)}(i)\right]^T$, $i = 0,...,M_{\text{symb}}-1$ to be mapped onto resources on the antenna ports used for transmission, where $y^{(p)}(i)$ represents the signal for antenna port p. The PDCCH shall be transmitted on the same set of antenna ports as the PBCH.

6.8.5 Mapping to resource elements

The mapping to resource elements is defined by operations on quadruplets of complex-valued symbols. Let $z^{(p)}(i) = \left\langle y^{(p)}(4i), y^{(p)}(4i+1), y^{(p)}(4i+2), y^{(p)}(4i+3)\right\rangle$ denote symbol quadruplet i for antenna port p.

The block of quadruplets $z^{(p)}(0),...,z^{(p)}(M_{\text{quad}}-1)$, where $M_{\text{quad}} = M_{\text{symb}}/4$, shall be permuted resulting in $w^{(p)}(0),...,w^{(p)}(M_{\text{quad}}-1)$. The permutation shall be according to the sub-block interleaver in clause 5.1.4.2.1 of 3GPP TS 36.212 [3] with the following exceptions:

- the input and output to the interleaver is defined by symbol quadruplets instead of bits
- interleaving is performed on symbol quadruplets instead of bits by substituting the terms "bit", "bits" and "bit sequence" in clause 5.1.4.2.1 of 3GPP TS 36.212 [3] by "symbol quadruplet", "symbol quadruplets" and "symbol-quadruplet sequence", respectively

<NULL> elements at the output of the interleaver in 3GPP TS 36.212 [3] shall be removed when forming $w^{(p)}(0),...,w^{(p)}(M_{\text{quad}}-1)$. Note that the removal of <NULL> elements does not affect any <NIL> elements inserted in clause 6.8.2.

The block of quadruplets $w^{(p)}(0),...,w^{(p)}(M_{\text{quad}}-1)$ shall be cyclically shifted, resulting in $\overline{w}^{(p)}(0),...,\overline{w}^{(p)}(M_{\text{quad}}-1)$ where $\overline{w}^{(p)}(i) = w^{(p)}\left((i+N_{\text{ID}}^{\text{cell}}) \bmod M_{\text{quad}}\right)$.

Mapping of the block of quadruplets $\overline{w}^{(p)}(0),...,\overline{w}^{(p)}(M_{\text{quad}}-1)$ is defined in terms of resource-element groups, specified in clause 6.2.4, according to steps 1–10 below:

1) Initialize $m' = 0$ (resource-element group number)
2) Initialize $k' = 0$
    3) Initialize $l' = 0$
        4) If the resource element (k',l') represents a resource-element group and the resource-element group is not assigned to PCFICH or PHICH then perform step 5 and 6, else go to step 7
            5) Map symbol-quadruplet $\overline{w}^{(p)}(m')$ to the resource-element group represented by (k',l') for each antenna port p
            6) Increase m' by 1
        7) Increase l' by 1

Petitioners' Exhibit 1003, p. 1159
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

8) Repeat from step 4 if $l' < L$, where L corresponds to the number of OFDM symbols used for PDCCH transmission as indicated by the sequence transmitted on the PCFICH

9) Increase k' by 1

10) Repeat from step 3 if $k' < N_{\text{RB}}^{\text{DL}} \cdot N_{\text{sc}}^{\text{RB}}$

6.8A Enhanced physical downlink control channel

6.8A.1 EPDCCH formats

The enhanced physical downlink control channel (EPDCCH) carries scheduling assignments. An enhanced physical downlink control channel is transmitted using an aggregation of one or several consecutive enhanced control channel elements (ECCEs) where each ECCE consists of multiple enhanced resource element groups (EREGs), defined in clause 6.2.4A. The number of ECCEs used for one EPDCCH depends on the EPDCCH format as given by Table 6.8A.1-2 and the number of EREGs per ECCE is given by Table 6.8A.1-1.Both localized and distributed transmission is supported.

An EPDCCH can use either localized or distributed transmission, differing in the mapping of ECCEs to EREGs and PRB pairs.

A UE shall monitor multiple EPDCCHs as defined in 3GPP TS 36.213 [4]. One or two sets of physical resource-block pairs which a UE shall monitor for EPDCCH transmissions can be configured. All EPDCCH candidates in EPDCCH set X_m use either only localized or only distributed transmission as configured by higher layers. Within EPDCCH set X_m in subframe i, the ECCEs available for transmission of EPDCCHs are numbered from 0 to $N_{\text{ECCE},m,i} - 1$ and ECCE number n corresponds to

- EREGs numbered $\left(n \bmod N_{\text{ECCE}}^{\text{RB}}\right) + jN_{\text{ECCE}}^{\text{RB}}$ in PRB index $\left\lfloor n / N_{\text{ECCE}}^{\text{RB}} \right\rfloor$ for localized mapping, and
- EREGs numbered $\left\lfloor n / N_{\text{RB}}^{X_m} \right\rfloor + jN_{\text{ECCE}}^{\text{RB}}$ in PRB indices $\left(n + j \max\left(1, N_{\text{RB}}^{X_m} / N_{\text{EREG}}^{\text{ECCE}}\right)\right) \bmod N_{\text{RB}}^{X_m}$ for distributed mapping,

where $j = 0,1,\ldots, N_{\text{EREG}}^{\text{ECCE}} - 1$, $N_{\text{EREG}}^{\text{ECCE}}$ is the number of EREGs per ECCE, and $N_{\text{ECCE}}^{\text{RB}} = 16 / N_{\text{EREG}}^{\text{ECCE}}$ is the number of ECCEs per resource-block pair. The physical resource-block pairs constituting EPDCCH set X_m are in this paragraph assumed to be numbered in ascending order from 0 to $N_{\text{RB}}^{X_m} - 1$.

Table 6.8A.1-1: Number of EREGs per ECCE, $N_{\text{EREG}}^{\text{ECCE}}$

Normal cyclic prefix			Extended cyclic prefix	
Normal subframe	Special subframe, configuration 3, 4, 8	Special subframe, configuration 1, 2, 6, 7, 9	Normal subframe	Special subframe, configuration 1, 2, 3, 5, 6
4		8		

Table 6.8A.1-2: Supported EPDCCH formats

EPDCCH format	Number of ECCEs for one EPDCCH, $N_{\text{ECCE}}^{\text{EPDCCH}}$			
	Case A		Case B	
	Localized transmission	Distributed transmission	Localized transmission	Distributed transmission
0	2	2	1	1
1	4	4	2	2
2	8	8	4	4
3	16	16	8	8
4	-	32	-	16

Petitioners' Exhibit 1003, p. 1160
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Case A in Table 6.8A.1-2 is used when the conditions corresponding to case 1 in clause 9.1.4 of 3GPP TS 36.213 [4] are satisfied, otherwise case B is used. The quantity n_{EPDCCH} for a particular UE and referenced in 3GPP TS 36.213 [4] is defined as the number of downlink resource elements (k,l) available for EPDCCH transmission in a physical resource-block pair configured for possible EPDCCH transmission of EPDCCH set X_0 and fulfilling all of the following criteria:

- they are part of any one of the 16 EREGs in the physical resource-block pair, and
- they are assumed by the UE not to be used for cell-specific reference signals, where the positions of the cell-specific reference signals are given by clause 6.10.1.2 with the number of antenna ports for and the frequency shift of cell-specific reference signals derived as described in clause 6.10.1.2 unless other values for these parameters are provided by clause 9.1.4.3 in 3GPP TS 36.213 [4], and-
- they are assumed by the UE not to be used for transmission of CSI reference signals, where the positions of the CSI reference signals are given by clause 6.10.5.2 with the configuration for zero power CSI reference signals obtained as described in clause 6.10.5.2 unless other values are provided by clause 9.1.4.3 in 3GPP TS 36.213 [4], and with the configuration for non-zero power CSI reference signals obtained as described in clause 6.10.5.2, and
- for frame structure type 1 and 2, the index l in the first slot in a subframe fulfils $l \geq l_{\text{EPDCCHStart}}$ where $l_{\text{EPDCCHStart}}$ is given by clause 9.1.4.1 of 3GPP TS 36.213 [4], and
- for frame structure type 3,
  - if the higher layer parameter *subframeStartPosition* indicates "s07" and if the downlink transmission starts in the second slot of a subframe
    - the index l in the second slot in the subframe fulfils $l \geq l_{\text{EPDCCHStart}}$ where $l_{\text{EPDCCHStart}}$ is given by clause 7.1.6.4 of 3GPP TS 36.213 [4],
  - otherwise
    - the index l in the first slot in the subframe fulfils $l \geq l_{\text{EPDCCHStart}}$ where $l_{\text{EPDCCHStart}}$ is given by clause 7.6.1.4 of 3GPP TS 36.213 [4].

6.8A.2 Scrambling

The block of bits $b(0),...,b(M_{\text{bit}}-1)$ to be transmitted on an EPDCCH in a subframe shall be scrambled, resulting in a block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{bit}}-1)$ according to

$$\tilde{b}(i) = \left(b(i) + c(i)\right) \bmod 2$$

where the UE-specific scrambling sequence $c(i)$ is given by clause 7.2. The scrambling sequence generator shall be initialized with $c_{\text{init}} = \lfloor n_s/2 \rfloor \cdot 2^9 + n_{\text{ID},m}^{\text{EPDCCH}}$ where m is the EPDCCH set number.

6.8A.3 Modulation

The block of scrambled bits $\tilde{b}(0),...,\tilde{b}(M_{\text{bit}}-1)$ shall be modulated as described in clause 7.1, resulting in a block of complex-valued modulation symbols $d(0),...,d(M_{\text{symb}}-1)$. Table 6.8A.3-1 specifies the modulation mappings applicable for the enhanced physical downlink control channel.

Table 6.8A.3-1: EPDCCH modulation schemes

Physical channel	Modulation schemes
EPDCCH	QPSK

Petitioners' Exhibit 1003, p. 1161
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.8A.4 Layer mapping and precoding

The block of complex-valued modulation symbols shall be mapped to a single layer and precoded according to $y(i) = d(i)$, $i = 0,...,M_{\text{symb}} - 1$.

6.8A.5 Mapping to resource elements

The block of complex-valued symbols $y(0),...,y(M_{\text{symb}} - 1)$ shall be mapped in sequence starting with $y(0)$ to resource elements (k,l) on the associated antenna port which meet all of the following criteria:

- they are part of the EREGs assigned for the EPDCCH transmission, and
- they are assumed by the UE not to be used for cell-specific reference signals, where the positions of the cell-specific reference signals are given by clause 6.10.1.2 with the number of antenna ports for and the frequency shift of cell-specific reference signals derived as described in clause 6.10.1.2 unless other values for these parameters are provided by clause 9.1.4.3 in 3GPP TS 36.213 [4], and
- they are assumed by the UE not to be used for transmission of:
  - zero-power CSI reference signals, where the positions of the CSI reference signals are given by clause 6.10.5.2. The configuration for zero power CSI reference signals is
    - obtained as described in clause 6.10.5.2 unless other values are provided by clause 9.1.4.3 in 3GPP TS 36.213 [4], and
    - obtained by higher-layer configuration of up to five reserved CSI-RS resources as part of the discovery signal configuration following the procedure for zero-power CSI-RS in clause 6.10.5.2.
  - non-zero-power CSI reference signals for CSI reporting with the configuration for non-zero power CSI reference signals for CSI reporting obtained as described in clause 6.10.5.2, and
- for frame structure type 1 and 2, the index l in the first slot in a subframe fulfils $l \geq l_{\text{EPDCCHStart}}$ where $l_{\text{EPDCCHStart}}$ is given by clause 9.1.4.1 of 3GPP TS 36.213 [4], and
- for frame structure type 3,
  - if the higher layer parameter *subframeStartPosition* indicates "s07" and if the downlink transmission starts in the second slot of a subframe
    - the index l in the second slot in the subframe fulfils $l \geq l_{\text{EPDCCHStart}}$ where $l_{\text{EPDCCHStart}}$ is given by clause 7.1.6.4 of 3GPP TS 36.213 [4],
  - otherwise
    - the index l in the first slot in the subframe fulfils $l \geq l_{\text{EPDCCHStart}}$ where $l_{\text{EPDCCHStart}}$ is given by clause 7.6.1.4 of 3GPP TS 36.213 [4].

The mapping to resource elements (k,l) on antenna port p meeting the criteria above shall be in increasing order of first the index k and then the index l, starting with the first slot and ending with the second slot in a subframe.

For localized transmission, the single antenna port p to use is given by Table 6.8A.5-1 with

$$n' = n_{\text{ECCE,low}} \bmod N_{\text{ECCE}}^{\text{RB}} + n_{\text{RNTI}} \bmod \min(N_{\text{ECCE}}^{\text{EPDCCH}}, N_{\text{ECCE}}^{\text{RB}})$$

where $n_{\text{ECCE,low}}$ is the lowest ECCE index used by this EPDCCH transmission in the EPDCCH set, n_{RNTI} equals the C-RNTI, and $N_{\text{ECCE}}^{\text{EPDCCH}}$ is the number of ECCEs used for this EPDCCH.

Petitioners' Exhibit 1003, p. 1162
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.8A.5-1: Antenna port to use for localized EPDCCH transmission

n'	Normal cyclic prefix		Extended cyclic prefix
	Normal subframes, Special subframes, configurations 3, 4, 8	Special subframes, configurations 1, 2, 6, 7, 9	Any subframe
0	107	107	107
1	108	109	108
2	109	-	-
3	110	-	-

For distributed transmission, each resource element in an EREG is associated with one out of two antenna ports in an alternating manner, starting with antenna port 107, where $p \in \{107,109\}$ for normal cyclic prefix and $p \in \{107,108\}$ for extended cyclic prefix.

6.8B MTC physical downlink control channel

6.8B.1 MPDCCH formats

The MPDCCH formats are defined as in Clause 6.8A.1 with the following exceptions:

- The term EPDCCH is replaced by MPDCCH.
- The MTC physical downlink control channel carries downlink control information and is transmitted across $N_{\text{rep}}^{\text{MPDCCH}} \geq 1$ consecutive valid downlink subframes. Within each of the $N_{\text{rep}}^{\text{MPDCCH}}$ valid downlink subframes an MPDCCH is transmitted using an aggregation of one or several consecutive enhanced control channel elements (ECCEs) where each ECCE consists of multiple enhanced resource element groups (EREGs), defined in clause 6.2.4A.
- For frame structure type 2,
  - For a UE configured in CEModeA, if repetition is not configured for the MPDCCH, the number of EREGs per ECCE is given by Table 6.8A.1-1. If repetition is configured for the MPDCCH, the number of EREGs per ECCE is given by Table 6.8B.1-1. The MPDCCH is not supported in special subframe with configurations not listed in Table 6.8B.1-1.
  - For a UE configured in CEModeB, MPDCCH is not supported in the special subframe.
  - For both CEModeA and CEModeB, for those special subframes where the MPDCCH is not supported, these special subframes are considered valid downlink subframes for both MPDCCH and PDSCH transmission, only if they are indicated as valid downlink subframe by higher layer signalling.
- The supported MPDCCH formats are given by Table 6.8B.1-2.

Table 6.8B.1-1: Number of EREGs per ECCE, $N_{\text{EREG}}^{\text{ECCE}}$, for frame structure type 2.

Normal cyclic prefix		Extended cyclic prefix	
Normal subframe	Special subframe, configuration 3, 4, 8	Normal subframe	Special subframe, configuration 1, 2, 3, 5, 6
4		8	

Petitioners' Exhibit 1003, p. 1163
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.8B.1-2: Supported MPDCCH formats

MPDCCH format	Number of ECCEs in a subframe for one MPDCCH, N_{ECCE}^{MPDCCH}			
	Case A		Case B	
	Localized transmission	Distributed transmission	Localized transmission	Distributed transmission
0	2	2	-	-
1	4	4	2	2
2	8	8	4	4
3	16	16	8	8
4	-	-	-	16
5	24	24	12	12

6.8B.2 Scrambling

Scrambling shall be perfomed according to Clause 6.8A.2 with EPDCCH repladed by MPDCCH except that the same scrambling sequence is applied per subframe to MPDCCH for a given block of N_{acc} subframes and m is the MPDCCH set number. For an MPDCCH associated with a 2+4 PRB set as defined in [4], $m = 0$ is used to generate the scambling sequence for mapping to REs in 6 PRBs.

For the jth block of N_{acc} subframes, the scrambling sequence generator shall be initialised with

$$c_{init} = \begin{cases} \left[(j_0 + j)N_{acc} \bmod 10\right] \cdot 2^9 + N_{ID}^{cell} & \text{for P - RNTI, RA - RNTI, temporary C - RNTI} \\ \left[(j_0 + j)N_{acc} \bmod 10\right] \cdot 2^9 + n_{ID,m}^{MPDCCH} & \text{otherwise} \end{cases}$$

where

$$j = 0,1,\ldots,\left\lfloor \frac{i_0 + N_{abs}^{MPDCCH} + i_\Delta - 1}{N_{acc}} \right\rfloor - j_0$$

$$j_0 = \left\lfloor (i_0 + i_\Delta)/N_{acc} \right\rfloor$$

$$i_\Delta = \begin{cases} 0, & \text{for frame structure type 1} \\ N_{acc} - 2, & \text{for frame structure type 2} \end{cases}$$

and i_0 is the absolute subframe number of the first downlink subframe intended for the MPDCCH. The MPDCCH transmission spans N_{abs}^{MPDCCH} consecutive subframes, including invalid subframes where the MPDCCH transmission is postponed. For a UE configured in CEModeA, $N_{acc} = 1$. For a UE configured with CEModeB, $N_{acc} = 4$ for frame structure type 1 and $N_{acc} = 10$ for frame structure type 2.

6.8B.3 Modulation

Modulation shall ber perfomed according to 6.8A.3 with EPDCCH replaced by MPDCCH.

6.8B.4 Layer mapping and precoding

Layer mapping and precoding shall be done according to Clause 6.8A.4 with EPDCCH replaced by MPDCCH.

6.8B.5 Mapping to resource elements

Mapping to resource elements shall be done according to Clause 6.8A.5with the following exceptions:

- The term EPDCCH shall be replaced by MPDCCH.
- The mapping shall be repeated across each of the N_{rep}^{MPDCCH} valid downlink subframes.

Petitioners' Exhibit 1003, p. 1164
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- $N_{\text{ECCE}}^{\text{MPDCCH}}$ is the number of ECCEs used for this MPDCCH in the first of the $N_{\text{rep}}^{\text{MPDCCH}}$ subframes.

- For an MPDCCH associated with a 2+4 PRB set as defined in [4], the mapping to resource elements (k,l) on antenna port p shall be in increasing order of first the index k and then the index l over the 6 PRBs for MPDCCH format 5 and over the 2 or 4 PRBs for the other MPDCCH formats.

- Resource elements occupied by CSI reference signals shall be counted in the MPDCCH mapping but not used for transmission of the MPDCCH. The UE may assume there is no MPDCCH transmission which uses overlapping sets of subframes as PDSCH transmissions to that UE, where the MPDCCH is located at a different narrowband than the PDSCH.

- In the subframes where an MPDCCH or its associated PDSCH is transmitted in response to a physical random access transmission initiated by a PDCCH order, the UE shall receive the MPDCCH or its associated PDSCH, and assume no other UE-specific reception is needed.

- In the subframes that an MPDCCH or its associated PDSCH is transmitted in response to a physical random access transmission initiated by a PDCCH order, the UE shall receive the MPDCCH or its associated PDSCH, and assume there is no other UE-specific reception.

- For MPDCCH transmission associated with C-RNTI or SPS-RNTI, frequency hopping of the MPDCCH is enabled when higher layer parameter *mpdcch-pdsch-HoppingConfig* is set. For MPDCCH transmission associated with RA-RNTI or temporary C-RNTI, frequency hopping of the MPDCCH is enabled when higher layer parameter *rar-HoppingConfig* is set.

- The narrowband $n_{\text{NB}}^{(i_0)}$ for MPDCCH transmission in the first subframe of MPDCCH monitoring instance is provided by higher layers. Starting subframe configuration of UE-specific search space where UE monitors an MPDCCH is also provided by higher layers. The MPDCCH is transmitted with $N_{\text{rep}}^{\text{MPDCCH}} \geq 1$ repetitions, spanning $N_{\text{abs}}^{\text{MPDCCH}} \geq N_{\text{rep}}^{\text{MPDCCH}}$ consecutive subframes, including invalid subframes where the the MPDCCH transmission is postponed.

  - If frequency hopping is not enabled for MPDCCH, the repetitions of an MPDCCH candidate are located at the same PRB resources in the same narrowband $n_{\text{NB}}^{(i_0)}$, and

  - if frequency hopping is enabled for MPDCCH, an MPDCCH candidate shall be transmitted in subframe i within the $N_{\text{rep}}^{\text{MPDCCH}}$ consecutive downlink subframes using the same PRB resources within each narrowband

$$n_{\text{NB}}^{(i)} = \left(n_{\text{NB}}^{(i_0)} + \left(\left\lfloor \frac{i + i_\Delta}{N_{\text{NB}}^{\text{ch,DL}}} - j_0 \right\rfloor \bmod N_{\text{NB,hop}}^{\text{ch,DL}} \right) \cdot f_{\text{NB,hop}}^{\text{DL}} \right) \bmod N_{\text{NB}}^{\text{DL}}$$

$$j_0 = \left\lfloor (i_0 + i_\Delta) / N_{\text{NB}}^{\text{ch,DL}} \right\rfloor$$

$$i_0 \leq i \leq i_0 + N_{\text{abs}}^{\text{MPDCCH}} - 1$$

$$i_\Delta = \begin{cases} 0, & \text{for frame structure type 1} \\ N_{\text{NB}}^{\text{ch,DL}} - 2, & \text{for frame structure type 2} \end{cases}$$

  where i_0 is the absolute subframe number of the first downlink subframe of MPDCCH monitoring instance, and $N_{\text{NB,hop}}^{\text{ch,DL}}$, $N_{\text{NB}}^{\text{ch,DL}}$ and $f_{\text{NB,hop}}^{\text{DL}}$ are a cell-specific higher-layer parameters. The UE shall not expect MPDCCH transmission in subframe i if it is not a valid downlink subframe.

- The UE may assume the same precoding matrix being used for a PRB across a block of $N_{\text{NB}}^{\text{ch,DL}}$ consecutive subframes for MPDCCH.

Petitioners' Exhibit 1003, p. 1165
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The UE may asume that an MPDCCH associated with the P-RNTI is transmitted on the set $\{s_j\}$ of narrowbands where $\{s_j\}$ is defined in section 6.4.1. For a UE monitoring an MPDCCH associated with the P-RNTI, the first MPDCCH narrowband is given by s_m where $m = \left(\tilde{N}_{\mathrm{NB}}^{\mathrm{p}} + N_{\mathrm{ID}}^{\mathrm{cell}}\right) \bmod N_{\mathrm{NB}}^{\mathrm{S}}$, $\tilde{N}_{\mathrm{NB}}^{\mathrm{p}} \in \{0,1,\ldots, N_{\mathrm{NB}}^{\mathrm{p}} - 1\}$ is the Paging Narrowband (PN) obatained according to [10], and $N_{\mathrm{NB}}^{\mathrm{p}}$ is the higher-layer parameter *paging-narrowBands*.

- If the higher-layer parameter *SIx-HoppingConfigCommon* disables frequency hopping for an MPDCCH associted with P-RNTI, each MPDCCH candidate shall be located in the same PRB in narrowband s_m where $m = \left(\tilde{N}_{\mathrm{NB}}^{\mathrm{p}} + N_{\mathrm{ID}}^{\mathrm{cell}}\right) \bmod N_{\mathrm{NB}}^{\mathrm{S}}$.
- If the higher-layer parameter *SIx-HoppingConfigCommon* enables frequency hopping for an MPDCCH with P-RNTI, an MPDCCH candidate shall be located in narrowband s_j in subframe i within the $N_{\mathrm{rep}}^{\mathrm{MPDCCH}}$ consecutive downlink subframes using the same PRB resources within each narrowband s_j where

$$j = \left(\left(\tilde{N}_{\mathrm{NB}}^{\mathrm{p}} + N_{\mathrm{ID}}^{\mathrm{cell}}\right) + \left(\left\lfloor \frac{i}{N_{\mathrm{NB}}^{\mathrm{ch,DL}}} - j_0 \right\rfloor \bmod N_{\mathrm{NB,hop}}^{\mathrm{ch,DL}} \right) \cdot f_{\mathrm{NB,hop}}^{\mathrm{DL}} \right) \bmod N_{\mathrm{NB}}^{\mathrm{S}}$$

$$j_0 = \left\lfloor (i_0 + i_\Delta) / N_{\mathrm{NB}}^{\mathrm{ch,DL}} \right\rfloor$$

$$i_0 \le i \le i_0 + N_{\mathrm{abs}}^{\mathrm{MPDCCH}} - 1$$

$$i_\Delta = \begin{cases} 0 & \text{for frame structure type 1} \\ N_{\mathrm{NB}}^{\mathrm{ch,DL}} - 2 & \text{for frame structure type 2} \end{cases}$$

where i_0 is the absolute subframe number of the first downlink subframe of MPDCCH monitoring instance according to locations of paging opportunity subframes, and $N_{\mathrm{NB,hop}}^{\mathrm{ch,DL}}$, $N_{\mathrm{NB}}^{\mathrm{ch,DL}}$ and $f_{\mathrm{NB,hop}}^{\mathrm{DL}}$ are a cell-specific higher-layer parameters. The UE shall not expect MPDCCH transmission in subframe i if it is not a valid downlink subframe.

Petitioners' Exhibit 1003, p. 1166
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.9 Physical hybrid ARQ indicator channel

The PHICH carries the hybrid-ARQ ACK/NACK. Multiple PHICHs mapped to the same set of resource elements constitute a PHICH group, where PHICHs within the same PHICH group are separated through different orthogonal sequences. A PHICH resource is identified by the index pair $\left(n_{\text{PHICH}}^{\text{group}}, n_{\text{PHICH}}^{\text{seq}}\right)$, where $n_{\text{PHICH}}^{\text{group}}$ is the PHICH group number and $n_{\text{PHICH}}^{\text{seq}}$ is the orthogonal sequence index within the group.

For frame structure type 1 and type 3, the number of PHICH groups $N_{\text{PHICH}}^{\text{group}}$ is constant in all subframes and given by

$$N_{\text{PHICH}}^{\text{group}} = \begin{cases} \left\lceil N_{\text{g}}\left(N_{\text{RB}}^{\text{DL}}/8\right)\right\rceil & \text{for normal cyclic prefix} \\ 2\cdot\left\lceil N_{\text{g}}\left(N_{\text{RB}}^{\text{DL}}/8\right)\right\rceil & \text{for extended cyclic prefix} \end{cases}$$

where $N_{\text{g}} \in \{1/6, 1/2, 1, 2\}$ is provided by higher layers. The index $n_{\text{PHICH}}^{\text{group}}$ ranges from 0 to $N_{\text{PHICH}}^{\text{group}} - 1$.

For frame structure type 2, the number of PHICH groups may vary between subframes and is given by $m_i \cdot N_{\text{PHICH}}^{\text{group}}$ where $N_{\text{PHICH}}^{\text{group}}$ is given by the expression above and m_i is given by Table 6.9-1 with the uplink-downlink configuration provided by the higher-layer parameter *subframeAssignment*. The index $n_{\text{PHICH}}^{\text{group}}$ in a subframe with non-zero PHICH resources ranges from 0 to $m_i \cdot N_{\text{PHICH}}^{\text{group}} - 1$.

Table 6.9-1: The factor m_i for frame structure type 2

Uplink-downlink configuration	Subframe number i									
	0	1	2	3	4	5	6	7	8	9
0	2	1	0	0	0	2	1	0	0	0
1	0	1	0	0	1	0	1	0	0	1
2	0	0	0	1	0	0	0	0	1	0
3	1	0	0	0	0	0	0	0	1	1
4	0	0	0	0	0	0	0	0	1	1
5	0	0	0	0	0	0	0	0	1	0
6	1	1	0	0	0	1	1	0	0	1

6.9.1 Modulation

The block of bits $b(0),...,b(M_{\text{bit}}-1)$ transmitted on one PHICH in one subframe shall be modulated as described in clause 7.1, resulting in a block of complex-valued modulation symbols $z(0),...,z(M_{\text{s}}-1)$, where $M_{\text{s}} = M_{\text{bit}}$. Table 6.9.1-1 specifies the modulation mappings applicable for the physical hybrid ARQ indicator channel.

Table 6.9.1-1: PHICH modulation schemes.

Physical channel	Modulation schemes
PHICH	BPSK

The block of modulation symbols $z(0),...,z(M_{\text{s}}-1)$ shall be symbol-wise multiplied with an orthogonal sequence and scrambled, resulting in a sequence of modulation symbols $d(0),...,d(M_{\text{symb}}-1)$ according to

$$d(i) = w\left(i \bmod N_{\text{SF}}^{\text{PHICH}}\right)\cdot\left(1-2c(i)\right)\cdot z\left(\left\lfloor i/N_{\text{SF}}^{\text{PHICH}}\right\rfloor\right)$$

where

Petitioners' Exhibit 1003, p. 1167
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$i = 0,...,M_{\text{symb}} - 1$$

$$M_{\text{symb}} = N_{\text{SF}}^{\text{PHICH}} \cdot M_{\text{s}}$$

$$N_{\text{SF}}^{\text{PHICH}} = \begin{cases} 4 & \text{normal cyclic prefix} \\ 2 & \text{extended cyclic prefix} \end{cases}$$

and $c(i)$ is a cell-specific scrambling sequence generated according to clause 7.2. The scrambling sequence generator shall be initialised with $c_{\text{init}} = (\lfloor n_{\text{s}}/2 \rfloor + 1) \cdot (2N_{\text{ID}}^{\text{cell}} + 1) \cdot 2^9 + N_{\text{ID}}^{\text{cell}}$ at the start of each subframe.

The sequence $\left[w(0) \quad \cdots \quad w(N_{\text{SF}}^{\text{PHICH}} - 1) \right]$ is given by Table 6.9.1-2 where the sequence index $n_{\text{PHICH}}^{\text{seq}}$ corresponds to the PHICH number within the PHICH group.

Table 6.9.1-2: Orthogonal sequences $\left[w(0) \quad \cdots \quad w(N_{\text{SF}}^{\text{PHICH}} - 1) \right]$ for PHICH

Sequence index	Orthogonal sequence	
$n_{\text{PHICH}}^{\text{seq}}$	Normal cyclic prefix $N_{\text{SF}}^{\text{PHICH}} = 4$	Extended cyclic prefix $N_{\text{SF}}^{\text{PHICH}} = 2$
0	$[+1 \quad +1 \quad +1 \quad +1]$	$[+1 \quad +1]$
1	$[+1 \quad -1 \quad +1 \quad -1]$	$[+1 \quad -1]$
2	$[+1 \quad +1 \quad -1 \quad -1]$	$[+j \quad +j]$
3	$[+1 \quad -1 \quad -1 \quad +1]$	$[+j \quad -j]$
4	$[+j \quad +j \quad +j \quad +j]$	-
5	$[+j \quad -j \quad +j \quad -j]$	-
6	$[+j \quad +j \quad -j \quad -j]$	-
7	$[+j \quad -j \quad -j \quad +j]$	-

6.9.2 Resource group alignment, layer mapping and precoding

The block of symbols $d(0),...,d(M_{\text{symb}} - 1)$ should be first aligned with resource element group size, resulting in a block of symbols $d^{(0)}(0),...,d^{(0)}(c \cdot M_{\text{symb}} - 1)$, where $c = 1$ for normal cyclic prefix; and $c = 2$ for extended cyclic prefix.

For normal cyclic prefix, $d^{(0)}(i) = d(i)$, for $i = 0,...,M_{\text{symb}} - 1$.

For extended cyclic prefix,

$$\left[d^{(0)}(4i) \quad d^{(0)}(4i+1) \quad d^{(0)}(4i+2) \quad d^{(0)}(4i+3) \right]^T = \begin{cases} \left[d(2i) \quad d(2i+1) \quad 0 \quad 0 \right]^T & n_{\text{PHICH}}^{\text{group}} \bmod 2 = 0 \\ \left[0 \quad 0 \quad d(2i) \quad d(2i+1) \right]^T & n_{\text{PHICH}}^{\text{group}} \bmod 2 = 1 \end{cases}$$

for $i = 0,...,(M_{\text{symb}}/2) - 1$.

The block of symbols $d^{(0)}(0),...,d^{(0)}(c \cdot M_{\text{symb}} - 1)$ shall be mapped to layers and precoded, resulting in a block of vectors $y(i) = \left[y^{(0)}(i) \quad ... \quad y^{(P-1)}(i) \right]^T$, $i = 0,...,c \cdot M_{\text{symb}} - 1$, where $y^{(p)}(i)$ represents the signal for antenna port p, $p = 0,...,P-1$ and the number of cell-specific reference signals $P \in \{1,2,4\}$. The layer mapping and precoding operation depends on the cyclic prefix length and the number of antenna ports used for transmission of the PHICH. The PHICH shall be transmitted on the same set of antenna ports as the PBCH.

Petitioners' Exhibit 1003, p. 1168
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

For transmission on a single antenna port, $P=1$, layer mapping and precoding are defined by clauses 6.3.3.1 and 6.3.4.1, respectively, with $M_{\text{symb}}^{(0)} = c \cdot M_{\text{symb}}$.

For transmission on two antenna ports, $P=2$, layer mapping and precoding are defined by clauses 6.3.3.3 and 6.3.4.3, respectively, with $M_{\text{symb}}^{(0)} = c \cdot M_{\text{symb}}$.

For transmission on four antenna ports, $P=4$, layer mapping is defined by clause 6.3.3.3 with $M_{\text{symb}}^{(0)} = c \cdot M_{\text{symb}}$ and precoding by

$$\begin{bmatrix} y^{(0)}(4i) \\ y^{(1)}(4i) \\ y^{(2)}(4i) \\ y^{(3)}(4i) \\ y^{(0)}(4i+1) \\ y^{(1)}(4i+1) \\ y^{(2)}(4i+1) \\ y^{(3)}(4i+1) \\ y^{(0)}(4i+2) \\ y^{(1)}(4i+2) \\ y^{(2)}(4i+2) \\ y^{(3)}(4i+2) \\ y^{(0)}(4i+3) \\ y^{(1)}(4i+3) \\ y^{(2)}(4i+3) \\ y^{(3)}(4i+3) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 & 0 & 0 & j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & -j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & j & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & -j & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \text{Re}\left(x^{(0)}(i)\right) \\ \text{Re}\left(x^{(1)}(i)\right) \\ \text{Re}\left(x^{(2)}(i)\right) \\ \text{Re}\left(x^{(3)}(i)\right) \\ \text{Im}\left(x^{(0)}(i)\right) \\ \text{Im}\left(x^{(1)}(i)\right) \\ \text{Im}\left(x^{(2)}(i)\right) \\ \text{Im}\left(x^{(3)}(i)\right) \end{bmatrix}$$

if $(i + n_{\text{PHICH}}^{\text{group}}) \bmod 2 = 0$ for normal cyclic prefix, or $(i + \lfloor n_{\text{PHICH}}^{\text{group}}/2 \rfloor) \bmod 2 = 0$ for extended cyclic prefix, where $n_{\text{PHICH}}^{\text{group}}$ is the PHICH group number and $i = 0,1,2$, and by

$$\begin{bmatrix} y^{(0)}(4i) \\ y^{(1)}(4i) \\ y^{(2)}(4i) \\ y^{(3)}(4i) \\ y^{(0)}(4i+1) \\ y^{(1)}(4i+1) \\ y^{(2)}(4i+1) \\ y^{(3)}(4i+1) \\ y^{(0)}(4i+2) \\ y^{(1)}(4i+2) \\ y^{(2)}(4i+2) \\ y^{(3)}(4i+2) \\ y^{(0)}(4i+3) \\ y^{(1)}(4i+3) \\ y^{(2)}(4i+3) \\ y^{(3)}(4i+3) \end{bmatrix} = \frac{1}{\sqrt{2}} \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & j & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & -j & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & j & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & j \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & -j & 0 \end{bmatrix} \begin{bmatrix} \text{Re}\left(x^{(0)}(i)\right) \\ \text{Re}\left(x^{(1)}(i)\right) \\ \text{Re}\left(x^{(2)}(i)\right) \\ \text{Re}\left(x^{(3)}(i)\right) \\ \text{Im}\left(x^{(0)}(i)\right) \\ \text{Im}\left(x^{(1)}(i)\right) \\ \text{Im}\left(x^{(2)}(i)\right) \\ \text{Im}\left(x^{(3)}(i)\right) \end{bmatrix}$$

otherwise for $i = 0,1,2$.

Petitioners' Exhibit 1003, p. 1169
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.9.3 Mapping to resource elements

The sequence $\bar{y}^{(p)}(0),...,\bar{y}^{(p)}(M_{\text{symb}}^{(0)}-1)$ for each of the PHICH groups is defined by

$$\bar{y}^{(p)}(n)=\sum y_i^{(p)}(n)$$

where the sum is over all PHICHs in the PHICH group and $y_i^{(p)}(n)$ represents the symbol sequence from the i:th PHICH in the PHICH group.

PHICH groups are mapped to PHICH mapping units.

For normal cyclic prefix, the mapping of PHICH group m to PHICH mapping unit m' is defined by

$$\tilde{y}_{m'}^{(p)}(n)=\bar{y}_m^{(p)}(n)$$

where

$$m'=m=\begin{cases}0,1,...,N_{\text{PHICH}}^{\text{group}}-1 & \text{for frame structure type 1}\\ 0,1,...,m_i\cdot N_{\text{PHICH}}^{\text{group}}-1 & \text{for frame structure type 2}\end{cases},$$

and where m_i is given by Table 6.9-1.

For extended cyclic prefix, the mapping of PHICH group m and $m+1$ to PHICH mapping unit m' is defined by

$$\tilde{y}_{m'}^{(p)}(n)=\bar{y}_m^{(p)}(n)+\bar{y}_{m+1}^{(p)}(n)$$

where

$$m'=m/2$$

$$m=\begin{cases}0,2,...,N_{\text{PHICH}}^{\text{group}}-2 & \text{for frame structure type 1}\\ 0,2,...,m_i\cdot N_{\text{PHICH}}^{\text{group}}-2 & \text{for frame structure type 2}\end{cases}$$

and where m_i is given by Table 6.9-1.

Let $z^{(p)}(i)=\left\langle \tilde{y}^{(p)}(4i),\tilde{y}^{(p)}(4i+1),\tilde{y}^{(p)}(4i+2),\tilde{y}^{(p)}(4i+3)\right\rangle$, $i=0,1,2$ denote symbol quadruplet i for antenna port p. Mapping to resource elements is defined in terms of symbol quadruplets according to steps 1–10 below:

1) For each value of l'

   2) Let $n_{l'}$ denote the number of resource element groups not assigned to PCFICH in OFDM symbol l'

   3) Number the resource-element groups not assigned to PCFICH in OFDM symbol l' from 0 to $n_{l'}-1$, starting from the resource-element group with the lowest frequency-domain index.

4) Initialize $m'=0$ (PHICH mapping unit number)

5) For each value of $i=0,1,2$

   6) Symbol-quadruplet $z^{(p)}(i)$ from PHICH mapping unit m' is mapped to the resource-element group represented by $(k',l')_i$ as defined in clause 6.2.4 where the indices k_i' and l_i' are given by steps 7 and 8 below:

      7) The time-domain index l_i' is given by

Petitioners' Exhibit 1003, p. 1170
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$l'_i = \begin{cases} 0 & \text{normal PHICH duration, all subframes} \\ \left(\lfloor m'/2 \rfloor + i + 1\right) \bmod 2 & \text{extended PHICH duration, MBSFN subframes} \\ \left(\lfloor m'/2 \rfloor + i + 1\right) \bmod 2 & \text{extended PHICH duration, subframe 1 and 6 in frame structure type 2} \\ i & \text{otherwise} \end{cases}$$

8) Set the frequency-domain index k'_i to the resource-element group assigned the number $\bar{n}_i$ in step 3 above, where $\bar{n}_i$ is given by

$$\bar{n}_i = \begin{cases} \left(\lfloor N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l'_i} / n_1 \rfloor + m'\right) \bmod n_{l'_i} & i = 0 \\ \left(\lfloor N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l'_i} / n_1 \rfloor + m' + \lfloor n_{l'_i} / 3 \rfloor\right) \bmod n_{l'_i} & i = 1 \\ \left(\lfloor N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l'_i} / n_1 \rfloor + m' + \lfloor 2\, n_{l'_i} / 3 \rfloor\right) \bmod n_{l'_i} & i = 2 \end{cases}$$

in case of extended PHICH duration in MBSFN subframes, or extended PHICH duration in subframes 1 and 6 for frame structure type 2 and by

$$\bar{n}_i = \begin{cases} \left(\lfloor N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l'_i} / n_0 \rfloor + m'\right) \bmod n_{l'_i} & i = 0 \\ \left(\lfloor N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l'_i} / n_0 \rfloor + m' + \lfloor n_{l'_i} / 3 \rfloor\right) \bmod n_{l'_i} & i = 1 \\ \left(\lfloor N_{\mathrm{ID}}^{\mathrm{cell}} \cdot n_{l'_i} / n_0 \rfloor + m' + \lfloor 2\, n_{l'_i} / 3 \rfloor\right) \bmod n_{l'_i} & i = 2 \end{cases}$$

otherwise.

9) Increase m' by 1.

10) Repeat from step 5 until all PHICH mapping units have been assigned.

The PHICH duration is configurable by higher layers according to Table 6.9.3-1.

Table 6.9.3-1: PHICH duration in MBSFN and non-MBSFN subframes

PHICH duration	Non-MBSFN subframes		MBSFN subframes on a carrier supporting PDSCH
	Subframes 1 and 6 in case of frame structure type 2	All other cases	
Normal	1	1	1
Extended	2	3	2

Petitioners' Exhibit 1003, p. 1171
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.10 Reference signals

Six types of downlink reference signals are defined:

- Cell-specific Reference Signal (CRS)
- MBSFN reference signal
- UE-specific Reference Signal (DM-RS) associated with PDSCH
- DeModulation Reference Signal (DM-RS) associated with EPDCCH or MPDCCH
- Positioning Reference Signal (PRS)
- CSI Reference Signal (CSI-RS)

There is one reference signal transmitted per downlink antenna port.

6.10.1 Cell-specific Reference Signal (CRS)

The UE may assume cell-specific reference signals are, unless otherwise stated in [4, clause 12], transmitted in

- all downlink subframes for frame structure type 1,
- all downlink subframes and DwPTS for frame structure type 2,
- non-empty subframes for frame structure type 3

in a cell supporting PDSCH transmission.

Cell-specific reference signals are transmitted on one or several of antenna ports 0 to 3.

Cell-specific reference signals are defined for $\Delta f = 15\,\text{kHz}$ only.

6.10.1.1 Sequence generation

The reference-signal sequence $r_{l,n_s}(m)$ is defined by

$$r_{l,n_s}(m) = \frac{1}{\sqrt{2}}(1-2\cdot c(2m)) + j\frac{1}{\sqrt{2}}(1-2\cdot c(2m+1)), \quad m = 0,1,...,2N_{\text{RB}}^{\max,\text{DL}} - 1$$

where n_s is the slot number within a radio frame and l is the OFDM symbol number within the slot. The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with $c_{\text{init}} = 2^{10}\cdot(7\cdot(n_s'+1)+l+1)\cdot(2\cdot N_{\text{ID}}^{\text{cell}}+1)+2\cdot N_{\text{ID}}^{\text{cell}}+N_{\text{CP}}$ at the start of each OFDM symbol where

$$n_s' = \begin{cases} 10\lfloor n_s/10 \rfloor + n_s \bmod 2 & \text{for frame structure type 3 when the CRS is part of a DRS} \\ n_s & \text{otherwise} \end{cases}$$

$$N_{\text{CP}} = \begin{cases} 1 & \text{for normal CP} \\ 0 & \text{for extended CP} \end{cases}$$

6.10.1.2 Mapping to resource elements

The reference signal sequence $r_{l,n_s}(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ used as reference symbols for antenna port p in slot n_s according to

$$a_{k,l}^{(p)} = r_{l,n_s}(m')$$

where

Petitioners' Exhibit 1003, p. 1172
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$k = 6m + (v + v_{\text{shift}}) \bmod 6$$
$$l = \begin{cases} 0, N_{\text{symb}}^{\text{DL}} - 3 & \text{if } p \in \{0,1\} \\ 1 & \text{if } p \in \{2,3\} \end{cases}$$
$$m = 0,1,\ldots,2 \cdot N_{\text{RB}}^{\text{DL}} - 1$$
$$m' = m + N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{DL}}$$

The variables v and v_{shift} define the position in the frequency domain for the different reference signals where v is given by

$$v = \begin{cases} 0 & \text{if } p = 0 \text{ and } l = 0 \\ 3 & \text{if } p = 0 \text{ and } l \neq 0 \\ 3 & \text{if } p = 1 \text{ and } l = 0 \\ 0 & \text{if } p = 1 \text{ and } l \neq 0 \\ 3(n_{\text{s}} \bmod 2) & \text{if } p = 2 \\ 3 + 3(n_{\text{s}} \bmod 2) & \text{if } p = 3 \end{cases}$$

The cell-specific frequency shift is given by $v_{\text{shift}} = N_{\text{ID}}^{\text{cell}} \bmod 6$.

Resource elements (k,l) used for transmission of cell-specific reference signals on any of the antenna ports in a slot shall not be used for any transmission on any other antenna port in the same slot and set to zero.

In an MBSFN subframe, cell-specific reference signals shall only be transmitted in the non-MBSFN region of the MBSFN subframe.

Figures 6.10.1.2-1 and 6.10.1.2-2 illustrate the resource elements used for reference signal transmission according to the above definition. The notation R_p is used to denote a resource element used for reference signal transmission on antenna port p.

Petitioners' Exhibit 1003, p. 1173
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

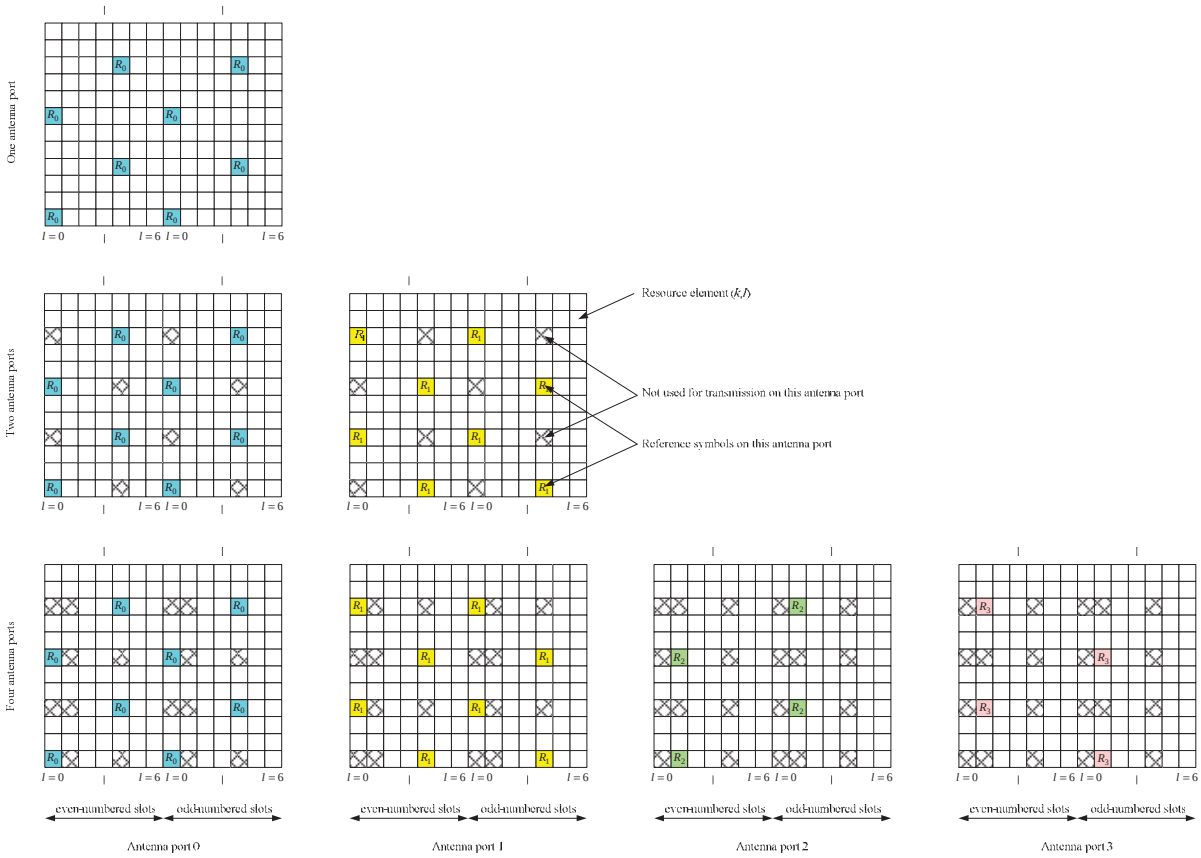


Figure 6.10.1.2-1. Mapping of downlink reference signals (normal cyclic prefix)

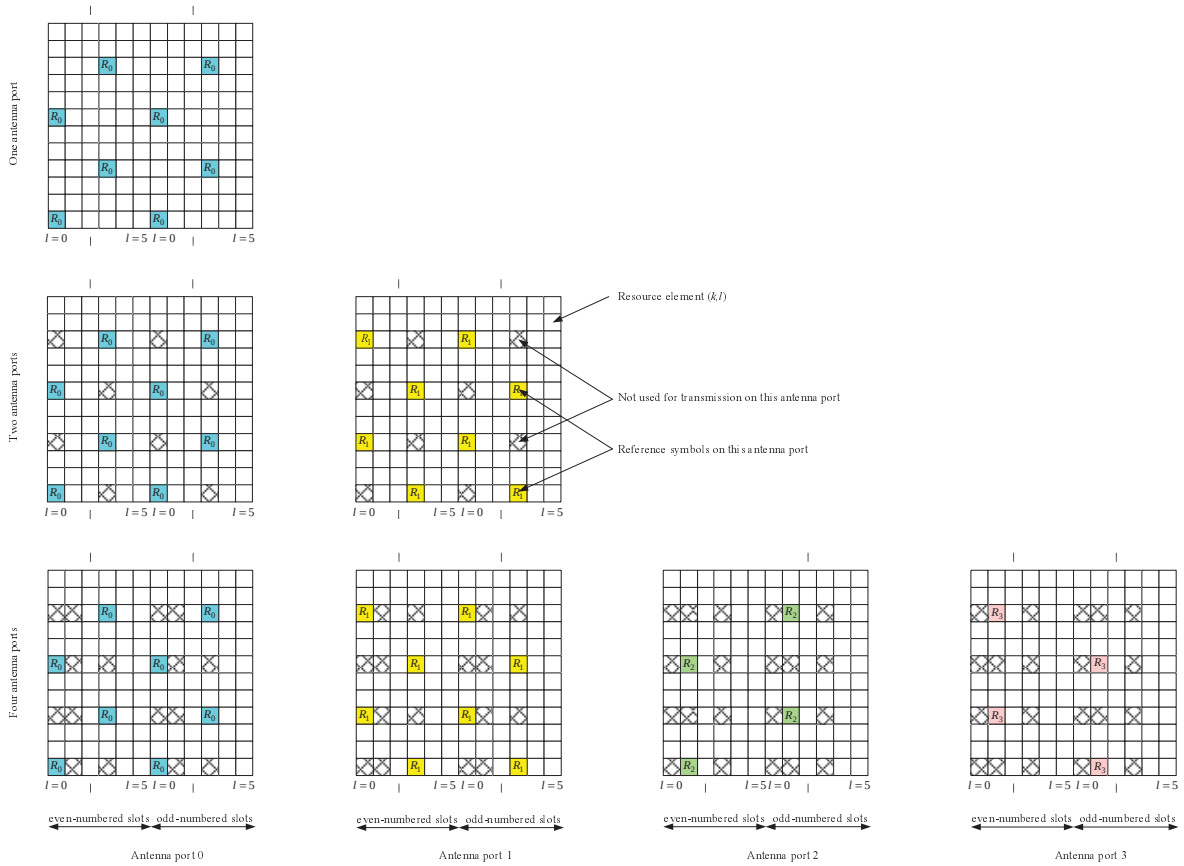


Figure 6.10.1.2-2. Mapping of downlink reference signals (extended cyclic prefix)

Petitioners' Exhibit 1003, p. 1175
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.10.2 MBSFN reference signals

MBSFN reference signals shall be transmitted in the MBSFN region of MBSFN subframes only when the PMCH is transmitted. MBSFN reference signals are transmitted on antenna port 4.

MBSFN reference signals are defined for extended cyclic prefix only.

6.10.2.1 Sequence generation

The MBSFN reference-signal sequence $r_{l,n_s}(m)$ is defined by

$$r_{l,n_s}(m) = \frac{1}{\sqrt{2}}\left(1-2\cdot c(2m)\right) + j\frac{1}{\sqrt{2}}\left(1-2\cdot c(2m+1)\right), \quad m = 0,1,\ldots,6N_{\text{RB}}^{\max,\text{DL}}-1$$

where n_s is the slot number within a radio frame and l is the OFDM symbol number within the slot. The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with $c_{\text{init}} = 2^9\cdot\left(7\cdot\left(n_s+1\right)+l+1\right)\cdot\left(2\cdot N_{\text{ID}}^{\text{MBSFN}}+1\right)+N_{\text{ID}}^{\text{MBSFN}}$ at the start of each OFDM symbol.

6.10.2.2 Mapping to resource elements

The reference-signal sequence $r_{l,n_s}(m')$ in OFDM symbol l shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ with $p=4$ according to

$$a_{k,l}^{(p)} = r_{l,n_s}(m')$$

where

$$k = \begin{cases} 2m & \text{if } l \neq 0 \text{ and } \Delta f = 15\text{ kHz} \\ 2m+1 & \text{if } l = 0 \text{ and } \Delta f = 15\text{ kHz} \\ 4m & \text{if } l \neq 0 \text{ and } \Delta f = 7.5\text{ kHz} \\ 4m+2 & \text{if } l = 0 \text{ and } \Delta f = 7.5\text{ kHz} \end{cases}$$

$$l = \begin{cases} 2 & \text{if } n_s \bmod 2 = 0 \text{ and } \Delta f = 15\text{ kHz} \\ 0,4 & \text{if } n_s \bmod 2 = 1 \text{ and } \Delta f = 15\text{ kHz} \\ 1 & \text{if } n_s \bmod 2 = 0 \text{ and } \Delta f = 7.5\text{ kHz} \\ 0,2 & \text{if } n_s \bmod 2 = 1 \text{ and } \Delta f = 7.5\text{ kHz} \end{cases}$$

$$m = 0,1,\ldots,6N_{\text{RB}}^{\text{DL}}-1$$

$$m' = m + 3\left(N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{DL}}\right)$$

Figure 6.10.2.2-1 illustrates the resource elements used for MBSFN reference signal transmission in case of $\Delta f = 15$ kHz. In case of $\Delta f = 7.5$ kHz for a MBSFN-dedicated cell, the MBSFN reference signal shall be mapped to resource elements according to Figure 6.10.2.2-3. The notation R_p is used to denote a resource element used for reference signal transmission on antenna port p.

Petitioners' Exhibit 1003, p. 1176
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

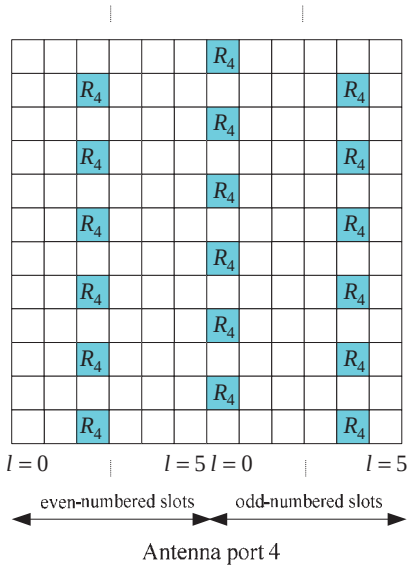


Figure 6.10.2.2-1: Mapping of MBSFN reference signals (extended cyclic prefix, $\Delta f = 15\,\text{kHz}$)

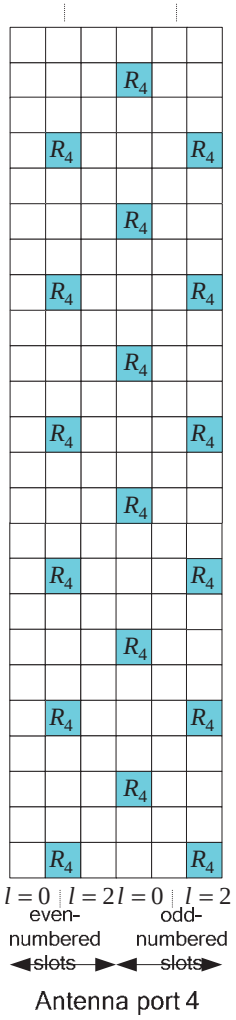


Figure 6.10.2.2-3: Mapping of MBSFN reference signals (extended cyclic prefix, $\Delta f = 7.5\,\text{kHz}$)

Petitioners' Exhibit 1003, p. 1177
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.10.3 UE-specific reference signals associated with PDSCH

UE-specific reference signals associated with PDSCH

- are transmitted on antenna port(s) $p=5$, $p=7$, $p=11$, $p=13$, $p=\{11,13\}$ or $p=7,8,...,\upsilon+6$, where υ is the number of layers used for transmission of the PDSCH;
- are present and are a valid reference for PDSCH demodulation only if the PDSCH transmission is associated with the corresponding antenna port according to clause 7.1 of 3GPP TS 36.213 [4];
- are transmitted only on the physical resource blocks upon which the corresponding PDSCH is mapped.

A UE-specific reference signal associated with PDSCH is not transmitted in resource elements (k,l) in which one of the physical channels or physical signals other than the UE-specific reference signals defined in 6.1 are transmitted using resource elements with the same index pair (k,l) regardless of their antenna port p.

6.10.3.1 Sequence generation

For antenna port 5, the UE-specific reference-signal sequence $r_{n_s}(m)$ is defined by

$$r_{n_s}(m)=\frac{1}{\sqrt{2}}(1-2\cdot c(2m))+j\frac{1}{\sqrt{2}}(1-2\cdot c(2m+1)),\qquad m=0,1,...,12N_{\mathrm{RB}}^{\mathrm{PDSCH}}-1$$

where $N_{\mathrm{RB}}^{\mathrm{PDSCH}}$ denotes the assigned bandwidth in resource blocks of the corresponding PDSCH transmission. The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with $c_{\mathrm{init}}=(\lfloor n_s/2\rfloor+1)\cdot(2N_{\mathrm{ID}}^{\mathrm{cell}}+1)\cdot 2^{16}+n_{\mathrm{RNTI}}$ at the start of each subframe where n_{RNTI} is as described in clause 7.1 3GPP TS 36.213 [4].

For any of the antenna ports $p\in\{7,8,...,\upsilon+6\}$, the reference-signal sequence $r(m)$ is defined by

$$r(m)=\frac{1}{\sqrt{2}}(1-2\cdot c(2m))+j\frac{1}{\sqrt{2}}(1-2\cdot c(2m+1)),\qquad m=\begin{cases}0,1,...,12N_{\mathrm{RB}}^{\max,\mathrm{DL}}-1 & \text{normal cyclic prefix}\\ 0,1,...,16N_{\mathrm{RB}}^{\max,\mathrm{DL}}-1 & \text{extended cyclic prefix}\end{cases}.$$

The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with

$$c_{\mathrm{init}}=(\lfloor n_s/2\rfloor+1)\cdot(2n_{\mathrm{ID}}^{(n_{\mathrm{SCID}})}+1)\cdot 2^{16}+n_{\mathrm{SCID}}$$

at the start of each subframe.

For BL/CE UEs, the same scrambling sequence is applied per subframe to the UE-specific reference-signal sequence for a given block of N_{acc} subframes. For the jth block of N_{acc} subframes, the scrambling sequence generator shall be initialised with

$$c_{\mathrm{init}}=([(j_0+j)N_{\mathrm{acc}}\bmod 10]+1)\cdot(2N_{\mathrm{ID}}^{\mathrm{cell}}+1)\cdot 2^{16}+n_{\mathrm{SCID}}$$

where

$$j=0,1,...,\left\lfloor\frac{i_0+N_{\mathrm{abs}}^{\mathrm{PDSCH}}+i_\Delta-1}{N_{\mathrm{acc}}}\right\rfloor-j_0$$

$$j_0=\lfloor(i_0+i_\Delta)/N_{\mathrm{acc}}\rfloor$$

$$i_\Delta=\begin{cases}0, & \text{for frame structure type 1}\\ N_{\mathrm{acc}}-2, & \text{for frame structure type 2}\end{cases}$$

Petitioners' Exhibit 1003, p. 1178
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

and i_0 is the absolute subframe number of the first downlink subframe intended for PDSCH. The PDSCH transmissions span $N_{\text{abs}}^{\text{PDSCH}}$ consecutive subframes, including invalid subframes where the PDSCH transmission is postponed. For a BL/CE UE configured in CEModeA, $N_{\text{acc}} = 1$. For a BL/CE UE configured with CEModeB, $N_{\text{acc}} = 4$ for frame structure type 1 and $N_{\text{acc}} = 10$ for frame structure type 2.

The quantities $n_{\text{ID}}^{(i)}$, $i = 0,1$, are given by

- $n_{\text{ID}}^{(i)} = N_{\text{ID}}^{\text{cell}}$ if no value for $n_{\text{ID}}^{\text{DMRS},i}$ is provided by higher layers or if DCI format 1A, 2B or 2C is used for the DCI associated with the PDSCH transmission
- $n_{\text{ID}}^{(i)} = n_{\text{ID}}^{\text{DMRS},i}$ otherwise

The value of n_{SCID} is zero unless specified otherwise. For a PDSCH transmission on ports 7 or 8, n_{SCID} is given by the DCI format 2B, 2C, 2D or 6-1A in 3GPP TS 36.212 [3] associated with the PDSCH transmission.
In the case of DCI format 2B, n_{SCID} is indicated by the scrambling identity field according to Table 6.10.3.1-1. In the case of DCI format 2C or 2D, n_{SCID} is given by Table 5.3.3.1.5C-1 or Table 5.3.3.1.5C-2 in 3GPP TS 36.212 [3]. For a PDSCH transmission on ports 11 or 13, n_{SCID} is given by the DCI format 2C or 2D in 3GPP TS 36.212 [3] associated with the PDSCH transmission where n_{SCID} is given by Table 5.3.3.1.5C-2 in 3GPP TS 36.212 [3].

Table 6.10.3.1-1: Mapping of scrambling identity field in DCI format 2B to n_{SCID} values for antenna ports 7 and 8

Scrambling identity field in DCI format 2B (3GPP TS 36.212 [3])	n_{SCID}
0	0
1	1

6.10.3.2 Mapping to resource elements

For antenna port 5, in a physical resource block with frequency-domain index n_{PRB} assigned for the corresponding PDSCH transmission, the reference signal sequence $r_{n_s}(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ with $p = 5$ in a subframe according to:

Normal cyclic prefix:

$$a_{k,l}^{(p)} = r_{n_s}(3 \cdot l' \cdot N_{\text{RB}}^{\text{PDSCH}} + m')$$

$$k = (k') \bmod N_{\text{sc}}^{\text{RB}} + N_{\text{sc}}^{\text{RB}} \cdot n_{\text{PRB}}$$

$$k' = \begin{cases} 4m' + v_{\text{shift}} & \text{if } l \in \{2,3\} \\ 4\text{m}' + (2 + v_{\text{shift}}) \bmod 4 & \text{if } l \in \{5,6\} \end{cases}$$

$$l = \begin{cases} 3 & l' = 0 \\ 6 & l' = 1 \\ 2 & l' = 2 \\ 5 & l' = 3 \end{cases}$$

$$l' = \begin{cases} 0,1 & \text{if } n_s \bmod 2 = 0 \\ 2,3 & \text{if } n_s \bmod 2 = 1 \end{cases}$$

$$m' = 0,1,\ldots,3N_{\text{RB}}^{\text{PDSCH}} - 1$$

Extended cyclic prefix:

$$a_{k,l}^{(p)} = r_{n_s}(4 \cdot l' \cdot N_{\text{RB}}^{\text{PDSCH}} + m')$$

Petitioners' Exhibit 1003, p. 1179
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$k = (k') \bmod N_{sc}^{RB} + N_{sc}^{RB} \cdot n_{PRB}$$

$$k' = \begin{cases} 3m' + v_{shift} & \text{if } l = 4 \\ 3m' + (2 + v_{shift}) \bmod 3 & \text{if } l = 1 \end{cases}$$

$$l = \begin{cases} 4 & l' \in \{0,2\} \\ 1 & l' = 1 \end{cases}$$

$$l' = \begin{cases} 0 & \text{if } n_s \bmod 2 = 0 \\ 1,2 & \text{if } n_s \bmod 2 = 1 \end{cases}$$

$$m' = 0,1,\ldots,4N_{RB}^{PDSCH} - 1$$

where m' is the counter of UE-specific reference signal resource elements within a respective OFDM symbol of the PDSCH transmission.

The cell-specific frequency shift is given by $v_{shift} = N_{ID}^{cell} \bmod 3$.

The mapping shall be in increasing order of the frequency-domain index n_{PRB} of the physical resource blocks assigned for the corresponding PDSCH transmission. The quantity N_{RB}^{PDSCH} denotes the assigned bandwidth in resource blocks of the corresponding PDSCH transmission.

Figure 6.10.3.2-1 illustrates the resource elements used for UE-specific reference signals for normal cyclic prefix for antenna port 5.

Figure 6.10.3.2-2 illustrates the resource elements used for UE-specific reference signals for extended cyclic prefix for antenna port 5.

The notation R_p is used to denote a resource element used for reference signal transmission on antenna port p.

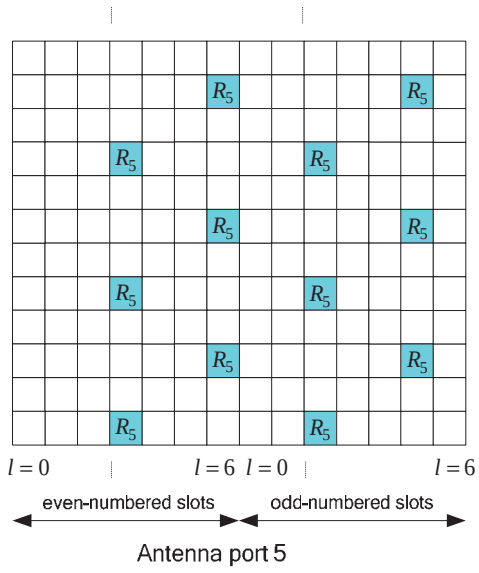


Figure 6.10.3.2-1: Mapping of UE-specific reference signals, antenna port 5 (normal cyclic prefix)

Petitioners' Exhibit 1003, p. 1180
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

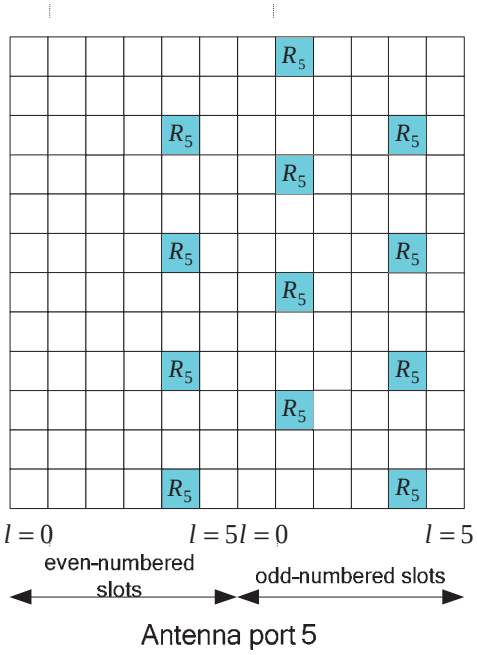


Figure 6.10.3.2-2: Mapping of UE-specific reference signals, antenna port 5 (extended cyclic prefix)

For antenna ports $p = 7$, $p = 8$, $p = 11$, $p = 13$, $p = \{11,13\}$ or $p = 7,8,\ldots,\upsilon+6$, in a physical resource block with frequency-domain index n_{PRB} assigned for the corresponding PDSCH transmission, a part of the reference signal sequence $r(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ in a subframe according to

Normal cyclic prefix:

$$a_{k,l}^{(p)} = w_p(l') \cdot r(3 \cdot l' \cdot N_{\text{RB}}^{\max,\text{DL}} + 3 \cdot n_{\text{PRB}} + m')$$

where

$$w_p(i) = \begin{cases} \overline{w}_p(i) & (m'+n_{\text{PRB}}) \bmod 2 = 0 \\ \overline{w}_p(3-i) & (m'+n_{\text{PRB}}) \bmod 2 = 1 \end{cases}$$

$$k = 5m' + N_{\text{sc}}^{\text{RB}} n_{\text{PRB}} + k'$$

$$k' = \begin{cases} 1 & p \in \{7,8,11,13\} \\ 0 & p \in \{9,10,12,14\} \end{cases}$$

$$l = \begin{cases} l' \bmod 2 + 2 & \text{if in a special subframe with configuration 3, 4, 8 or 9 (see Table 4.2-1)} \\ l' \bmod 2 + 2 + 3\lfloor l'/2 \rfloor & \text{if in a special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \\ l' \bmod 2 + 5 & \text{if not in a special subframe} \end{cases}$$

$$l' = \begin{cases} 0,1,2,3 & \text{if } n_s \bmod 2 = 0 \text{ and in a special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \\ 0,1 & \text{if } n_s \bmod 2 = 0 \text{ and not in special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \\ 2,3 & \text{if } n_s \bmod 2 = 1 \text{ and not in special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \end{cases}$$

$$m' = 0,1,2$$

The sequence $\overline{w}_p(i)$ is given by Table 6.10.3.2-1.

Petitioners' Exhibit 1003, p. 1181
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.10.3.2-1: The sequence $\overline{w}_p(i)$ for normal cyclic prefix

Antenna port p	$\left[\overline{w}_p(0) \quad \overline{w}_p(1) \quad \overline{w}_p(2) \quad \overline{w}_p(3)\right]$
7	$\left[+1 \quad +1 \quad +1 \quad +1\right]$
8	$\left[+1 \quad -1 \quad +1 \quad -1\right]$
9	$\left[+1 \quad +1 \quad +1 \quad +1\right]$
10	$\left[+1 \quad -1 \quad +1 \quad -1\right]$
11	$\left[+1 \quad +1 \quad -1 \quad -1\right]$
12	$\left[-1 \quad -1 \quad +1 \quad +1\right]$
13	$\left[+1 \quad -1 \quad -1 \quad +1\right]$
14	$\left[-1 \quad +1 \quad +1 \quad -1\right]$

Extended cyclic prefix:

$$a_{k,l'}^{(p)} = w_p(l' \bmod 2) \cdot r(4 \cdot l' \cdot N_{\mathrm{RB}}^{\max,\mathrm{DL}} + 4 \cdot n_{\mathrm{PRB}} + m')$$

where

$$w_p(i) = \begin{cases} \overline{w}_p(i) & m' \bmod 2 = 0 \\ \overline{w}_p(1-i) & m' \bmod 2 = 1 \end{cases}$$

$$k = 3m' + N_{\mathrm{sc}}^{\mathrm{RB}} n_{\mathrm{PRB}} + k'$$

$$k' = \begin{cases} 1 & \text{if } n_s \bmod 2 = 0 \text{ and } p \in \{7,8\} \\ 2 & \text{if } n_s \bmod 2 = 1 \text{ and } p \in \{7,8\} \end{cases}$$

$$l = l' \bmod 2 + 4$$

$$l' = \begin{cases} 0,1 & \text{if } n_s \bmod 2 = 0 \text{ and in a special subframe with configuration 1, 2, 3, 5 or 6 (see Table 4.2 - 1)} \\ 0,1 & \text{if } n_s \bmod 2 = 0 \text{ and not in a special subframe} \\ 2,3 & \text{if } n_s \bmod 2 = 1 \text{ and not in a special subframe} \end{cases}$$

$$m' = 0,1,2,3$$

The sequence $\overline{w}_p(i)$ is given by Table 6.10.3.2-2.

Table 6.10.3.2-2: The sequence $\overline{w}_p(i)$ for extended cyclic prefix

Antenna port p	$\left[\overline{w}_p(0) \quad \overline{w}_p(1)\right]$
7	$\left[+1 \quad +1\right]$
8	$\left[-1 \quad +1\right]$

For extended cyclic prefix, UE-specific reference signals are not supported on antenna ports 9 to 14.

Resource elements (k,l) used for transmission of UE-specific reference signals to one UE on any of the antenna ports in the set S, where $S = \{7,8,11,13\}$ or $S = \{9,10,12,14\}$ shall

- not be used for transmission of PDSCH on any antenna port in the same slot, and
- not be used for UE-specific reference signals to the same UE on any antenna port other than those in S in the same slot.

Figure 6.10.3.2-3 illustrates the resource elements used for UE-specific reference signals for normal cyclic prefix for antenna ports 7, 8, 9 and 10. Figure 6.10.3.2-4 illustrates the resource elements used for UE-specific reference signals for extended cyclic prefix for antenna ports 7, 8.

Petitioners' Exhibit 1003, p. 1182
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

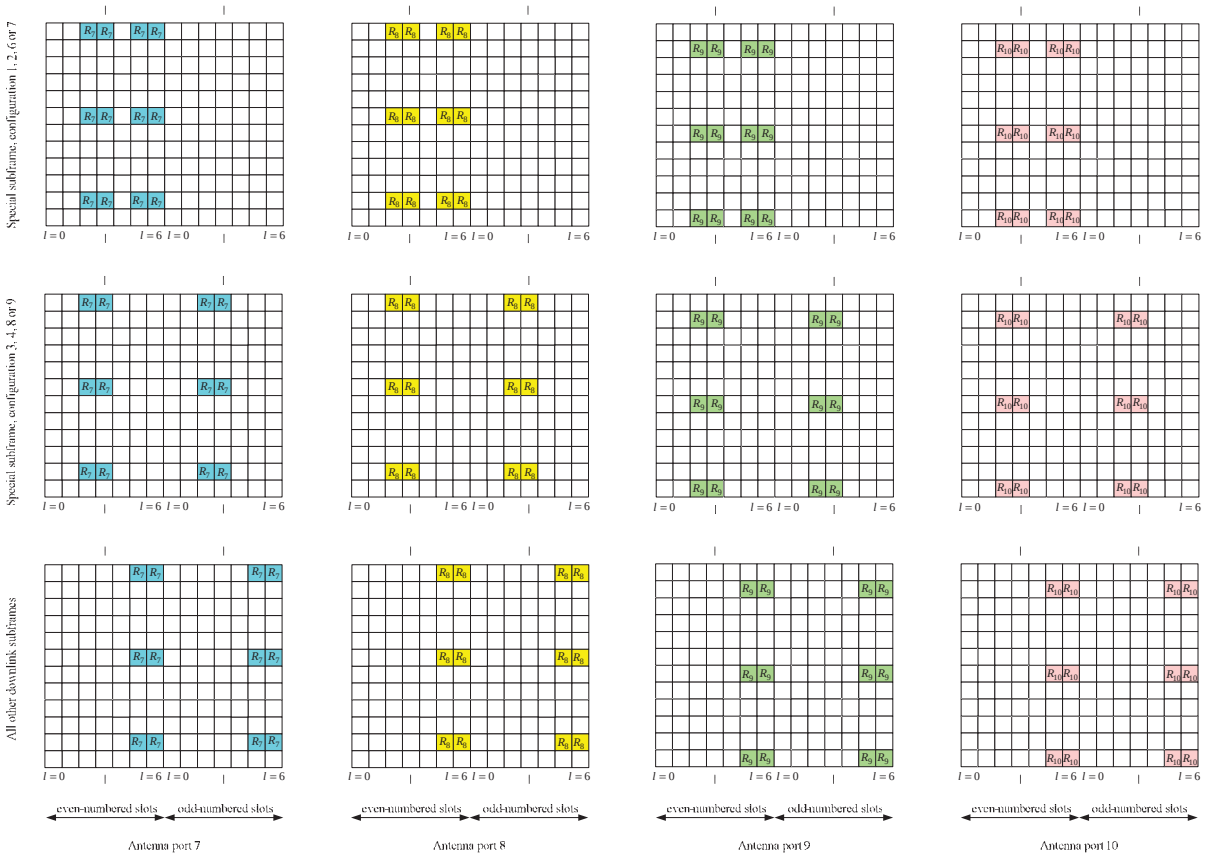


Figure 6.10.3.2-3: Mapping of UE-specific reference signals, antenna ports 7, 8, 9 and 10 (normal cyclic prefix)

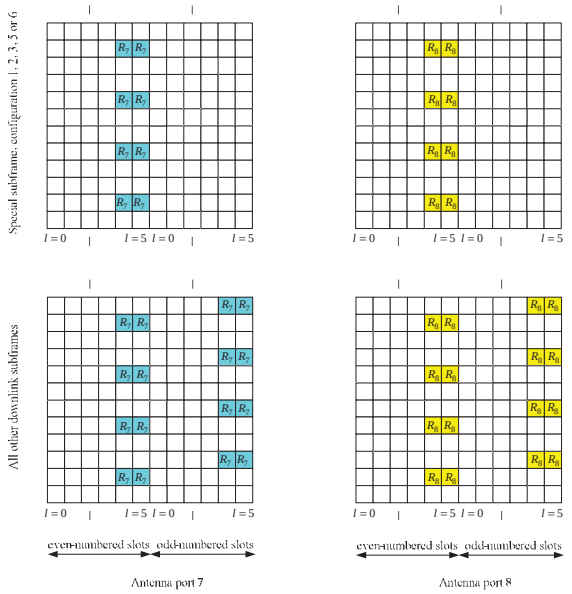


Figure 6.10.3.2-4: Mapping of UE-specific reference signals, antenna ports 7 and 8 (extended cyclic prefix)

Petitioners' Exhibit 1003, p. 1183
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.10.3A Demodulation reference signals associated with EPDCCH or MPDCCH

The demodulation reference signal associated with EPDCCH/MPDCCH

- is transmitted on the same antenna port $p \in \{107,108,109,110\}$ as the associated EPDCCH/MPDCCH physical resource;
- is present and is a valid reference for EPDCCH/MPDCCH demodulation only if the EPDCCH/MPDCCH transmission is associated with the corresponding antenna port;
- is transmitted only on the physical resource blocks upon which the corresponding EPDCCH/MPDCCH is mapped.

A demodulation reference signal associated with EPDCCH/MPDCCH is not transmitted in resource elements (k,l) in which one of the physical channels or physical signals other than the demodulation reference signals defined in 6.1 are transmitted using resource elements with the same index pair (k,l) regardless of their antenna port p.

6.10.3A.1 Sequence generation

For any of the antenna ports $p \in \{107,108,109,110\}$, the reference-signal sequence $r(m)$ is defined by

$$r(m) = \frac{1}{\sqrt{2}}(1-2\cdot c(2m)) + j\frac{1}{\sqrt{2}}(1-2\cdot c(2m+1)), \qquad m = \begin{cases} 0,1,\ldots,12N_{\text{RB}}^{\max,\text{DL}}-1 & \text{normal cyclic prefix} \\ 0,1,\ldots,16N_{\text{RB}}^{\max,\text{DL}}-1 & \text{extended cyclic prefix} \end{cases}.$$

For non-BL/CE UEs, the pseudo-random sequence $c(n)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with

$$c_{\text{init}} = (\lfloor n_{\text{s}}/2 \rfloor + 1)\cdot(2n_{\text{ID},i}^{\text{EPDCCH}} + 1)\cdot 2^{16} + n_{\text{SCID}}^{\text{EPDCCH}}$$

at the start of each subframe where $n_{\text{SCID}}^{\text{EPDCCH}} = 2$ and $n_{\text{ID},i}^{\text{EPDCCH}}$ is configured by higher layers. The EPDCCH set to which the EPDCCH associated with the demodulation reference signal belong is denoted $i \in \{0,1\}$.

For BL/CE UEs, the same scrambling sequence is applied per subframe to the demodulation reference signal associated with MPDCCH for a given block of N_{acc} subframes. For the jth block of N_{acc} subframes, the scrambling sequence generator shall be initialised with

$$c_{\text{init}} = \begin{cases} (\lfloor (j_0+j)N_{\text{acc}} \bmod 10 \rfloor + 1)\cdot(2N_{\text{ID},i}^{\text{MPDCCH}} + 1)\cdot 2^{16} + n_{\text{SCID}}^{\text{MPDCCH}} & \text{otherwise} \\ (\lfloor (j_0+j)N_{\text{acc}} \bmod 10 \rfloor + 1)\cdot(2N_{\text{ID}}^{\text{cell}} + 1)\cdot 2^{16} + n_{\text{SCID}}^{\text{MPDCCH}} & \text{for temporary C-RNTI} \end{cases}$$

where

$$j = 0,1,\ldots,\left\lfloor \frac{i_0 + N_{\text{abs}}^{\text{MPDCCH}} + i_\Delta - 1}{N_{\text{acc}}} \right\rfloor - j_0$$

$$j_0 = \lfloor (i_0 + i_\Delta)/N_{\text{acc}} \rfloor$$

$$i_\Delta = \begin{cases} 0, & \text{for frame structure type 1} \\ N_{\text{acc}} - 2, & \text{for frame structure type 2} \end{cases}$$

and i_0 is the absolute subframe number of the first downlink subframe intended for MPDCCH. The MPDCCH transmissions span $N_{\text{abs}}^{\text{MPDCCH}}$ consecutive subframes, including invalid subframes where the MPDCCH transmission is postponed. For a BL/CE UE configured with CEModeA, $N_{\text{acc}} = 1$. For a BL/CE UE configured with CEModeB, $N_{\text{acc}} = 4$ for frame structure type 1 and $N_{\text{acc}} = 10$ for frame structure type 2. The quantities $n_{\text{SCID}}^{\text{MPDCCH}} = 2$ and $n_{\text{ID},i}^{\text{MPDCCH}}$ are configured by higher layers. The MPDCCH set to which the MPDCCH associated with the demodulation

Petitioners' Exhibit 1003, p. 1184
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

reference signal belong is denoted $i \in \{0,1\}$. For an MPDCCH associated with a 2+4 PRB set as defined in [4], $i = 0$ is used to generate the scambling sequence for the 6 PRBs.

6.10.3A.2 Mapping to resource elements

For the antenna port $p \in \{107,108,109,110\}$ in a physical resource block n_{PRB} assigned for the associated EPDCCH/MPDCCH, a part of the reference signal sequence $r(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ in a subframe according to

Normal cyclic prefix:

$$a_{k,l}^{(p)} = w_p(l') \cdot r(3 \cdot l' \cdot N_{\text{RB}}^{\max,\text{DL}} + 3 \cdot n_{\text{PRB}} + m')$$

where

$$w_p(i) = \begin{cases} \overline{w}_p(i) & (m'+n_{\text{PRB}}) \bmod 2 = 0 \\ \overline{w}_p(3-i) & (m'+n_{\text{PRB}}) \bmod 2 = 1 \end{cases}$$

$$k = 5m' + N_{\text{sc}}^{\text{RB}} n_{\text{PRB}} + k'$$

$$k' = \begin{cases} 1 & p \in \{107,108\} \\ 0 & p \in \{109,110\} \end{cases}$$

$$l = \begin{cases} l' \bmod 2 + 2 & \text{if in a special subframe with configuration 3, 4, 8 or 9 (see Table 4.2-1)} \\ l' \bmod 2 + 2 + 3\lfloor l'/2 \rfloor & \text{if in a special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \\ l' \bmod 2 + 5 & \text{if not in a special subframe} \end{cases}$$

$$l' = \begin{cases} 0,1,2,3 & \text{if } n_s \bmod 2 = 0 \text{ and in a special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \\ 0,1 & \text{if } n_s \bmod 2 = 0 \text{ and not in special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \\ 2,3 & \text{if } n_s \bmod 2 = 1 \text{ and not in special subframe with configuration 1, 2, 6, or 7 (see Table 4.2-1)} \end{cases}$$

$$m' = 0,1,2$$

The sequence $\overline{w}_p(i)$ is given by Table 6.10.3A.2-1.

Table 6.10.3A.2-1: The sequence $\overline{w}_p(i)$ for normal cyclic prefix

Antenna port p	$[\overline{w}_p(0) \quad \overline{w}_p(1) \quad \overline{w}_p(2) \quad \overline{w}_p(3)]$
107	$[+1 \quad +1 \quad +1 \quad +1]$
108	$[+1 \quad -1 \quad +1 \quad -1]$
109	$[+1 \quad +1 \quad +1 \quad +1]$
110	$[+1 \quad -1 \quad +1 \quad -1]$

Extended cyclic prefix:

$$a_{k,l}^{(p)} = w_p(l' \bmod 2) \cdot r(4 \cdot l' \cdot N_{\text{RB}}^{\max,\text{DL}} + 4 \cdot n_{\text{PRB}} + m')$$

where

$$w_p(i) = \begin{cases} \overline{w}_p(i) & m' \bmod 2 = 0 \\ \overline{w}_p(1-i) & m' \bmod 2 = 1 \end{cases}$$

$$k = 3m' + N_{\text{sc}}^{\text{RB}} n_{\text{PRB}} + k'$$

$$k' = \begin{cases} 1 & \text{if } n_s \bmod 2 = 0 \text{ and } p \in \{107,108\} \\ 2 & \text{if } n_s \bmod 2 = 1 \text{ and } p \in \{107,108\} \end{cases}$$

$$l = l' \bmod 2 + 4$$

$$l' = \begin{cases} 0,1 & \text{if } n_s \bmod 2 = 0 \text{ and in a special subframe with configuration 1, 2, 3, 5 or 6 (see Table 4.2-1)} \\ 0,1 & \text{if } n_s \bmod 2 = 0 \text{ and not in a special subframe} \\ 2,3 & \text{if } n_s \bmod 2 = 1 \text{ and not in a special subframe} \end{cases}$$

$$m' = 0,1,2,3$$

Petitioners' Exhibit 1003, p. 1185
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The sequence $\overline{w}_p(i)$ is given by Table 6.10.3A.2-2.

Table 6.10.3A.2-2: The sequence $\overline{w}_p(i)$ for extended cyclic prefix

Antenna port p	$\left[\overline{w}_p(0) \quad \overline{w}_p(1)\right]$
107	$\left[+1 \quad +1\right]$
108	$\left[-1 \quad +1\right]$

For extended cyclic prefix, demodulation reference signals are not supported on antenna ports 109 to 110.

Resource elements (k,l) used for transmission of demodulation reference signals to one UE on any of the antenna ports in the set S, where $S=\{107,108\}$ or $S=\{109,110\}$ shall

- not be used for transmission of EPDCCH/MPDCCH on any antenna port in the same slot, and
- not be used for demodulation reference signals to the same UE on any antenna port other than those in S in the same slot.

Replacing antenna port numbers 7 – 10 by 107 – 110 in Figure 6.10.3.2-3 provides an illustration of the resource elements used for demodulation reference signals associated with EPDCCH/MPDCCH for normal cyclic prefix. Replacing antenna port numbers 7 – 8 by 107 – 108 in Figure 6.10.3.2-4 provides an illustration of the resource elements used for demodulation reference signals associated with EPDCCH/MPDCCH for extended cyclic prefix.

Petitioners' Exhibit 1003, p. 1186
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.10.4 Positioning reference signals

Positioning reference signals shall only be transmitted in resource blocks in downlink subframes configured for positioning reference signal transmission. If both normal and MBSFN subframes are configured as positioning subframes within a cell, the OFDM symbols in a MBSFN subframe configured for positioning reference signal transmission shall use the same cyclic prefix as used for subframe #0. If only MBSFN subframes are configured as positioning subframes within a cell, the OFDM symbols configured for positioning reference signals in the MBSFN region of these subframes shall use extended cyclic prefix length. In a subframe configured for positioning reference signal transmission, the starting positions of the OFDM symbols configured for positioning reference signal transmission shall be identical to those in a subframe in which all OFDM symbols have the same cyclic prefix length as the OFDM symbols configured for positioning reference signal transmission.

Positioning reference signals are transmitted on antenna port 6.

The positioning reference signals shall not be mapped to resource elements (k,l) allocated to the core part of the PBCH, PSS or SSS regardless of their antenna port p.

Positioning reference signals are defined for $\Delta f = 15\,\text{kHz}$ only.

6.10.4.1 Sequence generation

The reference-signal sequence $r_{l,n_s}(m)$ is defined by

$$r_{l,n_s}(m) = \frac{1}{\sqrt{2}}(1-2\cdot c(2m)) + j\frac{1}{\sqrt{2}}(1-2\cdot c(2m+1)), \quad m = 0,1,\ldots,2N_{\text{RB}}^{\max,\text{DL}} - 1$$

where n_s is the slot number within a radio frame, l is the OFDM symbol number within the slot. The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with $c_{\text{init}} = 2^{10}\cdot(7\cdot(n_s+1)+l+1)\cdot(2\cdot N_{\text{ID}}^{\text{cell}}+1)+2\cdot N_{\text{ID}}^{\text{cell}}+N_{\text{CP}}$ at the start of each OFDM symbol where

$$N_{\text{CP}} = \begin{cases} 1 & \text{for normal CP} \\ 0 & \text{for extended CP} \end{cases}$$

6.10.4.2 Mapping to resource elements

The reference signal sequence $r_{l,n_s}(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ used as reference signal for antenna port $p = 6$ in slot n_s according to

$$a_{k,l}^{(p)} = r_{l,n_s}(m')$$

where

Normal cyclic prefix:

$$k = 6\left(m + N_{\text{RB}}^{\text{DL}} - N_{\text{RB}}^{\text{PRS}}\right) + (6 - l + v_{\text{shift}}) \bmod 6$$

$$l = \begin{cases} 3,5,6 & \text{if } n_s \bmod 2 = 0 \\ 1,2,3,5,6 & \text{if } n_s \bmod 2 = 1 \text{ and } (1 \text{ or } 2 \text{ PBCH antenna ports}) \\ 2,3,5,6 & \text{if } n_s \bmod 2 = 1 \text{ and } (4 \text{ PBCH antenna ports}) \end{cases}$$

$$m = 0,1,\ldots,2\cdot N_{\text{RB}}^{\text{PRS}} - 1$$

$$m' = m + N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{PRS}}$$

Extended cyclic prefix:

Petitioners' Exhibit 1003, p. 1187
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$k = 6\left(m + N_{\mathrm{RB}}^{\mathrm{DL}} - N_{\mathrm{RB}}^{\mathrm{PRS}}\right) + \left(5 - l + v_{\mathrm{shift}}\right) \bmod 6$$

$$l = \begin{cases} 4,5 & \text{if } n_s \bmod 2 = 0 \\ 1,2,4,5 & \text{if } n_s \bmod 2 = 1 \text{ and } (1 \text{ or } 2 \text{ PBCH antenna ports}) \\ 2,4,5 & \text{if } n_s \bmod 2 = 1 \text{ and } (4 \text{ PBCH antenna ports}) \end{cases}$$

$$m = 0,1,\ldots,2 \cdot N_{\mathrm{RB}}^{\mathrm{PRS}} - 1$$

$$m' = m + N_{\mathrm{RB}}^{\mathrm{max,DL}} - N_{\mathrm{RB}}^{\mathrm{PRS}}$$

The bandwidth for positioning reference signals $N_{\mathrm{RB}}^{\mathrm{PRS}}$ is configured by higher layers and the cell-specific frequency shift is given by $v_{\mathrm{shift}} = N_{\mathrm{ID}}^{\mathrm{cell}} \bmod 6$.

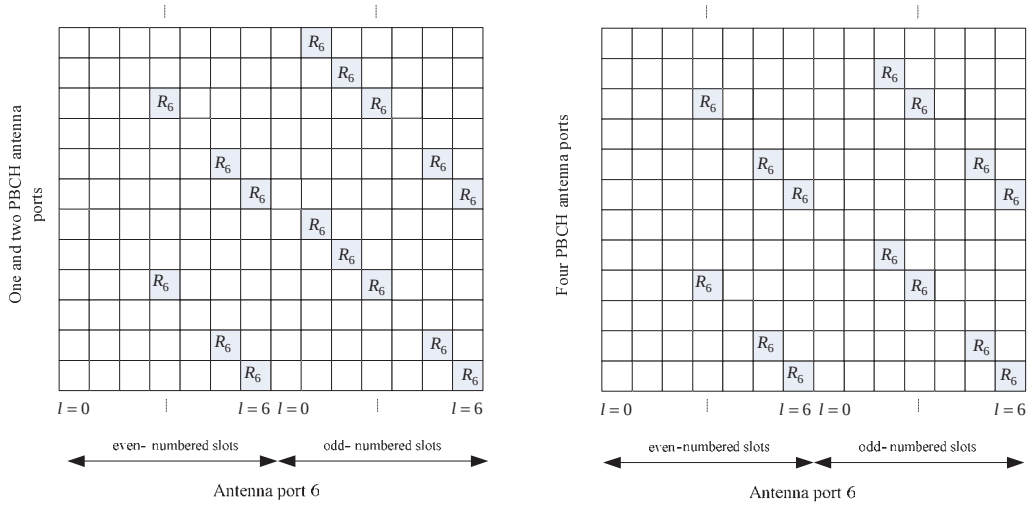


Figure 6.10.4.2-1: Mapping of positioning reference signals (normal cyclic prefix)

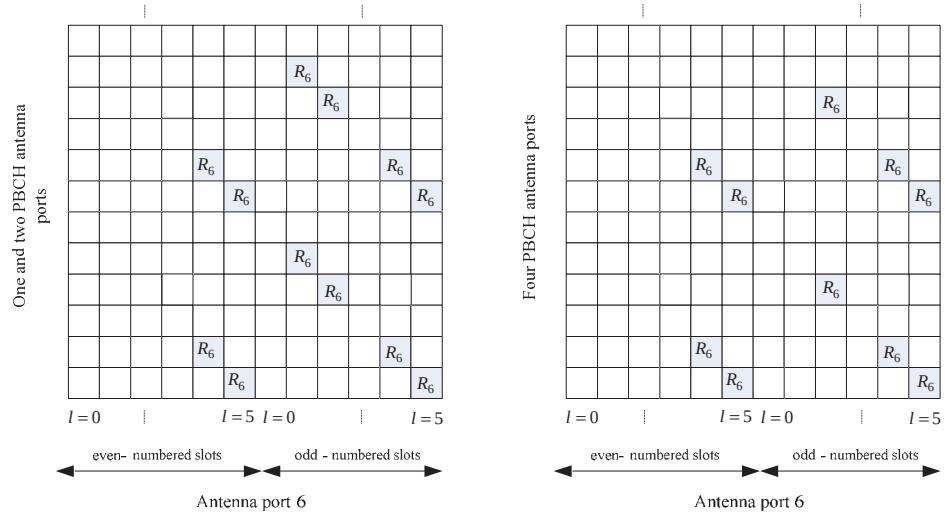


Figure 6.10.4.2-2: Mapping of positioning reference signals (extended cyclic prefix)

6.10.4.3 Positioning reference signal subframe configuration

The cell specific subframe configuration period T_{PRS} and the cell specific subframe offset Δ_{PRS} for the transmission of positioning reference signals are listed in Table 6.10.4.3-1. The PRS configuration index I_{PRS} is configured by higher layers. Positioning reference signals are transmitted only in configured DL subframes. Positioning reference signals

Petitioners' Exhibit 1003, p. 1188
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

shall not be transmitted in DwPTS. Positioning reference signals shall be transmitted in N_{PRS} consecutive downlink subframes, where N_{PRS} is configured by higher layers.

The positioning reference signal instances, for the first subframe of the N_{PRS} downlink subframes, shall satisfy $(10\times n_{\mathrm{f}} + \lfloor n_{\mathrm{s}}/2 \rfloor - \Delta_{\mathrm{PRS}}) \bmod T_{\mathrm{PRS}} = 0$.

Table 6.10.4.3-1: Positioning reference signal subframe configuration

PRS configuration Index I_{PRS}	PRS periodicity T_{PRS} (subframes)	PRS subframe offset Δ_{PRS} (subframes)
0 – 159	160	I_{PRS}
160 – 479	320	$I_{\mathrm{PRS}} - 160$
480 – 1119	640	$I_{\mathrm{PRS}} - 480$
1120 – 2399	1280	$I_{\mathrm{PRS}} - 1120$
2400-4095	Reserved	

Petitioners' Exhibit 1003, p. 1189
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.10.5 CSI reference signals

CSI reference signals are transmitted on one, two, four, eight, twelve, or sixteen antenna ports using $p=15$, $p=15,16$, $p=15,...,18$, $p=15,...,22$, $p=15,...,26$ and $p=15,...,30$, respectively.

For CSI reference signals using more than eight antenna ports, $N_{\text{res}}^{\text{CSI}}>1$ CSI-RS configurations in the same subframe, numbered from 0 to $N_{\text{res}}^{\text{CSI}}-1$, are aggregated to obtain $N_{\text{res}}^{\text{CSI}}N_{\text{ports}}^{\text{CSI}}$ antenna ports in total. Each CSI-RS configuration in such an aggregation corresponds to $N_{\text{ports}}^{\text{CSI}}\in\{4,8\}$ antenna ports and one of the configurations in Table 6.10.5.3-1 or 6.10.5.2-1 for normal cyclic prefix. The supported configurations of aggregated CSI-RS configurations are shown in Table 6.10.5-1.

CSI reference signals are defined for $\Delta f=15\,\text{kHz}$ only.

Table 6.10.5-1: Aggregation of CSI-RS configurations.

Total number of antenna ports $N_{\text{res}}^{\text{CSI}}N_{\text{ports}}^{\text{CSI}}$	Number of antenna ports per CSI-RS configuration $N_{\text{ports}}^{\text{CSI}}$	Number of CSI-RS configurations $N_{\text{res}}^{\text{CSI}}$
12	4	3
16	8	2

6.10.5.1 Sequence generation

The reference-signal sequence $r_{l,n_s}(m)$ is defined by

$$r_{l,n_s}(m)=\frac{1}{\sqrt{2}}(1-2\cdot c(2m))+j\frac{1}{\sqrt{2}}(1-2\cdot c(2m+1)),\quad m=0,1,...,N_{\text{RB}}^{\max,\text{DL}}-1$$

where n_s is the slot number within a radio frame and l is the OFDM symbol number within the slot. The pseudo-random sequence $c(i)$ is defined in clause 7.2. The pseudo-random sequence generator shall be initialised with $c_{\text{init}}=2^{10}\cdot(7\cdot(n_s'+1)+l+1)\cdot(2\cdot N_{\text{ID}}^{\text{CSI}}+1)+2\cdot N_{\text{ID}}^{\text{CSI}}+N_{\text{CP}}$ at the start of each OFDM symbol where

$$n_s'=\begin{cases}10\lfloor n_s/10\rfloor+n_s \bmod 2 & \text{for frame structure type 3 when the CSI - RS is part of a DRS}\\ n_s & \text{otherwise}\end{cases}$$

$$N_{\text{CP}}=\begin{cases}1 & \text{for normal CP}\\ 0 & \text{for extended CP}\end{cases}$$

The quantity $N_{\text{ID}}^{\text{CSI}}$ equals $N_{\text{ID}}^{\text{cell}}$ unless configured by higher layers.

6.10.5.2 Mapping to resource elements

In subframes configured for CSI reference signal transmission, the reference signal sequence $r_{l,n_s}(m)$ shall be mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ used as reference symbols on antenna port p. The mapping depends on the higher-layer parameter *CDMType*.

For the case of *CDMType* not equal to CDM4:

$$a_{k,l}^{(p')}=w_{l''}\cdot r_{l,n_s}(m')$$

where

Petitioners' Exhibit 1003, p. 1190
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$k = k' + 12m + \begin{cases} -0 & \text{for } p' \in \{15,16\}, \text{normal cyclic prefix} \\ -6 & \text{for } p' \in \{17,18\}, \text{normal cyclic prefix} \\ -1 & \text{for } p' \in \{19,20\}, \text{normal cyclic prefix} \\ -7 & \text{for } p' \in \{21,22\}, \text{normal cyclic prefix} \\ -0 & \text{for } p' \in \{15,16\}, \text{extended cyclic prefix} \\ -3 & \text{for } p' \in \{17,18\}, \text{extended cyclic prefix} \\ -6 & \text{for } p' \in \{19,20\}, \text{extended cyclic prefix} \\ -9 & \text{for } p' \in \{21,22\}, \text{extended cyclic prefix} \end{cases}$$

$$l = l' + \begin{cases} l'' & \text{CSI reference signal configurations 0 - 19, normal cyclic prefix} \\ 2l'' & \text{CSI reference signal configurations 20 - 31, normal cyclic prefix} \\ l'' & \text{CSI reference signal configurations 0 - 27, extended cyclic prefix} \end{cases}$$

$$w_{l''} = \begin{cases} 1 & p' \in \{15,17,19,21\} \\ (-1)^{l''} & p' \in \{16,18,20,22\} \end{cases}$$

$$l'' = 0,1$$

$$m = 0,1,\ldots, N_{\text{RB}}^{\text{DL}} - 1$$

$$m' = m + \left\lfloor \frac{N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{DL}}}{2} \right\rfloor$$

For the case of *CDMType* equal to *CDM4*:

$$a_{k,l}^{(p')} = w_{p'}(i) \cdot r_{l,n_s}(m')$$

where

$$k = k' + 12m - \begin{cases} k'' & \text{for } p' \in \{15,16,19,20\}, \text{normal cyclic prefix}, N_{\text{ports}}^{\text{CSI}} = 8 \\ k''+6 & \text{for } p' \in \{17,18,21,22\}, \text{normal cyclic prefix}, N_{\text{ports}}^{\text{CSI}} = 8 \\ 6k'' & \text{for } p' \in \{15,16,17,18\}, \text{normal cyclic prefix}, N_{\text{ports}}^{\text{CSI}} = 4 \end{cases}$$

$$l = l' + \begin{cases} l'' & \text{CSI reference signal configurations 0 - 19, normal cyclic prefix} \\ 2l'' & \text{CSI reference signal configurations 20 - 31, normal cyclic prefix} \end{cases}$$

$$l'' = 0,1$$

$$k'' = 0,1$$

$$i = 2k'' + l''$$

$$m = 0,1,\ldots, N_{\text{RB}}^{\text{DL}} - 1$$

$$m' = m + \left\lfloor \frac{N_{\text{RB}}^{\max,\text{DL}} - N_{\text{RB}}^{\text{DL}}}{2} \right\rfloor$$

and where $w_{p'}(i)$ is given by Table 6.10.5.2-0.

Petitioners' Exhibit 1003, p. 1191
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.10.5.2-0: The sequence $w_{p'}(i)$ for *CDM4*.

p'		$\left[w_{p'}(0) \quad w_{p'}(1) \quad w_{p'}(2) \quad w_{p'}(3)\right]$
$N_{\text{ports}}^{\text{CSI}} = 4$	$N_{\text{ports}}^{\text{CSI}} = 8$	
15	15,17	$\left[1 \quad 1 \quad 1 \quad 1\right]$
16	16,18	$\left[1 \quad -1 \quad 1 \quad -1\right]$
17	19,21	$\left[1 \quad 1 \quad -1 \quad -1\right]$
18	20,22	$\left[1 \quad -1 \quad -1 \quad 1\right]$

The quantity (k', l') and the necessary conditions on n_s are given by Tables 6.10.5.2-1 and 6.10.5.2-2 for normal and extended cyclic prefix, respectively.

The relation between the antenna port number p and the quantity p' depends on the number of CSI-RS antenna ports:

- for CSI reference signals using up to eight antenna ports, $p = p'$
- for CSI reference signals using more than eight antenna ports when the higher-layer parameter *CDMType* equals *CDM2*

$$p = \begin{cases} p' + \dfrac{N_{\text{ports}}^{\text{CSI}}}{2} i & \text{for } p' \in \left\{15,...,15 + N_{\text{ports}}^{\text{CSI}}/2 - 1\right\} \\ p' + \dfrac{N_{\text{ports}}^{\text{CSI}}}{2}\left(i + N_{\text{res}}^{\text{CSI}} - 1\right) & \text{for } p' \in \left\{15 + N_{\text{ports}}^{\text{CSI}}/2,...,15 + N_{\text{ports}}^{\text{CSI}} - 1\right\} \end{cases}$$

  where $i \in \left\{0,1,..., N_{\text{res}}^{\text{CSI}} - 1\right\}$ is the CSI-RS resource number.

- for CSI reference signals using more than eight antenna ports the higher-layer parameter *CDMType* equals *CDM4*, antenna port number $p = iN_{\text{ports}}^{\text{CSI}} + p'$ where $p' \in \left\{15,16,..,15 + N_{\text{ports}}^{\text{CSI}} - 1\right\}$ for CSI-RS resource number $i \in \left\{0,1,..., N_{\text{res}}^{\text{CSI}} - 1\right\}$.

Multiple CSI reference signal configurations can be used in a given cell. A UE can be configured with multiple sets of CSI reference signals,

- up to three configurations for CSI reporting for which the UE shall assume non-zero transmission power for the CSI-RS, and
- zero or more configurations for which the UE shall assume zero transmission power, and
- zero or more configurations valid across the system downlink bandwidth as part of the discovery signals for which the UE shall assume non-zero transmission power for the CSI-RS.

The CSI-RS configurations for which the UE shall assume non-zero transmission power are provided by higher layers.

The CSI-RS configurations for which the UE shall assume zero transmission power in a subframe are given by a bitmap derived according to clause 7.2.7 in 3GPP TS 36.213 [4]. For each bit set to one in the 16-bit bitmap, the UE shall assume zero transmission power for the resource elements corresponding to the four CSI reference signal column in Tables 6.10.5.2-1 and 6.10.5.2-2 for normal and extended cyclic prefix, respectively, except for resource elements that overlap with those for which the UE shall assume non-zero transmission power CSI-RS as configured by higher layers. The most significant bit corresponds to the lowest CSI reference signal configuration index and subsequent bits in the bitmap correspond to configurations with indices in increasing order.

CSI reference signals can only occur in

- downlink slots where $n_s \bmod 2$ fulfils the condition in Tables 6.10.5.2-1 and 6.10.5.2-2 for normal and extended cyclic prefix, respectively, and

Petitioners' Exhibit 1003, p. 1192
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- where the subframe number fulfils the conditions in clause 6.10.5.3.

The UE shall assume that CSI reference signals are not transmitted

- in the DwPTS for special subframe configuration 0, 5 and 9 for normal cyclic prefix and special subframe configuration 0, 4 and 7 for extended cyclic prefix, in case of frame structure type 2,
- in subframes where PDSCH/EPDCCH transmission starts in the second slot of a subframe for frame structure type 3,
- in subframes where PDSCH/EPDCCH transmission ends prior to the end of a subframe for frame structure type 3,
- in an empty subframe where there is no PDSCH or discovery signal transmission for frame structure type 3,
- in subframes where transmission of a CSI-RS would collide with *SystemInformationBlockType1* messages,
- in the primary cell in subframes configured for transmission of paging messages in the primary cell for any UE with the cell-specific paging configuration.

The UE shall assume that none of the CSI reference signals corresponding to a CSI reference signal configuration are transmitted in subframes where transmission of any of those CSI reference signals would collide with transmission of synchronization signals or the core part of PBCH.

Resource elements (k,l) used for transmission of CSI reference signals on any of the antenna ports in the set S, where $S=\{15\}$, $S=\{15,16\}$, $S=\{17,18\}$, $S=\{19,20\}$ or $S=\{21,22\}$ shall not be used for transmission of PDSCH on any antenna port in the same slot if higher layer parameter *CDMType* is not configured, or is configured to *CDM2*.

Resource elements (k,l) used for transmission of CSI reference signals on any of the antenna ports in the set S, where $S=\{15,16,17,18\}$, $S=\{19,20,21,22\}$ or $S=\{23,24,25,26\}$ for CSI reference signals on 12 ports or $S=\{15,16,19,20\}$, $S=\{17,18,21,22\}$, $S=\{23,24,27,28\}$ or $S=\{25,26,29,30\}$ for CSI reference signals on 16 ports shall not be used for transmission of PDSCH on any antenna port in the same slot if higher layer parameter *CDMType* is configured to *CDM4*.

The mapping for CSI reference signal configuration 0 is illustrated in Figures 6.10.5.2-1 and 6.10.5.2-2.

Petitioners' Exhibit 1003, p. 1193
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.10.5.2-1: Mapping from CSI reference signal configuration to (k',l') for normal cyclic prefix

CSI-RS config.	Number of CSI reference signals configured											
	1 or 2				4				8			
	Normal subframe		Special subframe		Normal subframe		Special subframe		Normal subframe		Special subframe	
	(k',l')	n_s'	(k',l')	n_s'	(k',l')	n_s'	(k',l')	n_s'	(k',l')	n_s'	(k',l')	n_s'
0	(9,5)	0	(9,5)	0	(9,5)	0	(9,5)	0	(9,5)	0	(9,5)	0
1	(11,2)	1	(11,5)	0	(11,2)	1	(11,5)	0	(11,2)	1	(11,5)	0
2	(9,2)	1	(9,2)	1	(9,2)	1	(9,2)	1	(9,2)	1	(9,2)	1
3	(7,2)	1	(7,5)	0	(7,2)	1	(7,5)	0	(7,2)	1	(7,5)	0
4	(9,5)	1			(9,5)	1			(9,5)	1		
5	(8,5)	0	(8,5)	0	(8,5)	0	(8,5)	0				
6	(10,2)	1	(10,5)	0	(10,2)	1	(10,5)	0				
7	(8,2)	1	(8,2)	1	(8,2)	1	(8,2)	1				
8	(6,2)	1	(6,5)	0	(6,2)	1	(6,5)	0				
9	(8,5)	1			(8,5)	1						
10	(3,5)	0	(3,5)	0								
11	(2,5)	0	(2,5)	0								
12	(5,2)	1	(5,5)	0								
13	(4,2)	1	(4,5)	0								
14	(3,2)	1	(3,2)	1								
15	(2,2)	1	(2,2)	1								
16	(1,2)	1	(1,5)	0								
17	(0,2)	1	(0,5)	0								
18	(3,5)	1										
19	(2,5)	1										
20	(11,1)	1			(11,1)	1			(11,1)	1		
21	(9,1)	1			(9,1)	1			(9,1)	1		
22	(7,1)	1			(7,1)	1			(7,1)	1		
23	(10,1)	1			(10,1)	1						
24	(8,1)	1			(8,1)	1						
25	(6,1)	1			(6,1)	1						
26	(5,1)	1										
27	(4,1)	1										
28	(3,1)	1										
29	(2,1)	1										
30	(1,1)	1										
31	(0,1)	1										

Note: $n_s' = n_s \bmod 2$. Configurations 0 – 19 for normal subframes are available for frame structure types 1, 2 and 3. Configurations 20 – 31 and configurations for special subframes are available for frame structure type 2 only.

Petitioners' Exhibit 1003, p. 1194
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 6.10.5.2-2: Mapping from CSI reference signal configuration to (k',l') for extended cyclic prefix.

CSI-RS config.	Number of CSI reference signals configured											
	1 or 2				4				8			
	Normal subframe		Special subframe		Normal subframe		Special subframe		Normal Subframe		Special subframe	
	(k',l')	n_s'	(k',l')	n_s'	(k',l')	n_s'	(k',l')	n_s'	(k',l')	n_s'	(k',l')	n_s'
0	(11,4)	0	(11,4)	0	(11,4)	0	(11,4)	0	(11,4)	0	(11,4)	0
1	(9,4)	0	(9,4)	0	(9,4)	0	(9,4)	0	(9,4)	0	(9,4)	0
2	(10,4)	1			(10,4)	1			(10,4)	1		
3	(9,4)	1			(9,4)	1			(9,4)	1		
4	(5,4)	0	(5,4)	0	(5,4)	0	(5,4)	0				
5	(3,4)	0	(3,4)	0	(3,4)	0	(3,4)	0				
6	(4,4)	1			(4,4)	1						
7	(3,4)	1			(3,4)	1						
8	(8,4)	0	(8,4)	0								
9	(6,4)	0	(6,4)	0								
10	(2,4)	0	(2,4)	0								
11	(0,4)	0	(0,4)	0								
12	(7,4)	1										
13	(6,4)	1										
14	(1,4)	1										
15	(0,4)	1										
16	(11,1)	1	(11,1)	1	(11,1)	1	(11,1)	1	(11,1)	1	(11,1)	1
17	(10,1)	1	(10,1)	1	(10,1)	1	(10,1)	1	(10,1)	1	(10,1)	1
18	(9,1)	1	(9,1)	1	(9,1)	1	(9,1)	1	(9,1)	1	(9,1)	1
19	(5,1)	1	(5,1)	1	(5,1)	1	(5,1)	1				
20	(4,1)	1	(4,1)	1	(4,1)	1	(4,1)	1				
21	(3,1)	1	(3,1)	1	(3,1)	1	(3,1)	1				
22	(8,1)	1	(8,1)	1								
23	(7,1)	1	(7,1)	1								
24	(6,1)	1	(6,1)	1								
25	(2,1)	1	(2,1)	1								
26	(1,1)	1	(1,1)	1								
27	(0,1)	1	(0,1)	1								

Note: $n_s' = n_s \bmod 2$. Configurations 0 – 15 for normal subframes are available for both frame structure type 1 and type 2. Configurations 16 – 27 and configurations for special subframes are available for frame structure type 2 only.

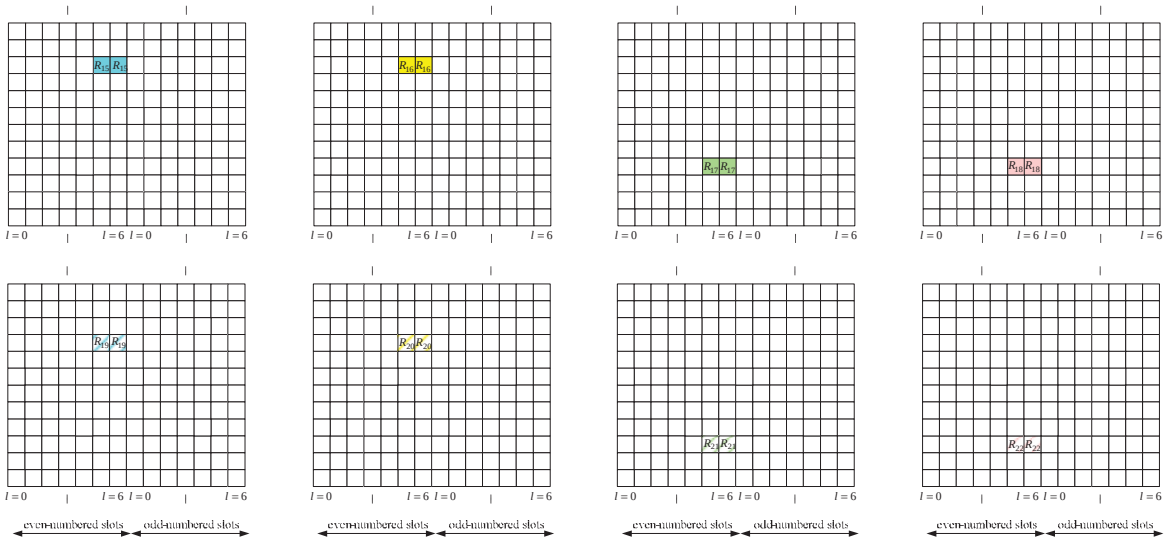


Figure 6.10.5.2-1: Mapping of CSI reference signals (CSI configuration 0, normal cyclic prefix)

Petitioners' Exhibit 1003, p. 1195
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

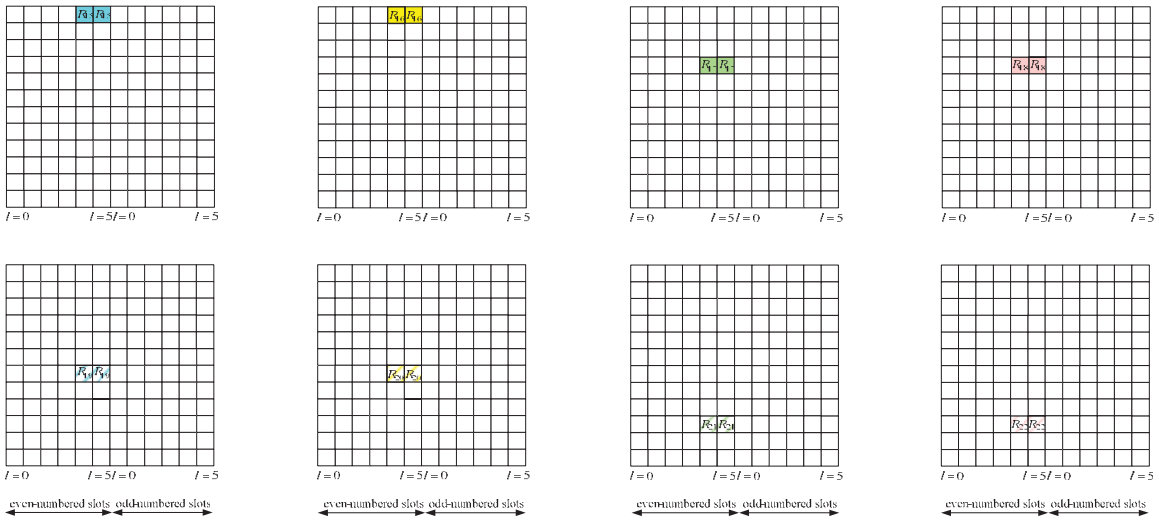


Figure 6.10.5.2-2: Mapping of CSI reference signals (CSI configuration 0, extended cyclic prefix)

6.10.5.3 CSI reference signal subframe configuration

The subframe configuration period $T_{\text{CSI-RS}}$ and the subframe offset $\Delta_{\text{CSI-RS}}$ for the occurence of CSI reference signals are listed in Table 6.10.5.3-1. The parameter $I_{\text{CSI-RS}}$ can be configured separately for CSI reference signals for which the UE shall assume non-zero and zero transmission power. Subframes containing CSI reference signals shall satisfy $(10n_{\text{f}} + \lfloor n_{\text{s}}/2 \rfloor - \Delta_{\text{CSI-RS}}) \bmod T_{\text{CSI-RS}} = 0$.

Table 6.10.5.3-1: CSI reference signal subframe configuration

CSI-RS-SubframeConfig $I_{\text{CSI-RS}}$	CSI-RS periodicity $T_{\text{CSI-RS}}$ (subframes)	CSI-RS subframe offset $\Delta_{\text{CSI-RS}}$ (subframes)
0 – 4	5	$I_{\text{CSI-RS}}$
5 – 14	10	$I_{\text{CSI-RS}} - 5$
15 – 34	20	$I_{\text{CSI-RS}} - 15$
35 – 74	40	$I_{\text{CSI-RS}} - 35$
75 – 154	80	$I_{\text{CSI-RS}} - 75$

Petitioners' Exhibit 1003, p. 1196
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.11 Synchronization signals

There are 504 unique physical-layer cell identities. The physical-layer cell identities are grouped into 168 unique physical-layer cell-identity groups, each group containing three unique identities. The grouping is such that each physical-layer cell identity is part of one and only one physical-layer cell-identity group. A physical-layer cell identity $N_{\mathrm{ID}}^{\mathrm{cell}} = 3N_{\mathrm{ID}}^{(1)} + N_{\mathrm{ID}}^{(2)}$ is thus uniquely defined by a number $N_{\mathrm{ID}}^{(1)}$ in the range of 0 to 167, representing the physical-layer cell-identity group, and a number $N_{\mathrm{ID}}^{(2)}$ in the range of 0 to 2, representing the physical-layer identity within the physical-layer cell-identity group.

6.11.1 Primary synchronization signal (PSS)

6.11.1.1 Sequence generation

The sequence $d(n)$ used for the primary synchronization signal is generated from a frequency-domain Zadoff-Chu sequence according to

$$d_u(n) = \begin{cases} e^{-j\frac{\pi u n(n+1)}{63}} & n = 0,1,\ldots,30 \\ e^{-j\frac{\pi u (n+1)(n+2)}{63}} & n = 31,32,\ldots,61 \end{cases}$$

where the Zadoff-Chu root sequence index u is given by Table 6.11.1.1-1.

Table 6.11.1.1-1: Root indices for the primary synchronization signal

$N_{\mathrm{ID}}^{(2)}$	**Root index** u
0	25
1	29
2	34

6.11.1.2 Mapping to resource elements

The mapping of the sequence to resource elements depends on the frame structure. The UE shall not assume that the primary synchronization signal is transmitted on the same antenna port as any of the downlink reference signals. The UE shall not assume that any transmission instance of the primary synchronization signal is transmitted on the same antenna port, or ports, used for any other transmission instance of the primary synchronization signal.

The sequence $d(n)$ shall be mapped to the resource elements according to

$$a_{k,l} = d(n), \qquad n = 0,\ldots,61$$
$$k = n - 31 + \frac{N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}}{2}$$

For frame structure type 1, the primary synchronization signal shall be mapped to the last OFDM symbol in slots 0 and 10.

For frame structure type 2, the primary synchronization signal shall be mapped to the third OFDM symbol in subframes 1 and 6. Resource elements (k,l) in the OFDM symbols used for transmission of the primary synchronization signal where

$$k = n - 31 + \frac{N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}}{2}$$
$$n = -5,-4,\ldots,-1,62,63,\ldots 66$$

are reserved and not used for transmission of the primary synchronization signal.

Petitioners' Exhibit 1003, p. 1197
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

For frame structure type 3, the primary synchronization signal shall be mapped according to frame structure type 1 with the following exceptions:

- the primary synchronization signal shall be transmitted only if the corresponding subframe is non-empty and at least 12 OFDM symbols are transmitted,
- a primary synchronization signal being part of a discovery signal shall be transmitted in the last OFDM symbol of the first slot of a discovery signal occasion.

6.11.2 Secondary synchronization signal (SSS)

6.11.2.1 Sequence generation

The sequence $d(0),...,d(61)$ used for the second synchronization signal is an interleaved concatenation of two length-31 binary sequences. The concatenated sequence is scrambled with a scrambling sequence given by the primary synchronization signal.

The combination of two length-31 sequences defining the secondary synchronization signal differs between subframes according to

$$d(2n) = \begin{cases} s_0^{(m_0)}(n)c_0(n) & \text{in subframes } 0, 1, 2, 3, 4 \\ s_1^{(m_1)}(n)c_0(n) & \text{in subframes } 5, 6, 7, 8, 9 \end{cases}$$
$$d(2n+1) = \begin{cases} s_1^{(m_1)}(n)c_1(n)z_1^{(m_0)}(n) & \text{in subframes } 0, 1, 2, 3, 4 \\ s_0^{(m_0)}(n)c_1(n)z_1^{(m_1)}(n) & \text{in subframes } 5, 6, 7, 8, 9 \end{cases}$$

where $0 \le n \le 30$. The indices m_0 and m_1 are derived from the physical-layer cell-identity group $N_{\mathrm{ID}}^{(1)}$ according to

$$m_0 = m' \bmod 31$$
$$m_1 = (m_0 + \lfloor m'/31 \rfloor + 1) \bmod 31$$
$$m' = N_{\mathrm{ID}}^{(1)} + q(q+1)/2, \quad q = \left\lfloor \frac{N_{\mathrm{ID}}^{(1)} + q'(q'+1)/2}{30} \right\rfloor, \quad q' = \lfloor N_{\mathrm{ID}}^{(1)}/30 \rfloor$$

where the output of the above expression is listed in Table 6.11.2.1-1.

The two sequences $s_0^{(m_0)}(n)$ and $s_1^{(m_1)}(n)$ are defined as two different cyclic shifts of the m-sequence $\tilde{s}(n)$ according to

$$s_0^{(m_0)}(n) = \tilde{s}((n + m_0) \bmod 31)$$
$$s_1^{(m_1)}(n) = \tilde{s}((n + m_1) \bmod 31)$$

where $\tilde{s}(i) = 1 - 2x(i)$, $0 \le i \le 30$, is defined by

$$x(\bar{i} + 5) = (x(\bar{i} + 2) + x(\bar{i})) \bmod 2, \qquad 0 \le \bar{i} \le 25$$

with initial conditions $x(0) = 0, \quad x(1) = 0, \quad x(2) = 0, \quad x(3) = 0, \quad x(4) = 1$.

The two scrambling sequences $c_0(n)$ and $c_1(n)$ depend on the primary synchronization signal and are defined by two different cyclic shifts of the m-sequence $\tilde{c}(n)$ according to

$$c_0(n) = \tilde{c}((n + N_{\mathrm{ID}}^{(2)}) \bmod 31)$$
$$c_1(n) = \tilde{c}((n + N_{\mathrm{ID}}^{(2)} + 3) \bmod 31)$$

Petitioners' Exhibit 1003, p. 1198
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

where $N_{\mathrm{ID}}^{(2)} \in \{0,1,2\}$ is the physical-layer identity within the physical-layer cell identity group $N_{\mathrm{ID}}^{(1)}$ and $\tilde{c}(i) = 1 - 2x(i)$, $0 \le i \le 30$, is defined by

$$x(\bar{i}+5) = \left(x(\bar{i}+3) + x(\bar{i})\right) \bmod 2, \qquad 0 \le \bar{i} \le 25$$

with initial conditions $x(0) = 0, \quad x(1) = 0, \quad x(2) = 0, \quad x(3) = 0, \quad x(4) = 1$.

The scrambling sequences $z_1^{(m_0)}(n)$ and $z_1^{(m_1)}(n)$ are defined by a cyclic shift of the m-sequence $\tilde{z}(n)$ according to

$$z_1^{(m_0)}(n) = \tilde{z}((n + (m_0 \bmod 8)) \bmod 31)$$

$$z_1^{(m_1)}(n) = \tilde{z}((n + (m_1 \bmod 8)) \bmod 31)$$

where m_0 and m_1 are obtained from Table 6.11.2.1-1 and $\tilde{z}(i) = 1 - 2x(i)$, $0 \le i \le 30$, is defined by

$$x(\bar{i}+5) = \left(x(\bar{i}+4) + x(\bar{i}+2) + x(\bar{i}+1) + x(\bar{i})\right) \bmod 2, \qquad 0 \le \bar{i} \le 25$$

with initial conditions $x(0) = 0, \quad x(1) = 0, \quad x(2) = 0, \quad x(3) = 0, \quad x(4) = 1$.

Table 6.11.2.1-1: Mapping between physical-layer cell-identity group $N_{\mathrm{ID}}^{(1)}$ and the indices m_0 and m_1

$N_{\mathrm{ID}}^{(1)}$	m_0	m_1	$N_{\mathrm{ID}}^{(1)}$	m_0	m_1	$N_{\mathrm{ID}}^{(1)}$	m_0	m_1	$N_{\mathrm{ID}}^{(1)}$	m_0	m_1	$N_{\mathrm{ID}}^{(1)}$	m_0	m_1
0	0	1	34	4	6	68	9	12	102	15	19	136	22	27
1	1	2	35	5	7	69	10	13	103	16	20	137	23	28
2	2	3	36	6	8	70	11	14	104	17	21	138	24	29
3	3	4	37	7	9	71	12	15	105	18	22	139	25	30
4	4	5	38	8	10	72	13	16	106	19	23	140	0	6
5	5	6	39	9	11	73	14	17	107	20	24	141	1	7
6	6	7	40	10	12	74	15	18	108	21	25	142	2	8
7	7	8	41	11	13	75	16	19	109	22	26	143	3	9
8	8	9	42	12	14	76	17	20	110	23	27	144	4	10
9	9	10	43	13	15	77	18	21	111	24	28	145	5	11
10	10	11	44	14	16	78	19	22	112	25	29	146	6	12
11	11	12	45	15	17	79	20	23	113	26	30	147	7	13
12	12	13	46	16	18	80	21	24	114	0	5	148	8	14
13	13	14	47	17	19	81	22	25	115	1	6	149	9	15
14	14	15	48	18	20	82	23	26	116	2	7	150	10	16
15	15	16	49	19	21	83	24	27	117	3	8	151	11	17
16	16	17	50	20	22	84	25	28	118	4	9	152	12	18
17	17	18	51	21	23	85	26	29	119	5	10	153	13	19
18	18	19	52	22	24	86	27	30	120	6	11	154	14	20
19	19	20	53	23	25	87	0	4	121	7	12	155	15	21
20	20	21	54	24	26	88	1	5	122	8	13	156	16	22
21	21	22	55	25	27	89	2	6	123	9	14	157	17	23
22	22	23	56	26	28	90	3	7	124	10	15	158	18	24
23	23	24	57	27	29	91	4	8	125	11	16	159	19	25
24	24	25	58	28	30	92	5	9	126	12	17	160	20	26
25	25	26	59	0	3	93	6	10	127	13	18	161	21	27
26	26	27	60	1	4	94	7	11	128	14	19	162	22	28
27	27	28	61	2	5	95	8	12	129	15	20	163	23	29
28	28	29	62	3	6	96	9	13	130	16	21	164	24	30
29	29	30	63	4	7	97	10	14	131	17	22	165	0	7
30	0	2	64	5	8	98	11	15	132	18	23	166	1	8
31	1	3	65	6	9	99	12	16	133	19	24	167	2	9
32	2	4	66	7	10	100	13	17	134	20	25	-	-	-
33	3	5	67	8	11	101	14	18	135	21	26	-	-	-

Petitioners' Exhibit 1003, p. 1199
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.11.2.2 Mapping to resource elements

The mapping of the sequence to resource elements depends on the frame structure. In a subframe for frame structure type 1 and 3 and in a half-frame for frame structure type 2, the same antenna port as for the primary synchronization signal shall be used for the secondary synchronization signal.

The sequence $d(n)$ shall be mapped to resource elements according to

$$a_{k,l} = d(n), \qquad n = 0,\ldots,61$$

$$k = n - 31 + \frac{N_{\text{RB}}^{\text{DL}} N_{\text{sc}}^{\text{RB}}}{2}$$

$$l = \begin{cases} N_{\text{symb}}^{\text{DL}} - 2 & \text{in slots 0 and 10} \quad \text{for frame structure type 1} \\ N_{\text{symb}}^{\text{DL}} - 1 & \text{in slots 1 and 11} \quad \text{for frame structure type 2} \\ N_{\text{symb}}^{\text{DL}} - 2 & \text{in slots where the PSS is transmitted} \quad \text{for frame structure type 3} \end{cases}$$

Resource elements (k,l) where

$$k = n - 31 + \frac{N_{\text{RB}}^{\text{DL}} N_{\text{sc}}^{\text{RB}}}{2}$$

$$l = \begin{cases} N_{\text{symb}}^{\text{DL}} - 2 & \text{in slots 0 and 10} \quad \text{for frame structure type 1} \\ N_{\text{symb}}^{\text{DL}} - 1 & \text{in slots 1 and 11} \quad \text{for frame structure type 2} \\ N_{\text{symb}}^{\text{DL}} - 2 & \text{in slots where the PSS is transmitted} \quad \text{for frame structure type 3} \end{cases}$$

$$n = -5,-4,\ldots,-1,62,63,\ldots 66$$

are reserved and not used for transmission of the secondary synchronization signal.

6.11A Discovery signal

A discovery signal occasion for a cell consists of a period with a duration of

- one to five consecutive subframes for frame structure type 1
- two to five consecutive subframes for frame structure type 2
- 12 OFDM symbols within one non-empty subframe for frame structure type 3

where the UE in the downlink subframes may assume presence of a discovery signal consisting of

- cell-specific reference signals on antenna port 0 in all downlink subframes and in DwPTS of all special subframes in the period,
- primary synchronization signal in the first subframe of the period for frame structure types 1 and 3 or the second subframe of the period for frame structure type 2,
- secondary synchronization signal in the first subframe of the period, and
- non-zero-power CSI reference signals in zero or more subframes in the period. The configuration of non-zero-power CSI reference signals part of the discovery signal is obtained as described in clause 6.10.5.2

For frame structures 1 and 2 the UE may assume a discovery signal occasion once every *dmtc-Periodicity*.

For frame structure type 3, the UE may assume a discovery signal occasion may occur in any subframe within the discovery signals measurement timing configuration in clause 5.5.2.10 of [9].

For frame structure type 3, simultaneous transmission of a discovery signal and PDSCH/PDCCH/EPDCCH may occur in subframes 0 and 5 only.

Petitioners' Exhibit 1003, p. 1200
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

For frame structure type 3, the UE may assume that a discovery signal occasion occurs in the first subframe containing a primary synchronization signal, secondary synchronization signal and cell-specific reference signals within the discovery measurement timing configuration in clause 5.5.2.10 of [9].

Petitioners' Exhibit 1003, p. 1201
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.12 OFDM baseband signal generation

The time-continuous signal $s_l^{(p)}(t)$ on antenna port p in OFDM symbol l in a downlink slot is defined by

$$s_l^{(p)}(t) = \sum_{k=-\left\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}/2 \right\rfloor}^{-1} a_{k^{(-)},l}^{(p)} \cdot e^{j2\pi k\Delta f\left(t-N_{\mathrm{CP},l}T_{\mathrm{s}}\right)} + \sum_{k=1}^{\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}/2 \right\rceil} a_{k^{(+)},l}^{(p)} \cdot e^{j2\pi k\Delta f\left(t-N_{\mathrm{CP},l}T_{\mathrm{s}}\right)}$$

for $0 \le t < (N_{\mathrm{CP},l} + N) \times T_{\mathrm{s}}$ where $k^{(-)} = k + \left\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}/2 \right\rfloor$ and $k^{(+)} = k + \left\lfloor N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}/2 \right\rfloor - 1$. The variable N equals 2048 for $\Delta f = 15\,\mathrm{kHz}$ subcarrier spacing and 4096 for $\Delta f = 7.5\,\mathrm{kHz}$ subcarrier spacing.

The OFDM symbols in a slot shall be transmitted in increasing order of l, starting with $l = 0$, where OFDM symbol $l > 0$ starts at time $\sum_{l'=0}^{l-1}(N_{\mathrm{CP},l'} + N)T_{\mathrm{s}}$ within the slot. In case the first OFDM symbol(s) in a slot use normal cyclic prefix and the remaining OFDM symbols use extended cyclic prefix, the starting position the OFDM symbols with extended cyclic prefix shall be identical to those in a slot where all OFDM symbols use extended cyclic prefix. Thus there will be a part of the time slot between the two cyclic prefix regions where the transmitted signal is not specified.

Table 6.12-1 lists the value of $N_{\mathrm{CP},l}$ that shall be used. Note that different OFDM symbols within a slot in some cases have different cyclic prefix lengths.

Table 6.12-1: OFDM parameters

Configuration		Cyclic prefix length $N_{\mathrm{CP},l}$
Normal cyclic prefix	$\Delta f = 15\,\mathrm{kHz}$	160 for $l = 0$ 144 for $l = 1,2,...,6$
Extended cyclic prefix	$\Delta f = 15\,\mathrm{kHz}$	512 for $l = 0,1,...,5$
	$\Delta f = 7.5\,\mathrm{kHz}$	1024 for $l = 0,1,2$

6.13 Modulation and upconversion

Modulation and upconversion to the carrier frequency of the complex-valued OFDM baseband signal for each antenna port is shown in Figure 6.13-1. The filtering required prior to transmission is defined by the requirements in 3GPP TS 36.104 [6].

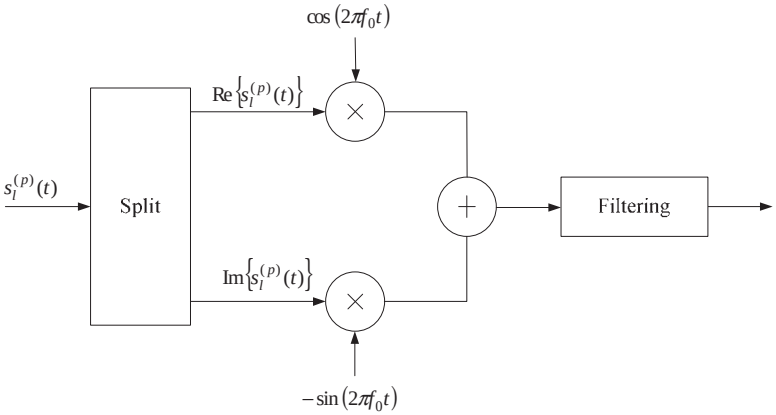


Figure 6.13-1: Downlink modulation

Petitioners' Exhibit 1003, p. 1202
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7 Generic functions

7.1 Modulation mapper

The modulation mapper takes binary digits, 0 or 1, as input and produces complex-valued modulation symbols, $x=I+jQ$, as output.

7.1.1 BPSK

In case of BPSK modulation, a single bit, $b(i)$, is mapped to a complex-valued modulation symbol $x=I+\mathrm{j}Q$ according to Table 7.1.1-1.

Table 7.1.1-1: BPSK modulation mapping

$b(i)$	*I*	*Q*
0	$1/\sqrt{2}$	$1/\sqrt{2}$
1	$-1/\sqrt{2}$	$-1/\sqrt{2}$

7.1.2 QPSK

In case of QPSK modulation, pairs of bits, $b(i), b(i+1)$, are mapped to complex-valued modulation symbols $x=I+\mathrm{j}Q$ according to Table 7.1.2-1.

Table 7.1.2-1: QPSK modulation mapping

$b(i), b(i+1)$	*I*	*Q*
00	$1/\sqrt{2}$	$1/\sqrt{2}$
01	$1/\sqrt{2}$	$-1/\sqrt{2}$
10	$-1/\sqrt{2}$	$1/\sqrt{2}$
11	$-1/\sqrt{2}$	$-1/\sqrt{2}$

Petitioners' Exhibit 1003, p. 1203
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.1.3 16QAM

In case of 16QAM modulation, quadruplets of bits, $b(i),b(i+1),b(i+2),b(i+3)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.3-1.

Table 7.1.3-1: 16QAM modulation mapping

$b(i),b(i+1),b(i+2),b(i+3)$	*I*	*Q*
0000	$1/\sqrt{10}$	$1/\sqrt{10}$
0001	$1/\sqrt{10}$	$3/\sqrt{10}$
0010	$3/\sqrt{10}$	$1/\sqrt{10}$
0011	$3/\sqrt{10}$	$3/\sqrt{10}$
0100	$1/\sqrt{10}$	$-1/\sqrt{10}$
0101	$1/\sqrt{10}$	$-3/\sqrt{10}$
0110	$3/\sqrt{10}$	$-1/\sqrt{10}$
0111	$3/\sqrt{10}$	$-3/\sqrt{10}$
1000	$-1/\sqrt{10}$	$1/\sqrt{10}$
1001	$-1/\sqrt{10}$	$3/\sqrt{10}$
1010	$-3/\sqrt{10}$	$1/\sqrt{10}$
1011	$-3/\sqrt{10}$	$3/\sqrt{10}$
1100	$-1/\sqrt{10}$	$-1/\sqrt{10}$
1101	$-1/\sqrt{10}$	$-3/\sqrt{10}$
1110	$-3/\sqrt{10}$	$-1/\sqrt{10}$
1111	$-3/\sqrt{10}$	$-3/\sqrt{10}$

Petitioners' Exhibit 1003, p. 1204
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.1.4 64QAM

In case of 64QAM modulation, hextuplets of bits, $b(i),b(i+1),b(i+2),b(i+3),b(i+4),b(i+5)$, are mapped to complex-valued modulation symbols $x=I+jQ$ according to Table 7.1.4-1.

Table 7.1.4-1: 64QAM modulation mapping

$b(i),b(i+1),b(i+2),b(i+3),b(i+4),b(i+5)$	I	Q	$b(i),b(i+1),b(i+2),b(i+3),b(i+4),b(i+5)$	I	Q
000000	$3/\sqrt{42}$	$3/\sqrt{42}$	100000	$-3/\sqrt{42}$	$3/\sqrt{42}$
000001	$3/\sqrt{42}$	$1/\sqrt{42}$	100001	$-3/\sqrt{42}$	$1/\sqrt{42}$
000010	$1/\sqrt{42}$	$3/\sqrt{42}$	100010	$-1/\sqrt{42}$	$3/\sqrt{42}$
000011	$1/\sqrt{42}$	$1/\sqrt{42}$	100011	$-1/\sqrt{42}$	$1/\sqrt{42}$
000100	$3/\sqrt{42}$	$5/\sqrt{42}$	100100	$-3/\sqrt{42}$	$5/\sqrt{42}$
000101	$3/\sqrt{42}$	$7/\sqrt{42}$	100101	$-3/\sqrt{42}$	$7/\sqrt{42}$
000110	$1/\sqrt{42}$	$5/\sqrt{42}$	100110	$-1/\sqrt{42}$	$5/\sqrt{42}$
000111	$1/\sqrt{42}$	$7/\sqrt{42}$	100111	$-1/\sqrt{42}$	$7/\sqrt{42}$
001000	$5/\sqrt{42}$	$3/\sqrt{42}$	101000	$-5/\sqrt{42}$	$3/\sqrt{42}$
001001	$5/\sqrt{42}$	$1/\sqrt{42}$	101001	$-5/\sqrt{42}$	$1/\sqrt{42}$
001010	$7/\sqrt{42}$	$3/\sqrt{42}$	101010	$-7/\sqrt{42}$	$3/\sqrt{42}$
001011	$7/\sqrt{42}$	$1/\sqrt{42}$	101011	$-7/\sqrt{42}$	$1/\sqrt{42}$
001100	$5/\sqrt{42}$	$5/\sqrt{42}$	101100	$-5/\sqrt{42}$	$5/\sqrt{42}$
001101	$5/\sqrt{42}$	$7/\sqrt{42}$	101101	$-5/\sqrt{42}$	$7/\sqrt{42}$
001110	$7/\sqrt{42}$	$5/\sqrt{42}$	101110	$-7/\sqrt{42}$	$5/\sqrt{42}$
001111	$7/\sqrt{42}$	$7/\sqrt{42}$	101111	$-7/\sqrt{42}$	$7/\sqrt{42}$
010000	$3/\sqrt{42}$	$-3/\sqrt{42}$	110000	$-3/\sqrt{42}$	$-3/\sqrt{42}$
010001	$3/\sqrt{42}$	$-1/\sqrt{42}$	110001	$-3/\sqrt{42}$	$-1/\sqrt{42}$
010010	$1/\sqrt{42}$	$-3/\sqrt{42}$	110010	$-1/\sqrt{42}$	$-3/\sqrt{42}$
010011	$1/\sqrt{42}$	$-1/\sqrt{42}$	110011	$-1/\sqrt{42}$	$-1/\sqrt{42}$
010100	$3/\sqrt{42}$	$-5/\sqrt{42}$	110100	$-3/\sqrt{42}$	$-5/\sqrt{42}$
010101	$3/\sqrt{42}$	$-7/\sqrt{42}$	110101	$-3/\sqrt{42}$	$-7/\sqrt{42}$
010110	$1/\sqrt{42}$	$-5/\sqrt{42}$	110110	$-1/\sqrt{42}$	$-5/\sqrt{42}$
010111	$1/\sqrt{42}$	$-7/\sqrt{42}$	110111	$-1/\sqrt{42}$	$-7/\sqrt{42}$
011000	$5/\sqrt{42}$	$-3/\sqrt{42}$	111000	$-5/\sqrt{42}$	$-3/\sqrt{42}$
011001	$5/\sqrt{42}$	$-1/\sqrt{42}$	111001	$-5/\sqrt{42}$	$-1/\sqrt{42}$
011010	$7/\sqrt{42}$	$-3/\sqrt{42}$	111010	$-7/\sqrt{42}$	$-3/\sqrt{42}$
011011	$7/\sqrt{42}$	$-1/\sqrt{42}$	111011	$-7/\sqrt{42}$	$-1/\sqrt{42}$
011100	$5/\sqrt{42}$	$-5/\sqrt{42}$	111100	$-5/\sqrt{42}$	$-5/\sqrt{42}$
011101	$5/\sqrt{42}$	$-7/\sqrt{42}$	111101	$-5/\sqrt{42}$	$-7/\sqrt{42}$
011110	$7/\sqrt{42}$	$-5/\sqrt{42}$	111110	$-7/\sqrt{42}$	$-5/\sqrt{42}$
011111	$7/\sqrt{42}$	$-7/\sqrt{42}$	111111	$-7/\sqrt{42}$	$-7/\sqrt{42}$

Petitioners' Exhibit 1003, p. 1205
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.1.5 256QAM

In case of 256QAM modulation, octuplets of bits, $b(i),b(i+1),b(i+2),b(i+3),b(i+4),b(i+5),b(i+6),b(i+7)$, are mapped to complex-valued modulation symbols $x=(I+jQ)/\sqrt{170}$ according to Table 7.1.5-1.

Petitioners' Exhibit 1003, p. 1206
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 7.1.5-1: 256QAM modulation mapping

$b(i),...,b(i+7)$	*I*	*Q*	$b(i),...,b(i+7)$	*I*	*Q*	$b(i),...,b(i+7)$	*I*	*Q*	$b(i),...,b(i+7)$	*I*	*Q*
00000000	5	5	01000000	5	-5	10000000	-5	5	11000000	-5	-5
00000001	5	7	01000001	5	-7	10000001	-5	7	11000001	-5	-7
00000010	7	5	01000010	7	-5	10000010	-7	5	11000010	-7	-5
00000011	7	7	01000011	7	-7	10000011	-7	7	11000011	-7	-7
00000100	5	3	01000100	5	-3	10000100	-5	3	11000100	-5	-3
00000101	5	1	01000101	5	-1	10000101	-5	1	11000101	-5	-1
00000110	7	3	01000110	7	-3	10000110	-7	3	11000110	-7	-3
00000111	7	1	01000111	7	-1	10000111	-7	1	11000111	-7	-1
00001000	3	5	01001000	3	-5	10001000	-3	5	11001000	-3	-5
00001001	3	7	01001001	3	-7	10001001	-3	7	11001001	-3	-7
00001010	1	5	01001010	1	-5	10001010	-1	5	11001010	-1	-5
00001011	1	7	01001011	1	-7	10001011	-1	7	11001011	-1	-7
00001100	3	3	01001100	3	-3	10001100	-3	3	11001100	-3	-3
00001101	3	1	01001101	3	-1	10001101	-3	1	11001101	-3	-1
00001110	1	3	01001110	1	-3	10001110	-1	3	11001110	-1	-3
00001111	1	1	01001111	1	-1	10001111	-1	1	11001111	-1	-1
00010000	5	11	01010000	5	-11	10010000	-5	11	11010000	-5	-11
00010001	5	9	01010001	5	-9	10010001	-5	9	11010001	-5	-9
00010010	7	11	01010010	7	-11	10010010	-7	11	11010010	-7	-11
00010011	7	9	01010011	7	-9	10010011	-7	9	11010011	-7	-9
00010100	5	13	01010100	5	-13	10010100	-5	13	11010100	-5	-13
00010101	5	15	01010101	5	-15	10010101	-5	15	11010101	-5	-15
00010110	7	13	01010110	7	-13	10010110	-7	13	11010110	-7	-13
00010111	7	15	01010111	7	-15	10010111	-7	15	11010111	-7	-15
00011000	3	11	01011000	3	-11	10011000	-3	11	11011000	-3	-11
00011001	3	9	01011001	3	-9	10011001	-3	9	11011001	-3	-9
00011010	1	11	01011010	1	-11	10011010	-1	11	11011010	-1	-11
00011011	1	9	01011011	1	-9	10011011	-1	9	11011011	-1	-9
00011100	3	13	01011100	3	-13	10011100	-3	13	11011100	-3	-13
00011101	3	15	01011101	3	-15	10011101	-3	15	11011101	-3	-15
00011110	1	13	01011110	1	-13	10011110	-1	13	11011110	-1	-13
00011111	1	15	01011111	1	-15	10011111	-1	15	11011111	-1	-15
00100000	11	5	01100000	11	-5	10100000	-11	5	11100000	-11	-5
00100001	11	7	01100001	11	-7	10100001	-11	7	11100001	-11	-7
00100010	9	5	01100010	9	-5	10100010	-9	5	11100010	-9	-5
00100011	9	7	01100011	9	-7	10100011	-9	7	11100011	-9	-7
00100100	11	3	01100100	11	-3	10100100	-11	3	11100100	-11	-3
00100101	11	1	01100101	11	-1	10100101	-11	1	11100101	-11	-1
00100110	9	3	01100110	9	-3	10100110	-9	3	11100110	-9	-3
00100111	9	1	01100111	9	-1	10100111	-9	1	11100111	-9	-1
00101000	13	5	01101000	13	-5	10101000	-13	5	11101000	-13	-5
00101001	13	7	01101001	13	-7	10101001	-13	7	11101001	-13	-7
00101010	15	5	01101010	15	-5	10101010	-15	5	11101010	-15	-5
00101011	15	7	01101011	15	-7	10101011	-15	7	11101011	-15	-7
00101100	13	3	01101100	13	-3	10101100	-13	3	11101100	-13	-3
00101101	13	1	01101101	13	-1	10101101	-13	1	11101101	-13	-1
00101110	15	3	01101110	15	-3	10101110	-15	3	11101110	-15	-3
00101111	15	1	01101111	15	-1	10101111	-15	1	11101111	-15	-1
00110000	11	11	01110000	11	-11	10110000	-11	11	11110000	-11	-11
00110001	11	9	01110001	11	-9	10110001	-11	9	11110001	-11	-9
00110010	9	11	01110010	9	-11	10110010	-9	11	11110010	-9	-11
00110011	9	9	01110011	9	-9	10110011	-9	9	11110011	-9	-9
00110100	11	13	01110100	11	-13	10110100	-11	13	11110100	-11	-13
00110101	11	15	01110101	11	-15	10110101	-11	15	11110101	-11	-15
00110110	9	13	01110110	9	-13	10110110	-9	13	11110110	-9	-13
00110111	9	15	01110111	9	-15	10110111	-9	15	11110111	-9	-15
00111000	13	11	01111000	13	-11	10111000	-13	11	11111000	-13	-11
00111001	13	9	01111001	13	-9	10111001	-13	9	11111001	-13	-9
00111010	15	11	01111010	15	-11	10111010	-15	11	11111010	-15	-11
00111011	15	9	01111011	15	-9	10111011	-15	9	11111011	-15	-9
00111100	13	13	01111100	13	-13	10111100	-13	13	11111100	-13	-13
00111101	13	15	01111101	13	-15	10111101	-13	15	11111101	-13	-15

Petitioners' Exhibit 1003, p. 1207
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

00111110	15	13	01111110	15	-13	10111110	-15	13	11111110	-15	-13
00111111	15	15	01111111	15	-15	10111111	-15	15	11111111	-15	-15

Petitioners' Exhibit 1003, p. 1208
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7.2 Pseudo-random sequence generation

Pseudo-random sequences are defined by a length-31 Gold sequence. The output sequence $c(n)$ of length M_{PN}, where $n = 0,1,...,M_{\text{PN}} - 1$, is defined by

$$c(n) = \left(x_1(n + N_C) + x_2(n + N_C)\right) \bmod 2$$
$$x_1(n + 31) = \left(x_1(n + 3) + x_1(n)\right) \bmod 2$$
$$x_2(n + 31) = \left(x_2(n + 3) + x_2(n + 2) + x_2(n + 1) + x_2(n)\right) \bmod 2$$

where $N_C = 1600$ and the first m-sequence shall be initialized with $x_1(0) = 1, x_1(n) = 0, n = 1,2,...,30$. The initialization of the second m-sequence is denoted by $c_{\text{init}} = \sum_{i=0}^{30} x_2(i) \cdot 2^i$ with the value depending on the application of the sequence.

8 Timing

8.1 Uplink-downlink frame timing

Transmission of the uplink radio frame number i from the UE shall start $(N_{\text{TA}} + N_{\text{TA offset}}) \times T_s$ seconds before the start of the corresponding downlink radio frame at the UE, where $0 \le N_{\text{TA}} \le 4096$ if the UE is configured with a SCG and $0 \le N_{\text{TA}} \le 20512$ otherwise. For frame structure type 1 $N_{\text{TA offset}} = 0$ and for frame structure type 2 $N_{\text{TA offset}} = 624$ unless stated otherwise in [4]. Note that not all slots in a radio frame may be transmitted. One example hereof is TDD, where only a subset of the slots in a radio frame is transmitted.

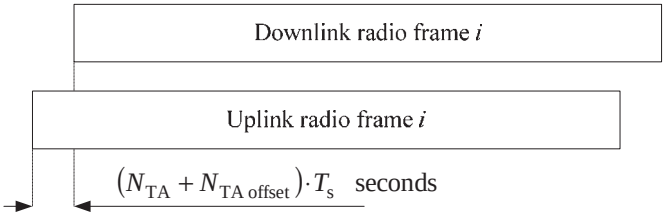


Figure 8.1-1: Uplink-downlink timing relation

9 Sidelink

9.1 Overview

A sidelink is used for ProSe direct communication and ProSe direct discovery between UEs.

9.1.1 Physical channels

A sidelink physical channel corresponds to a set of resource elements carrying information originating from higher layers and is the interface defined between 3GPP TS 36.212 [3] and the present document 3GPP TS 36.211. The following sidelink physical channels are defined:

Petitioners' Exhibit 1003, p. 1209
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Physical Sidelink Shared Channel, PSSCH
- Physical Sidelink Control Channel, PSCCH
- Physical Sidelink Discovery Channel, PSDCH
- Physical Sidelink Broadcast Channel, PSBCH

Generation of the baseband signal representing the different physical sidelink channels is illustrated in Figrue 5.3-1.

9.1.2 Physical signals

A sidelink physical signal is used by the physical layer but does not carry information originating from higher layers. The following sidelink physical signals are defined:

- Demodulation reference signal
- Synchronization signal

9.1.3 Handling of simultaneous sidelink and uplink/downlink transmissions

For a given frequency, on an uplink subframe included in *discTxGapConfig* [9], a UE shall not transmit an uplink transmission that is not a PRACH transmission and that is partly or completely overlapping in time with a PSDCH transmission or a SLSS transmission for PSDCH by the same UE. Else, for a given carrier frequency, a UE shall not transmit a sidelink signal or channel overlapping partly or completely in time with an uplink transmission from the same UE.

For a given carrier frequency, no PSDCH, PSCCH, or PSSCH transmission shall occur from a UE in a sidelink subframe configured for synchronization purposes by the higher-layer parameters

- *syncOffsetIndicator1* or *syncOffsetIndicator2* in [9] if the UE has no serving cell fulfilling the S criterion according to [10, clause 5.2.3.2], or
- *syncOffsetIndicator* in *commSyncConfig* or *discSyncConfig* which includes *txParameters* in [9] if the UE has a serving cell fulfilling the S criterion according to [10, clause 5.2.3.2]. The UE may assume the same configuration in *commSyncConfig* and *discSyncConfig*.

For a given carrier frequency, with the exception of PSSCH transmissions with transmission mode 1 and same sidelink cyclic prefix as PUSCH, no sidelink transmissions shall occur in sidelink subframe n from a UE if uplink SRS is transmitted from the same UE in uplink subframe n.

In case of a UE capable of transmission on multiple carriers, sidelink transmission may only occur on a single carrier frequency at a given time.

A UE with limited transmission capabilities, on an uplink subframe included in *discTxGapConfig* [9], shall first prioritize a PSDCH transmission or a SLSS transmission for PSDCH over an uplink transmission that is not a PRACH transmission. Else, a UE with limited transmission capabilities shall at a given time first prioritize uplink transmissions, followed by sidelink transmissions.

A UE with limited transmission capabilities shall at a given time prioritize sidelink communication transmissions (PSSS, SSSS, PSBCH, PSSCH, PSCCH) over sidelink discovery transmissions (PSDCH).

A UE with limited reception capabilities, on a downlink subframe included in *discRxGapConfig* [9], shall first prioritize reception of PSDCH or reception of SLSS for PSDCH over downlink reception. Else, a UE with limited reception capabilities shall at a given time first prioritize downlink reception over sidelink reception.

A UE with limited reception capabilities shall at a given time first prioritize sidelink communication reception, sidelink discovery reception on carriers configured by the eNodeB, and last sidelink discovery reception on carriers not configured by the eNodeB.

Petitioners' Exhibit 1003, p. 1210
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

9.2 Slot structure and physical resources

Sidelink transmissions are organized into radio frames with a duration of T_f, each consisting of 20 slots of duration T_{slot}. A sidelink subframe consists of two consecutive slots, starting with an even-numbered slot.

9.2.1 Resource grid

A transmitted physical channel or signal in a slot is described by a resource grid of $N_{RB}^{SL}N_{sc}^{RB}$ subcarriers and N_{symb}^{SL} SC-FDMA symbols. The sidelink bandwidth $N_{RB}^{SL} = N_{RB}^{UL}$ if the S criterion according to [10, clause 5.2.3.2] is fulfilled for a serving cell having the same uplink carrier frequency as the sidelink, otherwise a preconfigured value is used [9].

The sidelink cyclic prefix is configured independently for type 1 discovery, type 2B discovery, sidelink transmission mode 1, sidelink transmission mode 2, control signalling, and PSBCH and synchronization signals. Configuration is per resource pool for discovery, sidelink transmission mode 2, and control signalling. The PSBCH and synchronization signals always use the same cyclic prefix.

The resource grid is illustrated in Figure 5.2.1-1.

An antenna port is defined such that the channel over which a symbol on the antenna port is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed. There is one resource grid per antenna port. The antenna ports used for transmission of a physical channel or signal are shown in Table 9.2.1-1.

Table 9.2.1-1: Antenna ports used for different physical channels and signals

Physical channel or signal	Antenna port number
PSSCH	1000
PSCCH	1000
PSDCH	1000
PSBCH	1010
Synchronization signals	1020

9.2.2 Resource elements

Each element in the resource grid is called a resource element and is uniquely defined by the index pair (k,l) in a slot where $k = 0,...,N_{RB}^{SL}N_{sc}^{RB} - 1$ and $l = 0,...,N_{symb}^{SL} - 1$ are the indices in the frequency and time domains, respectively. Resource element (k,l) on antenna port p corresponds to the complex value $a_{k,l}^{(p)}$. When there is no risk for confusion, or no particular antenna port is specified, the index p may be dropped.

Quantities $a_{k,l}^{(p)}$ corresponding to resource elements not used for transmission of a physical channel or a physical signal in a slot shall be set to zero.

9.2.3 Resource blocks

A physical resource block is defined as N_{symb}^{SL} consecutive SC-FDMA symbols in the time domain and N_{sc}^{RB} consecutive subcarriers in the frequency domain, where N_{symb}^{SL} and N_{sc}^{RB} are given by Table 9.2.3-1. A physical resource block in the sidelink thus consists of $N_{symb}^{SL} \times N_{sc}^{RB}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.

Petitioners' Exhibit 1003, p. 1211
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 9.2.3-1: Resource block parameters

Configuration	N_{sc}^{RB}	N_{symb}^{SL}
Normal cyclic prefix	12	7
Extended cyclic prefix	12	6

The relation between the physical resource block number n_{PRB} in the frequency domain and resource elements (k,l) in a slot is given by

$$n_{PRB} = \left\lfloor \frac{k}{N_{sc}^{RB}} \right\rfloor$$

9.2.4 Resource pool

The subframe pools and resource block pools are defined in [4].

For PSSCH, the number of the current slot in the subframe pool $n_{ss}^{PSSCH} = 2n_{ssf}^{PSSCH} + i$, where $i \in \{0,1\}$ is the number of the current slot within the current sidelink subframe $n_{ssf}^{PSSCH} = j \bmod 10$ with j equal to the subscript of l_j^{PSSCH}, defined in clauses 14.1.4 and 14.2.3 of [4] for sidelink transmission modes 1 and 2, respectively

9.2.5 Guard period

The last SC-FDMA symbol in a sidelink subframe serves as a guard period and shall not be used for sidelink transmission.

9.3 Physical Sidelink Shared Channel

9.3.1 Scrambling

The block of bits $b(0),...,b(M_{bit}-1)$, where M_{bit} is the number of bits transmitted on the physical sidelink shared channel in one subframe shall be scrambled according to clause 5.3.1.

The scrambling sequence generator shall be initialised with $c_{init} = n_{ID}^{SA} \cdot 2^{14} + n_{ssf}^{PSSCH} \cdot 2^9 + 510$ at the start of every PSSCH subframe where n_{ID}^{SA} is destination identity obtained from the sidelink control channel.

9.3.2 Modulation

Modulation shall be done according to clause 5.3.2. Table 9.3.2-1 specifies the modulation mappings applicable for the physical sidelink shared channel.

Table 9.3.2-1: PSSCH modulation schemes

Physical channel	Modulation schemes
PSSCH	QPSK, 16QAM

9.3.3 Layer mapping

Layer mapping shall be done according to clause 5.3.2A assuming a single antenna port, $\upsilon = 1$.

Petitioners' Exhibit 1003, p. 1212
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

9.3.4 Transform precoding

Transform precoding shall be done according to clause 5.3.3 with $M_{\text{RB}}^{\text{PUSCH}}$ and $M_{\text{sc}}^{\text{PUSCH}}$ replaced by $M_{\text{RB}}^{\text{PSSCH}}$ and $M_{\text{sc}}^{\text{PSSCH}}$, respectively.

9.3.5 Precoding

Precoding shall be done according to clause 5.3.3A assuming a single antenna port, $\upsilon = 1$.

9.3.6 Mapping to physical resources

The block of complex-valued symbols $z(0),...,z(M_{\text{symb}}^{\text{ap}}-1)$ shall be multiplied with the amplitude scaling factor β_{PSSCH} in order to conform to the transmit power P_{PSSCH} specified in [4], and mapped in sequence starting with $z(0)$ to physical resource blocks on antenna port p and assigned for transmission of PSSCH. The mapping to resource elements (k,l) corresponding to the physical resource blocks assigned for transmission and not used for transmission of reference signals shall be in increasing order of first the index k, then the index l, starting with the first slot in the subframe. Resource elements in the last SC-FDFMA symbol within a subframe shall be counted in the mapping process but not transmitted.

If sidelink frequency hopping is disabled the set of physical resource blocks to be used for transmission is given by $n_{\text{PRB}} = n'_{\text{VRB}}$ where n'_{VRB} is obtained from [4, clause 14.1.1.2.1].

If sidelink frequency hopping with type 1 hopping is enabled, the set of physical resource blocks to be used for transmission is given by [4].

If sidelink frequency hopping with predefined hopping pattern is enabled, the set of physical resource blocks to be used for transmission is given by the sidelink control information together with a predefined pattern in clause 5.3.4 with the following exceptions:

- only inter-subframe hopping shall be used
- the number of subbands $N_{\text{sb}} \in \{1,2,4\}$ is given by higher layers as described in [4, clause 14.1.1.2]
- the quantity $N_{\text{RB}}^{\text{HO}} \in \{0,...,110\}$ is given by higher layers as described in [4, clause 14.1.1.2]
- the quantity $n_{\text{s}} = n_{\text{ss}}^{\text{PSSCH}}$ where $n_{\text{ss}}^{\text{PSSCH}}$ is given by clause 9.2.4
- the quantity $\text{CURRENT\_TX\_NB} = n_{\text{ssf}}^{\text{PSSCH}}$
- the pseudo-random sequence generator is initialized at the start of each slot fulfilling $n_{\text{ss}}^{\text{PSSCH}} = 0$ with the initialization value $c_{\text{init}} \in \{0,1,...,503,510\}$ given by *hoppingParameter-r12* in [9]
- the quantity n_{VRB} shall be replaced by n'_{VRB}, given by [4, clause 14.1.1.2.1]
- for sidelink transmission mode 1
  - $N_{\text{RB}}^{\text{UL}} = N_{\text{RB}}^{\text{SL}}$
- for sidelink transmission mode 2
  - $N_{\text{RB}}^{\text{UL}} = M_{\text{RB}}^{\text{PSSCH\_RP}}$ where $M_{\text{RB}}^{\text{PSSCH\_RP}}$ is given by [4, clause 14.1.3]
  - the quantity n_{PRB} shall be replaced by n'_{PRB}, given by [4, clause 14.1.1.4]
  - the physical resource block to use for transmission $n_{\text{PRB}} = m_{n'_{\text{PRB}}}^{\text{PSSCH}}$ with m_j^{PSSCH} given by [4, clause 14.1.3]

Petitioners' Exhibit 1003, p. 1213
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

9.4 Physical Sidelink Control Channel

9.4.1 Scrambling

The block of bits $b(0),...,b(M_{\text{bit}}-1)$, where M_{bit} is the number of bits transmitted on the physical sidelink control channel in one subframe shall be scrambled according to clause 5.3.1.

The scrambling sequence generator shall be initialised with $c_{\text{init}}=510$ at the start of every PSCCH subframe.

9.4.2 Modulation

Modulation shall be done according to clause 5.3.2. Table 9.4.2-1 specifies the modulation mappings applicable for the physical sidelink control channel.

Table 9.4.2-1: PSCCH modulation schemes

Physical channel	Modulation schemes
PSCCH	QPSK

9.4.3 Layer mapping

Layer mapping shall be done according to clause 5.3.2A assuming a single antenna port, $\upsilon=1$.

9.4.4 Transform precoding

Transform precoding shall be done according to clause 5.3.3 with $M_{\text{RB}}^{\text{PUSCH}}$ and $M_{\text{sc}}^{\text{PUSCH}}$ replaced by $M_{\text{RB}}^{\text{PSCCH}}$ and $M_{\text{sc}}^{\text{PSCCH}}$, respectively.

9.4.5 Precoding

Precoding shall be done according to clause 5.3.3A assuming a single antenna port, $\upsilon=1$.

9.4.6 Mapping to physical resources

The block of complex-valued symbols $z(0),...,z(M_{\text{symb}}^{\text{ap}}-1)$ shall be multiplied with the amplitude scaling factor β_{PSCCH} in order to conform to the transmit power P_{PSCCH} specified in [4], and mapped in sequence starting with $z(0)$ to physical resource blocks on antenna port p and assigned for transmission of PSCCH. The mapping to resource elements (k,l) corresponding to the physical resource blocks assigned for transmission and not used for transmission of reference signals shall be in increasing order of first the index k, then the index l, starting with the first slot in the subframe. Resource elements in the last SC-FDFMA symbol within a subframe shall be counted in the mapping process but not transmitted.

9.5 Physical Sidelink Discovery Channel

9.5.1 Scrambling

The block of bits $b(0),...,b(M_{\text{bit}}-1)$, where M_{bit} is the number of bits transmitted on the physical sidelink discovery channel in one subframe shall be scrambled according to clause 5.3.1.

The scrambling sequence generator shall be initialised with $c_{\text{init}}=510$ at the start of each PSDCH subframe.

Petitioners' Exhibit 1003, p. 1214
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

9.5.2 Modulation

Modulation shall be done according to clause 5.3.2. Table 9.5.2-1 specifies the modulation mappings applicable for the physical sidelink discovery channel.

Table 9.5.2-1: Sidelink modulation schemes

Physical channel	Modulation schemes
PSDCH	QPSK

9.5.3 Layer mapping

Layer mapping shall be done according to clause 5.3.2A assuming a single antenna port, $\upsilon = 1$.

9.5.4 Transform precoding

Transform precoding shall be done according to clause 5.3.3 with $M_{\text{RB}}^{\text{PUSCH}}$ and $M_{\text{sc}}^{\text{PUSCH}}$ replaced by $M_{\text{RB}}^{\text{PSDCH}}$ and $M_{\text{sc}}^{\text{PSDCH}}$, respectively.

9.5.5 Precoding

Precoding shall be done according to clause 5.3.3A assuming a single antenna port, $\upsilon = 1$.

9.5.6 Mapping to physical resources

The block of complex-valued symbols $z(0),...,z(M_{\text{symb}}^{\text{ap}} - 1)$ shall be multiplied with the amplitude scaling factor β_{PSDCH} in order to conform to the transmit power P_{PSDCH} specified in [4], and mapped in sequence starting with $z(0)$ to physical resource blocks on antenna port p and assigned for transmission of PSDCH. The mapping to resource elements (k,l) corresponding to the physical resource blocks assigned for transmission and not used for transmission of reference signals shall be in increasing order of first the index k, then the index l, starting with the first slot in the subframe. Resource elements in the last SC-FDFMA symbol within a subframe shall be counted in the mapping process but not transmitted.

The set of physical resource blocks that shall be used are given by [4, clause 14.3.1].

9.6 Physical Sidelink Broadcast Channel

9.6.1 Scrambling

The block of bits $b(0),...,b(M_{\text{bit}} - 1)$, where M_{bit} is the number of bits transmitted on the physical sidelink broadcast channel in one subframe, shall be scrambled according to clause 5.3.1. The scrambling sequence generator shall be initialised at the start of every PSBCH subframe with $c_{\text{init}} = N_{\text{ID}}^{\text{SL}}$.

9.6.2 Modulation

Modulation shall be done according to clause 5.3.2. Table 9.6.2-1 specifies the modulation mappings applicable for the physical sidelink broadcast channel.

Table 9.6.2-1: PSBCH modulation schemes

Physical channel	Modulation schemes
PSBCH	QPSK

Petitioners' Exhibit 1003, p. 1215
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

9.6.3 Layer mapping

Layer mapping shal be done according to clause 5.3.2A assuming a single antenna port, $\upsilon = 1$.

9.6.4 Transform precoding

Transform precoding shall be done according to clause 5.3.3 with $M_{\text{RB}}^{\text{PUSCH}}$ and $M_{\text{sc}}^{\text{PUSCH}}$ replaced by $M_{\text{RB}}^{\text{PSBCH}}$ and $M_{\text{sc}}^{\text{PSBCH}}$, respectively.

9.6.5 Precoding

Precoding shall be done according to clause 5.3.3A assuming a single antenna port, $\upsilon = 1$.

9.6.6 Mapping to physical resources

The block of complex-valued symbols $z(0),...,z(M_{\text{symb}}^{\text{ap}} - 1)$ shall be multiplied with the amplitude scaling factor β_{PSBCH} in order to conform to the transmit power P_{PSBCH} specified in [4], and mapped in sequence starting with $z(0)$ to physical resource blocks on antenna port p. The PSBCH shall use the same set of resource blocks as the synchronization signal. The mapping to resource elements (k,l) corresponding to the physical resource blocks used for the PSBCH and not used for transmission of reference signals or synchronization signals shall be in increasing order of first the index k, then the index l, starting with the first slot in the subframe. The resource-element index k given by

$$k = k' - 36 + \frac{N_{\text{RB}}^{\text{SL}} N_{\text{sc}}^{\text{RB}}}{2}, \quad k' = 0,1,...,71$$

Resource elements in the last SC-FDMA symbol within a subframe should be counted in the mapping process but not transmitted.

9.7 Sidelink Synchronization Signals

A physical-layer sidelink synchronization identity is represented by $N_{\text{ID}}^{\text{SL}} \in \{0,1,...,335\}$, divided into two sets id_net and id_oon consisting of identities $\{0,1,...,167\}$ and $\{168,169,...,335\}$, respectively.

9.7.1 Primary sidelink synchronization signal

The primary sidelink synchronization signal is transmitted in two adjacent SC-FDMA symbols in the same subframe.

9.7.1.1 Sequence generation

Each of the two sequences $d_i(0),...,d_i(61), i = 1,2$ used for the primary sidelink synchronization signal in the two SC-FDMA symbols is given by clause 6.11.1.1 with root index $u = 26$ if $N_{\text{ID}}^{\text{SL}} \le 167$ and $u = 37$ otherwise.

9.7.1.2 Mapping to resource elements

The sequence $d_i(n)$ shall be multiplied with the amplitude scaling factor $\sqrt{72/62} \cdot \beta_{\text{PSBCH}}$ and mapped to resource elements on antenna port 1020 in the first slot in the subframe according to

Petitioners' Exhibit 1003, p. 1216
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$a_{k,l} = d_i(n), \qquad n = 0,...,61$$
$$k = n - 31 + \frac{N_{\text{RB}}^{\text{SL}} N_{\text{sc}}^{\text{RB}}}{2}$$
$$l = \begin{cases} 1,2 & \text{normal cyclic prefix} \\ 0,1 & \text{extended cyclic prefix} \end{cases}$$

9.7.2 Secondary sidelink synchronization signal

The secondary sidelink synchronization signal is transmitted in two adjacent SC-FDMA symbols in the same subframe.

9.7.2.1 Sequence generation

Each of the two sequences $d_i(0),...,d_i(61), i = 1,2$ used for the secondary sidelink synchronization signal is given by clause 6.11.2.1 assuming subframe 0 with $N_{\text{ID}}^{(1)} = N_{\text{ID}}^{\text{SL}} \bmod 168$ and $N_{\text{ID}}^{(2)} = \left\lfloor N_{\text{ID}}^{\text{SL}} / 168 \right\rfloor$.

9.7.2.2 Mapping to resource elements

The sequence $d_i(n)$ shall be multiplied with the amplitude scaling factor β_{SSSS} in order to conform to the transmit power specified in clause 14.4 in 3GPP TS 36.213 [4] and mapped to resource elements on antenna port 1020 in the second slot in the subframe according to

$$a_{k,l} = d_i(n), \qquad n = 0,...,61$$
$$k = n - 31 + \frac{N_{\text{RB}}^{\text{SL}} N_{\text{sc}}^{\text{RB}}}{2}$$
$$l = \begin{cases} 4,5 & \text{normal cyclic prefix} \\ 3,4 & \text{extended cyclic prefix} \end{cases}$$

9.8 Demodulation reference signals

Demodulation reference signals associated with PSSCH, PSCCH, PSDCH, and PSBCH transmission shall be transmitted according to PUSCH in clause 5.5.2.1 with the following exceptions:

- The parameters in Tables 9.8-1 and 9.8-2 shall be used.
- The term PUSCH shall be replaced by PSSCH, PSCCH, PSDCH or PSBCH, depending on the physical channel to which the reference signal is associated.
- Antenna ports are given by Table 9.2-1.
- The set of physical resource blocks used in the mapping process shall be identical to the corresponding PSSCH/PSCCH/PSDCH/PSBCH transmission.
- The index k in the mapping process in clause 5.5.2.1.2 shall be identical to that for the corresponding PSSCH/PSCCH/PSDCH/PSBCH transmission.
- The pseudo-random sequence generator in clause 5.5.1.3 shall be initialized at the start of each slot fulfilling $n_{\text{ss}}^{\text{PSSCH}} = 0$

Petitioners' Exhibit 1003, p. 1217
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 9.8-1: Reference signal parameters for PSSCH and PSCCH.

Parameter in clause 5.5.2.1		PSSCH	PSCCH
Group hopping		enabled	disabled
	$n_{\mathrm{ID}}^{\mathrm{RS}}$	$n_{\mathrm{ID}}^{\mathrm{SA}}$	-
	n_{s}	$n_{\mathrm{ss}}^{\mathrm{PSSCH}}$	-
	f_{ss}	$n_{\mathrm{ID}}^{\mathrm{SA}} \bmod 30$	0
Sequence hopping		disabled	disabled
Cyclic shift	$n_{\mathrm{cs},\lambda}$	$\lfloor n_{\mathrm{ID}}^{\mathrm{SA}}/2 \rfloor \bmod 8$	0
Orthogonal sequence	$\left[w^{\lambda}(0) \quad w^{\lambda}(1)\right]$	$[+1 \quad +1]$ if $n_{\mathrm{ID}}^{\mathrm{SA}} \bmod 2 = 0$ $[+1 \quad -1]$ if $n_{\mathrm{ID}}^{\mathrm{SA}} \bmod 2 = 1$	$[+1 \quad +1]$
Reference signal length	$M_{\mathrm{sc}}^{\mathrm{RS}}$	$M_{\mathrm{sc}}^{\mathrm{PSSCH}}$	$M_{\mathrm{sc}}^{\mathrm{PSCCH}}$
Number of layers	υ	1	1
Number of antenna ports	P	1	1

Table 9.8-2: Reference signal parameters for PSDCH and PSBCH.

Parameter in clause 5.5.2.1		PSDCH	PSBCH
Group hopping		disabled	disabled
	f_{ss}	0	$\lfloor N_{\mathrm{ID}}^{\mathrm{SL}}/16 \rfloor \bmod 30$
Sequence hopping		disabled	disabled
Cyclic shift	$n_{\mathrm{cs},\lambda}$	0	$\lfloor N_{\mathrm{ID}}^{\mathrm{SL}}/2 \rfloor \bmod 8$
Orthogonal sequence	$\left[w^{\lambda}(0) \quad w^{\lambda}(1)\right]$	$[+1 \quad +1]$	$[+1 \quad +1]$ if $N_{\mathrm{ID}}^{\mathrm{SL}} \bmod 2 = 0$ $[+1 \quad -1]$ if $N_{\mathrm{ID}}^{\mathrm{SL}} \bmod 2 = 1$
Reference signal length	$M_{\mathrm{sc}}^{\mathrm{RS}}$	$M_{\mathrm{sc}}^{\mathrm{PSDCH}}$	$M_{\mathrm{sc}}^{\mathrm{PSBCH}}$
Number of layers	υ	1	1
Number of antenna ports	P	1	1

9.9 SC-FDMA baseband signal generation

The time-continuous signal $s_l^{(p)}(t)$ for antenna port p in SC-FDMA symbol l in a sidelink slot is defined by clause 5.6 with $N_{\mathrm{RB}}^{\mathrm{UL}}$ replaced by $N_{\mathrm{RB}}^{\mathrm{SL}}$.

The cyclic prefix length for each sidelink channel or signal may differ from that configured for uplink transmissions.

9.10 Timing

Transmission of a sidelink radio frame number i from the UE shall start $(N_{\mathrm{TA,SL}} + N_{\mathrm{TA\,offset}}) \cdot T_{\mathrm{s}}$ seconds before the start of the corresponding timing reference frame at the UE. The UE is not required to receive sidelink or downlink transmissions earlier than $624T_{\mathrm{s}}$ after the end of a sidelink transmission.

For PSDCH transmission and sidelink synchronization signal transmission for PSDCH:

if the UE has a serving cell fulfilling the S criterion according to [10, clause 5.2.3.2]

- the timing of reference radio frame i equals that of downlink radio frame i of the cell c as given in Section 14.3.1 of [4] and
- $N_{\mathrm{TA\,offset}}$ is given by clause 8.1,

otherwise

Petitioners' Exhibit 1003, p. 1218
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- the timing of reference radio frame i is implicitly obtained from [4] and
- $N_{\text{TA offset}} = 0$.

For all other sidelink transmissions:

if the UE has a serving cell fulfilling the S criterion according to [10, clause 5.2.3.2]

- the timing of reference radio frame i equals that of downlink radio frame i in the cell with the same uplink carrier frequency as the sidelink and
- $N_{\text{TA offset}}$ is given by clause 8.1,

otherwise

- the timing of reference radio frame i is implicitly obtained from [4] and
- $N_{\text{TA offset}} = 0$.

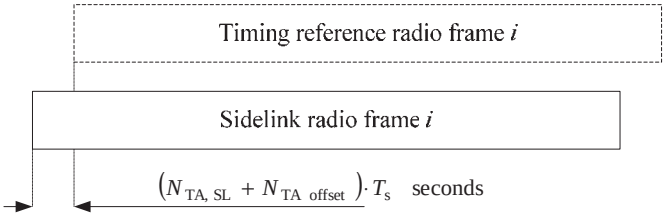


Figure 9.9-1: Sidelink timing relation.

The quantity $N_{\text{TA,SL}}$ differs between channels and signals according to

$$N_{\text{TA, SL}} = \begin{cases} N_{\text{TA}} & \text{for PSSCH in sidelink transmission mode 1} \\ 0 & \text{for all other cases} \end{cases}$$

Petitioners' Exhibit 1003, p. 1219
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Annex A (informative): Change history

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
2006-09-24	-	-	-		Draft version created	-	0.0.0
2006-10-09	-	-	-		Updated skeleton	0.0.0	0.0.1
2006-10-13	-	-	-		Endorsed by RAN1	0.0.1	0.1.0
2006-10-23	-	-	-		Inclusion of decision from RAN1#46bis	0.1.0	0.1.1
2006-11-06	-	-	-		Updated editor"s version	0.1.1	0.1.2
2006-11-09	-	-	-		Updated editor"s version	0.1.2	0.1.3
2006-11-10	-	-	-		Endorsed by RAN1#47	0.1.3	0.2.0
2006-11-27	-	-	-		Editor"s version, including decisions from RAN1#47	0.2.0	0.2.1
2006-12-14	-	-	-		Updated editor"s version	0.2.1	0.2.2
2007-01-15	-	-	-		Updated editor"s version	0.2.2	0.2.3
2007-01-19	-	-	-		Endorsed by RAN1#47bis	0.2.3	0.3.0
2007-02-01	-	-	-		Editor"s version, including decisions from RAN1#47bis	0.3.0	0.3.1
2007-02-12	-	-	-		Updated editor"s version	0.3.1	0.3.2
2007-02-16	-	-	-		Endorsed by RAN1#48	0.3.2	0.4.0
2007-02-16	-	-	-		Editor"s version, including decisions from RAN1#48	0.4.0	0.4.1
2007-02-21	-	-	-		Updated editor"s version	0.4.1	0.4.2
2007-03-03	RP_35	RP-070169			For information at RAN#35	0.4.2	1.0.0
2007-04-25	-	-	-		Editor"s version, including decisions from RAN1#48bis and RAN1 TDD Ad Hoc	1.0.0	1.0.1
2007-05-03	-	-	-	-	Updated editor"s version	1.0.1	1.0.2
2007-05-08	-	-	-	-	Updated editor"s version	1.0.2	1.0.3
2007-05-11	-	-	-	-	Updated editor"s version	1.0.3	1.0.4
2007-05-11	-	-	-	-	Endorsed by RAN1#49	1.0.4	1.1.0
2007-05-15	-	-	-	-	Editor"s version, including decisions from RAN1#49	1.1.0	1.1.1
2007-06-05	-	-	-	-	Updated editor"s version	1.1.1	1.1.2
2007-06-25	-	-	-	-	Endorsed by RAN1#49bis	1.1.2	1.2.0
2007-07-10	-	-	-	-	Editor"s version, including decisions from RAN1#49bis	1.2.0	1.2.1
2007-08-10	-	-	-	-	Updated editor"s version	1.2.1	1.2.2
2007-08-20	-	-	-	-	Updated editor"s version	1.2.2	1.2.3
2007-08-24	-	-	-	-	Endorsed by RAN1#50	1.2.3	1.3.0
2007-08-27	-	-	-	-	Editor"s version, including decisions from RAN1#50	1.3.0	1.3.1
2007-09-05	-	-	-	-	Updated editor"s version	1.3.1	1.3.2
2007-09-08	RP_37	RP-070729	-	-	For approval at RAN#37	1.3.2	2.0.0
12/09/07	RP_37	RP-070729			Approved version	2.0.0	8.0.0
28/11/07	RP_38	RP-070949	0001	-	Introduction of optimized FS2 for TDD	8.0.0	8.1.0
28/11/07	RP_38	RP-070949	0002	-	Introduction of scrambling sequences, uplink reference signal sequences, secondary synchronization sequences and control channel processing	8.0.0	8.1.0
05/03/08	RP_39	RP-080219	0003	1	Update of uplink reference-signal hopping, downlink reference signals, scrambling sequences, DwPTS/UpPTS lengths for TDD and control channel processing	8.1.0	8.2.0
28/05/08	RP_40	RP-080432	0004	-	Correction of the number of subcarriers in PUSCH transform precoding	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0005	-	Correction of PHICH mapping	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0006	-	Correction of PUCCH resource index for PUCCH format 2	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0007	3	Correction of the predefined hopping pattern for PUSCH	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0008	-	Non-binary hashing functions	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0009	1	PUCCH format 1	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0010	1	CR on Uplink DM RS hopping	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0012	1	Correction to limitation of constellation size of ACK transmission in PUSCH	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0015	1	PHICH mapping for one and two antenna ports in extended CP	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0016	1	Correction of PUCCH in absent of mixed format	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0017	-	Specification of CCE size and PHICH resource indication	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0018	3	Correction of the description of frame structure type 2	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0019	-	On Delta^pucch_shift correction	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0021	-	Corrections to Secondary Synchronization Signal Mapping	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0022	-	Downlink VRB mapping to PRB for distributed transmission	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0023	-	Clarification of modulation symbols to REs mapping for DVRB	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0024	1	Consideration on the scrambling of PDSCH	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0025	-	Corrections to Initialization of DL RS Scrambling	8.2.0	8.3.0

Petitioners' Exhibit 1003, p. 1220
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
28/05/08	RP_40	RP-080432	0026	1	CR on Downlink RS	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0027	-	CR on Uplink RS	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0028	1	Fixed timing advance offset for LTE TDD and half-duplex FDD	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0029	1	Timing of random access preamble format 4	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0030	1	Uplink sounding RS bandwidth configuration	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0031	-	Use of common RS when UE-specific RS are configured	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0032	1	Uplink RS Updates	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0033	-	Orthogonal cover sequence for shortened PUCCH format 1a and 1b	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0034	-	Clarification of PDCCH mapping	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0035	-	TDD PRACH time/frequency mapping	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0036	-	Cell Specific Uplink Sounding RS Subframe Configuration	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0038	-	PDCCH length for carriers with mixed MBSFN and Unicast Traffic	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0040	-	Correction to the scrambling sequence generation for PUCCH, PCFICH, PHICH, MBSFN RS and UE specific RS	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0041	-	PDCCH coverage in narrow bandwidths	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0042	-	Closed-Loop and Open-Loop Spatial Multiplexing	8.2.0	8.3.0
28/05/08	RP_40	RP-080432	0043	-	Removal of small-delay CDD	8.2.0	8.3.0
09/09/08	RP_41	RP-080668	48	1	Frequency Shifting of UE-specific RS	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	49	1	Correction of PHICH to RE mapping in extended CP subframe	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	50	-	Corrections to for handling remaining Res	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	51	-	PRACH configuration for frame structure type 1	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	52	2	Correction of PUCCH index generation formula	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	53	-	Orthogonal cover sequence for shortened PUCCH format 1a and 1b	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	54	-	Correction of mapping of ACK/NAK to binary bit values	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	56	2	Remaining issues on SRS hopping	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	57	1	Correction of n_cs(n_s) and OC/CS remapping for PUCCH formats 1/1a/1b and 2/2a/2b	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	59	-	Corrections to Rank information scrambling in Uplink Shared Channel	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	60	-	Definition on the slot number for frame structure type 2	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	61	-	Correction of the Npucch sequence upper limit for the formats 1/1a/1b	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	62	1	Clarifications for DMRS parameters	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	63	-	Correction of n_prs	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	64	1	Introducing missing L1 parameters to 36.211	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	65	3	Clarification on reception of synchronization signals	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	66	-	Correction to the downlink/uplink timing	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	67	-	ACK/NACK Scrambling scheme on PUCCH	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	68	-	DCI format1C	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	69	-	Refinement for REG Definition for n = 4	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	71	-	Correcting Ncs value for PRACH preamble format 0-3	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	73	-	Correction of the half duplex timing advance offset value	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	74	-	Correction to Precoding for Transmit Diversity	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	75	-	Clarification on number of OFDM symbols used for PDCCH	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	77	-	Number of antenna ports for PDSCH	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	78	-	Correction to Type 2 PUSCH predetermined hopping for Nsb=1 operation	8.3.0	8.4.0
09/09/08	RP_41	RP-080668	79	-	PRACH frequency location	8.3.0	8.4.0
03/12/08	RP_42	RP-081074	70	1	Correction for the definition of UE-specific reference signals	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	72	2	Corrections to precoding for large delay CDD	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	80	-	Correction to the definition of nbar_oc for extended CP	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	81	1	Specification of reserved REs not used for RS	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	82	2	Clarification of the random access preamble transmission timing	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	83	1	Indexing of PRACH resources within the radio frame	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	84	6	Alignment of RAN1/RAN2 specification	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	86	-	Clarification on scrambling of ACK/NAK bits for PUCCH format 2a/2b	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	87	-	Correction of introduction of shortened SR	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	88	-	Corrections to 36.211	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	89	-	Clarification on PUSCH DM RS Cyclic Shift Hopping	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	92	1	Correction to the uplink DM RS assignment	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	93	-	Clarify the RNTI used in scrambling sequence initialization	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	94	1	On linkage Among UL Power Control Parameters	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	95	-	Clarification on PUSCH pre-determined hopping pattern	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	96	-	Clarification of SRS sequence-group and base sequence number	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	97	1	SRS subframe configuration	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	98	-	Remaining SRS details for TDD	8.4.0	8.5.0

Petitioners' Exhibit 1003, p. 1221
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
03/12/08	RP_42	RP-081074	99	-	Clarifying UL VRB Allocation	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	100	-	Clarification on PUCCH resource hopping	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	101	-	Correction for definition of Qm and a pseudo code syntax error in Scrambling.	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	105	1	Remaining Issues on SRS of TDD	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	106	-	Correction of reference to RAN4 specification of supported uplink bandwidth	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	107	-	General corrections to SRS	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	109	2	Correction to PCFICH specification	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	110	1	Correction to Layer Mapping for Transmit Diversity with Four Antenna Ports	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	111	-	Correction of the mapping of cyclic shift filed in DCI format 0 to the dynamic cyclic shift offset	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	112	-	DRS collision handling	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	113	-	Clarification to enable reuse of non-active PUCCH CQI RBs for PUSCH	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	114	1	PUSCH Mirror Hopping operation	8.4.0	8.5.0
03/12/08	RP_42	RP-081074	108	1	Extended and normal cyclic prefix in DL and UL for LTE TDD	8.4.0	8.5.0
04/03/09	RP_43	RP-090234	115	1	Alignment of PRACH configuration index for FS type 1 and type 2	8.5.0	8.6.0
04/03/09	RP_43	RP-090234	118	1	Clarification for DRS Collision handling	8.5.0	8.6.0
04/03/09	RP_43	RP-090234	121	1	Removing inverse modulo operation	8.5.0	8.6.0
04/03/09	RP_43	RP-090234	123	1	Clarification on the use of preamble format 4	8.5.0	8.6.0
04/03/09	RP_43	RP-090234	124	-	Clarification of RNTI used in scrambling sequence	8.5.0	8.6.0
04/03/09	RP_43	RP-090234	125	1	Clarifying PDCCH RE mapping	8.5.0	8.6.0
04/03/09	RP_43	RP-090234	126	-	Correction of preamble format 4 timing	8.5.0	8.6.0
04/03/09	RP_43	RP-090234	127	2	Corrections to SRS	8.5.0	8.6.0
04/03/09	RP_43	RP-090234	128	2	Clarification of PDSCH Mapping to Resource Elements	8.5.0	8.6.0
04/03/09	RP_43	RP-090234	129	1	Alignment with correct ASN1 parameter names	8.5.0	8.6.0
04/03/09	RP_43	RP-090234	130	-	Correction to PUCCH format 1 mapping to physical resources	8.5.0	8.6.0
04/03/09	RP_43	RP-090234	132	-	Correction to type-2 PUSCH hopping	8.5.0	8.6.0
04/03/09	RP_43	RP-090234	134	-	Alignment of SRS configuration	8.5.0	8.6.0
27/05/09	RP_44	RP-090527	135	-	Correction on UE behavior for PRACH 20ms periodicity	8.6.0	8.7.0
15/09/09	RP_45	RP-090888	137	1	Clarification on DMRS sequence for PUSCH	8.7.0	8.8.0
15/09/09	RP_45	RP-090888	138	1	Correction to PHICH resource mapping for TDD and to PHICH scrambling	8.7.0	8.8.0
01/12/09	RP_46	RP-091168	142	-	Clarification of the transmit condition for UE specific reference signals	8.8.0	8.9.0
01/12/09	RP_46	RP-091172	139	2	Introduction of LTE positioning	8.9.0	9.0.0
01/12/09	RP_46	RP-091177	140	3	Editorial corrections to 36.211	8.9.0	9.0.0
01/12/09	RP_46	RP-091257	141	1	Introduction of enhanced dual layer transmission	8.9.0	9.0.0
16/03/10	RP_47	RP-100209	144	1	Removal of square brackets on positioning subframe periodicities	9.0.0	9.1.0
16/03/10	RP_47	RP-100209	145	-	Clarification of the CP length of empty OFDM symbols in PRS subframes	9.0.0	9.1.0
16/03/10	RP_47	RP-100210	146	-	Clarification of MBSFN subframe definition	9.0.0	9.1.0
07/12/10	RP_50	RP-101320	148	-	Introduction of Rel-10 LTE-Advanced features in 36.211	9.1.0	10.0.0
15/03/11	RP_51	RP-110254	149	1	Correction on UE behavior for PRACH preamble format 4	10.0.0	10.1.0
15/03/11	RP_51	RP-110256	150	-	Corrections to Rel-10 LTE-Advanced features in 36.211	10.0.0	10.1.0
01/06/11	RP_52	RP-110818	153	2	PUSCH interaction with periodic SRS	10.1.0	10.2.0
01/06/11	RP_52	RP-110819	154	1	Correction on describing PUCCH format 3	10.1.0	10.2.0
01/06/11	RP_52	RP-110821	155	3	Correction on codebooks for CSI-RS based feedback for up to 4 CSI-RS ports.	10.1.0	10.2.0
01/06/11	RP_52	RP-110821	156	-	Correction on overlapping non-zero-power and zero-power CSI-RS configurations	10.1.0	10.2.0
01/06/11	RP_52	RP-110821	157	-	Correction on CSI-RS configuration	10.1.0	10.2.0
01/06/11	RP_52	RP-110821	158	-	PDSCH transmission in MBSFN subframes	10.1.0	10.2.0
01/06/11	RP_52	RP-110823	159	-	Correction on implicit derivation of transmission comb per antenna port for SRS	10.1.0	10.2.0
01/06/11	RP_52	RP-110823	160	-	Uplink DMRS sequence in RACH procedure	10.1.0	10.2.0
15/09/11	RP_53	RP-111229	162	-	Corrections on DMRS for Extended CP	10.2.0	10.3.0
15/09/11	RP_53	RP-111228	163	-	Clarification of applicability of precoding power scaling factors for PDSCH	10.2.0	10.3.0
15/09/11	RP_53	RP-111228	164	-	Correction to modulation and upconversion on PRACH	10.2.0	10.3.0
15/09/11	RP_53	RP-111229	165	-	Clarification on cyclic prefix of PDSCH in MBSFN subframes	10.2.0	10.3.0
15/09/11	RP_53	RP-111229	166	3	Corrections on indication in scrambling identity field in DCI format 2B and 2C	10.2.0	10.3.0
05/12/11	RP_54	RP-111668	167	-	A correction to PDSCH precoding for CQI calculation	10.3.0	10.4.0
05/12/11	RP_54	RP-111668	168	-	Correction to figure of CSI-RS pattern in extended-CP subframe	10.3.0	10.4.0
13/06/12	RP_56	RP-120736	169	-	Correction to resource mapping for PDSCH	10.4.0	10.5.0
13/06/12	RP_56	RP-120739	171	-	Correction for DMRS group hopping and sequence hopping	10.4.0	10.5.0
13/06/12	RP_56	RP-120738	172	-	Correction to assumed CSI-RS transmissions in subframes used	10.4.0	10.5.0

Petitioners' Exhibit 1003, p. 1222
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
					for paging		
04/09/12	RP_57	RP-121274	170	4	Introduction of an additional special subframe configuration	10.5.0	11.0.0
04/09/12	RP_57	RP-121272	173	-	Inclusion of Rel-11 features	10.5.0	11.0.0
04/12/12	RP_58	RP-121839	175	-	Correction to assumed CSI-RS transmissions in secondary cells	11.0.0	11.1.0
04/12/12	RP_58	RP-121846	176	-	Correction to assumed CSI-RS transmissions in secondary cells	11.0.0	11.1.0
26/02/13	RP_59	RP-130254	178	-	Clarification of CSI RS mapping to resource elements	11.1.0	11.2.0
26/02/13	RP_59	RP-130254	180	-	Correction to CSI Reference Signals	11.1.0	11.2.0
26/02/13	RP_59	RP-130255	181	-	Additional clarifications/corrections for introducing Rel-11 features	11.1.0	11.2.0
11/06/13	RP_60	RP-130752	182	-	Correction to EPDCCH PRB pair indication	11.2.0	11.3.0
11/06/13	RP_60	RP-130752	183	-	CR on collision between EPDCCH and PSS/SSS/PBCH	11.2.0	11.3.0
03/09/13					MCC clean-up	11.3.0	11.4.0
03/09/13	RP_60	RP-131250	185	-	Correction to QCL behaviour on CRS	11.3.0	11.4.0
03/12/13	RP_62	RP-131894	186	-	Correction on the derivation of the non-MBSFN region by PCFICH	11.4.0	11.5.0
03/12/13	RP_62	RP-131896	184	3	Introduction of Rel 12 feature for Downlink MIMO Enhancement	11.5.0	12.0.0
03/03/14	RP_63	RP-140286	187	-	On PMCH starting symbol in an MBSFN subframe	12.0.0	12.1.0
10/06/14	RP_64	RP-140858	189	-	CR on antenna port definitions	12.1.0	12.2.0
10/06/14	RP_64	RP-140858	190	1	Clarification of downlink subframes	12.1.0	12.2.0
10/06/14	RP_64	RP-140862	191	-	Inclusion of eIMTA, TDD-FDD CA, and coverage enhancements	12.1.0	12.2.0
10/09/14	RP_65	RP-141485	192	-	Inclusion of low-cost MTC and 256QAM	12.2.0	12.3.0
10/09/14	RP_65	RP-141477	194	-	CR on port 5 UE-specific reference signal when PDSCH is overlapped with EPDCCH	12.2.0	12.3.0
08/12/14	RP_66	RP-142098	195	3	Clarification of PUSCH rate matching with SRS	12.3.0	12.4.0
08/12/14	RP_66	RP-142106	197	4	Inclusion of small-cell enhancements	12.3.0	12.4.0
09/03/15	RP_67	RP-150366	196	7	Inclusion of ProSe	12.4.0	12.5.0
09/03/15	RP_67	RP-150364	198	-	Correction on 256QAM applicability to PMCH	12.4.0	12.5.0
09/03/15	RP_67	RP-150364	199	-	Correction of discovery signal transmission	12.4.0	12.5.0
15/06/15	RP_68	RP-150935	201	-	Alignment of ProSe parameters	12.5.0	12.6.0
14/09/15	RP_69	RP-151465	203	-	Clarification on SRS BW configuration	12.6.0	12.7.0
07/12/15	RP_70	RP-152036	209	1	Modify max TA for dual connectivity	12.7.0	12.8.0
07/12/15	RP_70	RP-152025	206	2	Introduction of EB/FD-MIMO	12.8.0	13.0.0
07/12/15	RP_70	RP-152027	208	1	Introduction of Rel-13 eCA	12.8.0	13.0.0
07/12/15	RP_70	RP-152125	204	2	eD2D CR for 36.211	12.8.0	13.0.0
07/12/15	RP_70	RP-152258	205	4	Introduction of LAA	12.8.0	13.0.0

Change history							
Date	Meeting	TDoc	CR	Rev	Cat	Subject/Comment	New version
2016-03	RAN#71	RP-160359	210	-	F	Alignment eD2D CR for 36.211	13.1.0
2016-03	RAN#71	RP-160367	212	-	F	Clarification on PDSCH collision with PSS/SSS/PBCH	13.1.0
2016-03	RAN#71	RP-160357	213	-	F	Correction on support of CA with up to 32 CCs	13.1.0
2016-03	RAN#71	RP-160357	214	-	F	Correction on PUCCH format 4 and 5	13.1.0
2016-03	RAN#71	RP-160360	217	-	F	Correction on DRS subframe in 36.211	13.1.0
2016-03	RAN#71	RP-160360	218	-	F	Correction on EPDCCH start symbol in LAA	13.1.0
2016-03	RAN#71	RP-160360	219	-	F	Correction to MBSFN subframe configuration	13.1.0
2016-03	RAN#71	RP-160358	220	-	F	CR on CSI-RS configuration for more than eight antenna ports in 36.211	13.1.0
2016-03	RAN#71	RP-160358	221	-	F	CR on mismatch between 36.211 and 36.331	13.1.0
2016-03	RAN#71	RP-160358	222	-	F	Clarification on additional SC-FDMA symbols in UpPTS for SRS	13.1.0
2016-03	RAN#71	RP-160358	223	-	F	Correction on Precoding and definition of DMRS ports	13.1.0
2016-03	RAN#71	RP-160361	207	9	B	Introduction of LC/CE MTC	13.1.0

Petitioners' Exhibit 1003, p. 1223
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

History

Document history		
V13.0.0	January 2016	Publication
V13.1.0	April 2016	Publication

Petitioners' Exhibit 1003, p. 1224
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

APPENDIX 10

3GPP TR 38.802 V1.0.0 (2016-11)

Technical Specification

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Study on New Radio (NR) Access Technology
Physical Layer Aspects

(Release 14)



The present document has been developed within the 3rd Generation Partnership Project (3GPP™) and may be further elaborated for the purposes of 3GPP..
The present document has not been subject to any approval process by the 3GPP Organizational Partners and shall not be implemented.
This Specification is provided for future development work within 3GPP only. The Organizational Partners accept no liability for any use of this Specification.
Specifications and Reports for implementation of the 3GPP™ system should be obtained via the 3GPP Organizational Partners' Publications Offices.

Petitioners' Exhibit 1003, p. 1226
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

__Logos:__ Use exactly one of the above lines. Delete the others.
Use the top line for documents which are specific to GERAN technology only.
Use the second line for documents which are specific to UTRAN technology only or to GERAN and UNTRAN technologies only.
Use the third line for documents which relate to LTE technology (regardless of their applicability to GERAN or to UTRAN technologies) in Releases __prior to__ Release 10.

Keywords
<keyword[, keyword, …]>
Use the fourth line for documents which relate to LTE technology (regardless of their applicability to GERAN or to UTRAN technologies) in Releases 10, 11 and 12.
Use the fifth line for documents which relate to LTE technology (regardless of their applicability to GERAN or to UTRAN technologies) in Release 13 onwards.

MCC selects keywords from stock list.

3GPP

Postal address

3GPP support office address
650 Route des Lucioles - Sophia Antipolis
Valbonne - FRANCE
Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Internet
http://www.3gpp.org

Copyright Notification

No part may be reproduced except as authorized by written permission.
The copyright and the foregoing restriction extend to reproduction in all media.

© 2016, 3GPP Organizational Partners (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC).
All rights reserved.

UMTS™ is a Trade Mark of ETSI registered for the benefit of its members
3GPP™ is a Trade Mark of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners
LTE™ is a Trade Mark of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners
GSM® and the GSM logo are registered and owned by the GSM Association

Petitioners' Exhibit 1003, p. 1227
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Contents

Foreword 5
1 Scope 6
2 References 6
3 Definitions, symbols and abbreviations 6
3.1 Definitions 6
3.2 Symbols 6
3.3 Abbreviations 7
4 Introduction 7
5 General description of layer 1 7
5.1 Duplexing 7
5.2 Forward compatibility 7
5.3 Numerologies and frame structure 7
5.4 LTE-NR Co-existence 8
6 DL concepts 8
6.1 Basic transmission scheme 8
6.1.1 Modulation scheme 9
6.1.2 Physical layer channel 9
6.1.2.1 Physical resource multiplexing 9
6.1.2.1 Data channel 9
6.1.2.2 Control channel 9
6.1.3 Waveform 9
6.1.4 Multiple access scheme 9
6.1.5 Channel coding 10
6.1.6 Multi-antenna scheme 10
6.1.6.1 Beam management 10
6.1.6.2 MIMO schemes 10
6.1.6.3 CSI acquisition 11
6.1.6.4 Reference signal related to multi-antenna scheme 12
6.1.6.4.1 CSI-RS 12
6.1.6.5 Quasi-colocation 12
6.2 Physical layer procedure 13
6.2.1 Scheduling 13
6.2.2 HARQ 13
6.2.3 Initial access and mobility 13
6.2.3.1 Synchronization signal and DL broadcast signal/channel structure 13
6.2.3.2 Initial access procedure 13
6.2.3.3 Mobility 13
6.3 Physical layer measurements 13
7 Evaluation of DL techniques 14
7.1 Performance evaluation 14
7.1.1 Performance evaluation of waveform 14
7.1.2 Performance evaluation of multiple access 15
7.1.3 Performance evaluation of channel coding 15
7.2 Analysis of UE complexity 18
7.3 Analysis of Node B impacts 18
8 UL concepts 18
8.1 Basic transmission scheme 18
8.1.1 Modulation scheme 18
8.1.2 Physical layer channel 18
8.1.2.1 Data channel 18
8.1.2.2 Control channel 18
8.1.3 Waveform 18

Petitioners' Exhibit 1003, p. 1228
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

8.1.4 Multiple access scheme 19
8.1.5 Channel coding 19
8.1.6 Multi-antenna scheme 19
8.1.6.1 Beam management 19
8.1.6.2 MIMO schemes 19
8.1.6.3 Reference signal related to multi-antenna scheme 19
8.1.6.3.1 SRS 20
8.2 Physical layer procedure 20
8.2.1 Random access procedure 20
8.2.1.1 Preamble 20
8.2.1.2 Procedure 20
8.2.2 Scheduling 20
8.2.3 HARQ 20
8.3 Physical layer measurements 21

9 Evaluation of UL techniques 21
9.1 Performance evaluation 21
9.1.1 Performance evaluation of waveform 21
9.1.2 Performance evaluation of multiple access 21
9.1.3 Performance evaluation of channel coding 33
9.2 Analysis of UE complexity 33
9.3 Analysis of Node B impacts 33

10 SL concepts 33
10.1 Basic transmission scheme 33
10.2 Physical layer procedure 33
10.3 Physical layer measurements 33

11 Evaluation of SL techniques 33
11.1 Performance evaluation 33
11.2 Analysis of UE complexity 33
11.3 Analysis of Node B impacts 33

12 Evaluation common for UL/DL 33
12.1 Performance evaluation related to eMBB 33
12.2 Performance evaluation related to URLLC 33
12.3 Performance evaluation related to high speed train 34
12.4 Performance evaluation related to mMTC 34
12.5 Performance evaluation related to eV2X 34

13 UE capability 34

Annex A: simulation scenarios and assumptions 35

A.1 Link level simulation assumptions 35
A.1.1 Simulation assumption for evaluation of waveform 35
A.1.2 Simulation assumption for evaluation of multiple access 37
A.1.3 Simulation assumption for evaluation of channel coding 39
A.1.4 Simulation assumption related to URLLC evaluation 40
A.1.5 Simulation assumption for evaluation related to initial access 40

A.2 System level simulation assumptions 42
A.2.1 General assumption 42
A.2.2 Simulation assumption for evaluation of multiple access scheme 61
A.2.3 Simulation assumption related to initial access 61
A.2.4 Simulation assumption for URLLC 63

Annex B: Change history 64

Petitioners' Exhibit 1003, p. 1229
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

- x the first digit:
  - 1 presented to TSG for information;
  - 2 presented to TSG for approval;
  - 3 or greater indicates TSG approved document under change control.
- y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.
- z the third digit is incremented when editorial only changes have been incorporated in the document.

Petitioners' Exhibit 1003, p. 1230
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

1 Scope

This document is related to the technical report for physical layer aspect of the study item “Study on New Radio Access Technology” [1]. The purpose of this TR is to help TSG RAN WG1 to define and describe the potential physical layer evolution under consideration and compare the benefits of each evolution techniques, along with the complexity evaluation of each technique.

This activity involves the Radio Access work area of the 3GPP studies and has impacts both on the Mobile Equipment and Access Network of the 3GPP systems.

This document is intended to gather all information in order to compare the solutions and gains vs. complexity, and draw a conclusion on way forward.

This document is a ‘living’ document, i.e. it is permanently updated and presented to TSG-RAN meetings.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP RP-161596, “New SID Proposal: Study on New Radio Access Technology”

3 Definitions, symbols and abbreviations

Delete from the above heading those words which are not applicable.

Clause numbering depends on applicability and should be renumbered accordingly.

3.1 Definitions

For the purposes of the present document, the terms and definitions given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

Definition format (Normal)

<defined term>: *<definition>.*

example: text used to clarify abstract rules by applying them literally.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

Symbol format (EW)

Petitioners' Exhibit 1003, p. 1231
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

<symbol> <Explanation>

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1].

Abbreviation format (EW)

<ACRONYM> <Explanation>

4 Introduction

At the 3GPP TSG RAN #71 meeting, the Study Item description on " New SID Proposal: Study on New Radio Access Technology " was approved [1]. The study item covers technology components to be considered for new radio access technologies, e.g. to fulfil the requirements on IMT-2020. This technical report covers the physical-layer aspects of these technology components.

5 General description of layer 1

5.1 Duplexing

NR supports paired and unpaired spectrum and strives to maximize commonality between the technical solutions, allowing FDD operation on a paired spectrum, different transmission directions in either part of a paired spectrum, TDD operation on an unpaired spectrum where the transmission direction of time resources is not dynamically changed, and TDD operation on an unpaired spectrum where the transmission direction of most time resources can be dynamically changing. It is noted that transmission directions include all of downlink, uplink, sidelink, and backhaul link. NR supports at least semi-statically assigned DL/UL transmission direction as gNB operation, i.e., the assigned DL/UL transmission direction can be signaled to UE by higher layer signaling.

5.2 Forward compatibility

Forward compatibility of NR shall ensure smooth introduction of future services and features while efficient access of the earlier services and UEs in the same spectrum is still ensured.

In order to ensure forward compatibility of NR, explicit signaling to NR UEs can indicate reserved resources.

Commented [T1]: [Editor's note]The details on signaling information and transmission are FFS

5.3 Numerologies and frame structure

Multiple numerologies are supported, derived by scaling a basic subcarrier spacing by an integer *N*. The numerology used can be selected independently of the frequency band although it is assumed not to use a very low subcarrier spacing at very high carrier frequencies. Flexible network and UE channel bandwidth is supported. The largest component carrier bandwidth not smaller than 80 MHz for at least one numerology is supported.

Commented [T2]: [Editor's note] Details regarding BW is still FFS.

A subframe duration is fixed to 1ms. Scalable numerology should allow at least from 15kHz to 480kHz subcarrier spacing. The numerology with 15 kHz and scaled numerology with different subcarrier spacing with the same CP overhead align at a symbol boundary every 1ms in a NR carrier. More specifically, for the normal CP family, the following is adopted.

- For subcarrier spacing of 15 kHz * 2^n (n is non-negative integer),
  - Each symbol length (including CP) of 15 kHz equals the sum of the corresponding 2^n symbols of the subcarrier spacing.
  - Other than the first OFDM symbol in every 0.5ms, all OFDM symbols within 0.5ms have the same size

Petitioners' Exhibit 1003, p. 1232
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- The first OFDM symbol in 0.5m is longer by $16T_s$ (assuming 15 kHz and FFT size of 2048) compared to other OFDM symbols.
  - $16\ T_s$ is used for CP for the first symbol.

- For subcarrier spacing of 15 kHz * 2^n (n is a negative integer)
  - Each symbol length (including CP) of the subcarrier spacing equals the sum of the corresponding 2^{-n} symbols of 15 kHz.

The physical layer design supports an extended CP. Extended CP will be only one in given subcarrier spacing.

Commented [T3]: [Editor's note]
Agreement says that from Phase 1, physical layer design should support an extended CP.
FFS: Exact for the services/scenarios for extended CP

No explicit DC subcarrier is reserved both for downlink and uplink. Regarding DC present within the transmitter, DC handling of DC subcarrier in transmitter side is specified as follows:

- Receiver knows where DC subcarrier is or is informed (e.g., by specification or signaling) of where DC subcarrier is or if DC subcarrier is not present within receiver bandwidth.
- When receiver is informed DC subcarrier is present, FFS: transmitter DC subcarrier is punctured, rate matched, modulated, or EVM is not specified.
- When DC subcarrier is not present, all subcarriers within the receiver bandwidth are transmitted.

On the other hand, at the receiver side, no special handling of the DC subcarrier(s) on the receiver side is specified in RAN1. Behavior is left to implementation, i.e., the receiver may for example puncture data received on the DC subcarrier.

A slot is defined as 7 or 14 OFDM symbols for the same subcarrier spacing of up to 60kHz with normal CP and as 14 OFDM symbols for the same subcarrier spacing higher than 60kHz with normal CP. A slot can contain all downlink, all uplink, or {at least one downlink part and at least one uplink part}. Slot aggregation is supported, i.e., data transmission can be scheduled to span one or multiple slots. At least for single carrier operation, NR should allow a UE to operate in a way where it receives at least downlink control information in a first RF bandwidth and where the UE is not expected to receive in a second RF bandwidth that is larger than the first RF bandwidth within less than X μs.The number of subcarriers per PRB is 12.

Commented [T4]: [Editor's note]FFS: whether/which to down select for certain SCS(s)

Commented [T5]: [Editor's note]FFS: whether/which to down select for certain SCS(s)

Commented [T6]: [Editor's note]FFS: value of X

5.4 LTE-NR Co-existence

To support the efficient coexistence between NR and LTE operating in the same licensed frequency band, at least legacy LTE features should be considered in the NR study, e.g.:

- MBSFN configuration (for LTE Rel-8 and beyond)
- TDD UL subframe (for LTE Rel-8 and beyond)
- SCell activation/deactivation (for LTE Rel-10 and beyond)
- TDD UL subframe configured by eIMTA feature (for LTE Rel-12 and beyond)

6 DL concepts

Editor's notes: FDD and TDD, and licensed and unlicensed bands will be considered. If there are specific transmission schemes or technical features for the specific usage case, new section(s) and/or subsection(s) will be created.

6.1 Basic transmission scheme

The downlink transmission scheme is based on OFDM.

Petitioners' Exhibit 1003, p. 1233
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.1.1 Modulation scheme

QPSK, 16QAM, 64QAM and 256QAM (with the same constellation mapping as in LTE) are supported.

Commented [T7]: [Editor's note] Nnot precluding other constellation mappings. Note that there might be possibility to exclude some of above constellation mapping based on the further study

6.1.2 Physical layer channel

NR defines physical resource block (PRB) where the number of subcarriers per PRB is the same for all numerologies.

Commented [T8]: TBD [12 or 16]

6.1.2.1 Physical resource multiplexing

Commented [T9]: [Editor's note] Mulitplexing different numerologies are catpured in this sub-section.

Multiplexing different numerologies within a same NR carrier bandwidth (from the network perspective) is supported in TDM and/or FDM manner for both downlink and uplink. From UE perspective, multiplexing different numerologies is performed in TDM and/or FDM manner within/across (a) subframe duration(s). For subcarrier spacing of $2^m \times 15$ kHz, subcarriers are mapped on the subset/superset of those for subcarrier spacing of 15kHz in a nested manner in the frequency domain and the PRB grids are defined as the subset/superset of the PRB grid for subcarrier spacing of 15kHz in a nested manner in the frequency domain.

Commented [T10]: [Editor's note]RB is modified to PRB

From network perspective, multiplexing of transmissions with different latency and/or reliability requirements for eMBB/URLLC in DL is supported by using the same subcarrier spacing with the same CP overhead or using different subcarrier spacing. In the specification, both approaches are to be supported. NR supports dynamic resource sharing between different latency and/or reliability requirements for eMBB/URLLC in DL.

6.1.2.1 Data channel

6.1.2.2 Control channel

In frequency-domain, a PRB (or a multiple of PRBs) is the resource unit size (may or may not including DM-RS) for control channel. A DL control channel can be mapped on one or more NR-CCEs where an NR-CCE includes an positive integer number of PRBs. This is at least for the case where the DL control region consists of one or a few OFDM symbol(s) of a slot or a mini-slot.

In the frequency-domain aspects, a UE monitors for downlink control information in one or more “control subband” where a “control subband” is smaller than or equal to the carrier bandwidth (up to a certain limit) and consists of an integer number of RBs/PRBs in the frequency domain. This does not preclude that UE may receive additional control information elsewhere within or outside the control subband in the same or different OFDM symbol(s). UE-specific DL control information monitoring occasions at least in time domain can be configured.

From gNB perspective, DL control channel can be located at the first OFDM symbol(s) in a slot and/or mini-slot

UE/NR-PDCCH-specific DM-RS and shared/common RS are supported for NR-PDCCH reception. At least for beamforming, UE may assume the same precoding operation for NR-PDCCH and associated DM-RS for NR-PDCCH.

Transmit diversity supported.

6.1.3 Waveform

OFDM-based waveform is supported. At least up to 40 GHz for eMBB and URLLC services, CP-OFDM based waveform supports spectral utilization of Y greater than that of LTE (assuming Y=90% for LTE) where Y (%) is defined as transmission bandwidth configuration / channel bandwidth * 100%.

6.1.4 Multiple access scheme

Synchronous/scheduling-based orthogonal multiple access is at least supported for DL transmissions, at least targeting for eMBB.

Petitioners' Exhibit 1003, p. 1234
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

6.1.5 Channel coding

The channel coding scheme for eMBB data is LDPC, at least for information block size > X. Channel coding techniques for NR should support info block size K flexibility and codeword size flexibility where basic code design with rate matching (i.e., puncturing and/or repetition) supports 1-bit granularity in codeword size. Channel coding technique(s) designed for data channels of NR support both Incremental Redundancy (IR) (or similar) and Chase Combining (CC) HARQ.

Commented [T11]: [Editor's note]
-FFS until RAN1#87 one of Polar, LDPC, Turbo is supported for information block size of eMBB data <= X
oThe selection will focus on all categories of observation, including overall implementation complexity, regardless of the number of coding schemes in the resulting solution (except if other factors are generally roughly equal)
-The value of X is FFS until RAN1#87, 128 <= X <= 1024 bits, taking complexity into account
-The channel coding scheme(s) for URLLC, mMTC and control channels are FFS

6.1.6 Multi-antenna scheme

6.1.6.1 Beam management

In NR, beam management is defined as follows:

- **Beam management:** a set of L1/L2 procedures to acquire and maintain a set of TRP(s) and/or UE beams that can be used for DL and UL transmission/reception, which include at least following aspects:
  - **Beam determination:** for TRP(s) or UE to select of its own Tx/Rx beam(s).
  - **Beam measurement:** for TRP(s) or UE to measure characteristics of received beamformed signals
  - **Beam reporting:** for UE to report information a property/quality of of beamformed signal(s) based on beam measurement
  - **Beam sweeping:** operation of covering a spatial area, with beams transmitted and/or received during a time interval in a predetermined way.

The following DL L1/L2 beam management procedures are supported within one or multiple TRPs:

- P-1: is used to enable UE measurement on different TRP Tx beams to support selection of TRP Tx beams/UE Rx beam(s)

Commented [T12]: FFS: TRP Tx beam and UE Rx beam can be determined jointly or sequentially

For beamforming at TRP, it typically includes a intra/inter-TRP Tx beam sweep from a set of different beams. For beamforming at UE, it typically includes a UE Rx beam sweep from a set of different beams.

- P-2: is used to enable UE measurement on different TRP Tx beams to possibly change inter/intra-TRP Tx beam(s)

From a possibly smaller set of beams for beam refinement than in P-1. Note that P-2 can be a special case of P-1.

- P-3: is used to enable UE measurement on the same TRP Tx beam to change UE Rx beam in the case UE uses beamforming

At least network triggered aperiodic beam reporting is supported under P-1, P-2, and P-3 related operations.

For downlink, NR supports beam management with and without beam-related indication. When beam-related indication is provided, information pertaining to UE-side beamforming/receiving procedure used for data reception can be indicated through QCL to UE.

Based on RS (used for beam management) transmitted by TRP, UE reports information associated with N selected Tx beams.

NR supports mechanism(s) in the case of link failure and/or blockage for NR.

NR supports using same or different beams on control channel and the corresponding data channel transmissions.

6.1.6.2 MIMO schemes

DL DMRS based spatial multiplexing (SU-MIMO/MU-MIMO) is supported. At least 8 orthogonal DL DMRS ports are supported for SU-MIMO scheduling and at least 8 orthogonal DL DMRS ports are supported for MU-MIMO scheduling.

Dynamic switching between transmission methods/schemes is supported.

Petitioners' Exhibit 1003, p. 1235
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

For coordinated transmission schemes for NR, both the case of co-located TRPs and the case of non-co-located TRPs are considered. For coordinated transmission schemes for NR, different types of coordinated transmission schemes for NR are supported.

Downlink transmission scheme(s) achieving diversity gain at least for some control information transmission is supported.

6.1.6.3 CSI acquisition

For NR, DL CSI measurement with X antenna ports is supported. At least for CSI acquisition, NR supports CSI-RS and SRS.

Commented [T13]: [Editor's note] The value of X is under investigation, as
Study the values of X = 1, 2 ,4,8,12,16,20,24,28,32

NR supports aperiodic CSI reporting. NR also supports at least one of following:

- Periodic CSI reporting
  - It can be configured by higher layer
- Semi-persistent CSI reporting
  - Configuration of CSI reporting can be activated or de-activated

CSI reporting with two types of spatial information feedback is supported.

- Type I feedback: Normal
  - Type I feedback is codebook-based PMI feedback with normal spatial resolution
  - Type I feedback supports at least the following (DL) CSI reporting parameters.
    - Resource selection indicator (Examples for further study are reference signal resource, port, reference signal sequence, beam)
    - RI (rank indicator)
    - PMI (precoding matrix indicator)
    - Channel quality feedback
- Type II feedback: Enhanced
  - "Explicit" feedback and/or codebook-based feedback with higher spatial resolution

For Type I and II, CSI feedback per subband as well as wideband feedback are supported. For Type I and II, beam-related feedback can be also included.

With regard to relating CSI-RS transmission and CSI reporting, the following combinations are supported at least

- Aperiodic CSI reporting with aperiodic CSI-RS
- Aperiodic CSI reporting with semi-persistent/periodic CSI-RS
- Semi-persistent/periodic CSI reporting with semi-persistent/periodic CSI-RS

To support combinations above more flexibly, NR should allow independent control of CSI-RS indication and CSI reporting indication timings. The indication may refer to triggering, activation, and deactivation depending on type of RS/reporting.

CSI-related settings consisting of:

- CSI reporting settings
- RS (at least for CSI measurement) settings, e.g. CSI-RS (CSI-IM as a special case)
- CSI measurement settings: To configure which RS setting is used for a particular CSI reporting setting

Petitioners' Exhibit 1003, p. 1236
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Interference measurement under different interference hypothesis should be supported in NR. For interference measurement, at least one of the following schemes is supported.

- Measurement subsets in both time and frequency domain
- Interference measurement restriction in both time and frequency domain

6.1.6.4 Reference signal related to multi-antenna scheme

All physical channels and reference signals in NR are transmitted using antenna ports NR supports NR RS configured on a per UE basis. At least the following RSs are supported for NR downlink

- CSI-RS: Reference signal with main functionalities of CSI acquisition, beam management
- DM-RS: Reference signal with main functionalities of data and control demodulation
- Reference signal for phase tracking
- Reference signal for time/freq. tracking
- Reference signal for Radio link monitoring
- RS for RRM measurement

Commented [T14]: [Editor's note] definition of antenna port is working assumption at RAN1#86

Commented [T15]: [Editor's note] Naming of NR-RS needs to be checked later.

6.1.6.4.1 CSI-RS

NR supports aperiodic transmission of CSI-RS. For CSI-RS transmission, in addition, NR supports at least one of following:

- Semi-persistent transmission
- Preconfigured CSI-RS resources can be activated or de-activated
- Periodic transmission

Periodic transmission can be configured by higher layer signaling

NR CSI-RS pattern with at least the following properties is supported.

- CSI-RS mapped in one or multiple [consecutive] symbols

The following configurations of NR CSI-RS are supported.

- UE-specific configuration to support
  - Wideband CSI-RS, i.e. from UE perspective, the full bandwidth the UE is configured to operate with
  - Partial-band CSI-RS, i.e. from UE perspective, part of the bandwidth the UE is configured to operate with

CSI-RS configuration for NR also includes at least ‘number of antenna ports’. Configuration can be explicit or implicit. The number of CSI-RS antenna ports can be independently configured for periodic/semi-persistent CSI reporting and aperiodic CSI reporting

6.1.6.5 Quasi-colocation

Definition of quasi-colocation (QCL) is that two antenna ports are said to be quasi co-located if properties of the channel over which a symbol on one antenna port is conveyed can be inferred from the channel over which a symbol on the other antenna port is conveyed.

For DM-RS antenna ports, NR supports:

- All ports are quasi-collocated.

Petitioners' Exhibit 1003, p. 1237
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Not all ports are quasi-collocated.

6.2 Physical layer procedure

6.2.1 Scheduling

NR supports both data and control with the same numerology. NR supports at least same-slot and cross-slot scheduling for both DL and UL. For slot-based scheduling, DL data reception in slot *N* and corresponding acknowledgment in slot *N*+*K*1 is to be specified.

6.2.2 HARQ

Operation of more than one DL HARQ processes is supported for a given UE while operation of one DL HARQ process is supported for some UEs. Asynchronous and adaptive DL HARQ is supported at least for eMBB. From UE perspective, HARQ ACK/NACK feedback for multiple DL transmissions in time can be transmitted in one UL data/control region. Timing relationship between DL data reception and corresponding acknowledgement can be dynamically indicated by L1 signaling (e.g., DCI), semi-statically indicated to a UE via higher layer, or a combination of indication by higher layers and dynamic L1 signaling (e.g., DCI).

Commented [T16]: [Editor's note] one or more of, FFS which ones

6.2.3 Initial access and mobility

6.2.3.1 Synchronization signal and DL broadcast signal/channel structure

NR synchronization signal is based on CP-OFDM. NR defines at least two types of synchronization signals; NR-PSS and NR-SSS. NR-PSS is defined at least for initial symbol boundary synchronization to the NR cell. NR-SSS is defined for detection of NR cell ID or at least part of NR cell ID. The number of NR cell IDs is targeted to be at least 504. NR-SSS detection is based on the fixed time/frequency relationship with NR-PSS resource position irrespective of duplex mode and beam operation type at least within a given frequency range and CP overhead.

At least one broadcast channel (NR-PBCH) is defined. NR-PBCH decoding is based on the fixed relationship with NR-PSS and/or NR-SSS resource position irrespective of duplex mode and beam operation type at least within a given frequency range and CP overhead.

NR-PSS, NR-SSS and/or NR-PBCH can be transmitted within a SS block. One or multiple SS block(s) compose an SS burst. One or multiple SS burst(s) further compose an SS burst set where the number of SS bursts within a SS burst set is finite. From physical layer specification perspective, at least one periodicity of SS burst set is supported.

At least one subcarrier spacing for each synchronization signal (e.g. NR PSS,SSS, PBCH) is predefined in the specification for a given frequency range.

6.2.3.2 Initial access procedure

6.2.3.3 Mobility

For RRM measurement in NR, DL measurement is supported with the consideration on both single-beam based operation and multi-beam based operation. NR supports cell-level mobility based on DL cell-level measurement (e.g. RSRP for each cell) in IDLE mode UE. Note that IDLE mode refers to a UE state similar to LTE IDLE state, whose exact definition is up to RAN2 and CONNECTED mode refers to a UE state similar to LTE CONNECTED state, whose exact definition is up to RAN2. Also, note that cell refers to NR cell which is tied to a same ID carried by NR-SS.

Commented [T17]: [Editor's note] There is no conclusion that DL measurement is a complete solution for RRM measurement in NR for now

For L3 mobility based on DL measurement in CONNECTED mode UE, at least, non-UE-specific DL signals can be used for CONNECTED mode RRM measurement.

At least one of cell-level and beam-level measurement quantities is supported for RRM reporting.

6.3 Physical layer measurements

Petitioners' Exhibit 1003, p. 1238
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

7 Evaluation of DL techniques

7.1 Performance evaluation

7.1.1 Performance evaluation of waveform

Four evaluation cases for the downlink and uplink are used in link level simulation depending on evaluation purposes of each usage scenario, which are

- Case 1a, 1b: single numerology case
  - ➢ 1a: Downlink
  - ➢ 1b: Uplink, only one UE with narrow bandwidth is located at the edge of wide frequency band. It is assumed that no wide-band filter upon the whole frequency band.
- Case 2: DL mixed numerology case
- Case 3: UL single numerology case (asynchronous reception between UEs)
- Case 4: UL mixed numerology case (synchronous reception between UEs)

(also refer to these illustrations in pages 5 – 9 in R1-163558)

For each waveform, the RF nonlinearity (refer to R1-167297) is considered in the evaluation. General evaluation assumptions are provided in Annex. A.1. In order to assess the candidate techniques, the following performance metrics are considered.

Commented [T18]: [Editor's note] The detailed modeling of RF nonlinearity will be added after RAN1 receive LS reply from RAN4.

- User spectrum efficiency as performance metric
  - ➢ Take into account guard band and time domain overhead. The values and their calculation method of guard band and time domain overhead should be reported.
  - ➢ BLER vs SNR should be reported for calibration
  - ➢ OOBE level is reported (Similar to ACLR but applied to adjacent sub-band/UE instead of carrier)
- EVM (FFS: clear definition)
- PAPR/Cubic metric
- UE Complexity (FFS: how to quantify)
- The following is also reported
  - ➢ Receiver waveform design
  - ➢ Rx processing delay (FFS: definition)
- Power spectral density

Commented [T19]: [Editor's note] This will be moved to Section 7.2 when details are clarified

UE spectrum efficiency is defined as follows.

$$\eta = \frac{\chi}{T \cdot \omega}$$

where χ denotes the number of correctly received information bits by target user, T is the transmission time of the target user.For Case 1a, $\omega = BW_{carrier}$ is the whole bandwidth including system guard band. For Case 1b, 2, 3, and 4, ω is the data bandwidth plus guard tone of the target UE. General evaluation assumptions are provided in Annex. A.1

Evaluation observations for the downlink are summarized as below.

Petitioners' Exhibit 1003, p. 1239
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Some evaluations in RAN1 show that Y for a NR carrier can be up to 98% of the evaluated channel bandwidths for both DL and UL without complexity and latency constraints [R1-166093]
- For in-band frequency multiplexing of different numerologies, it is expected that spectrum confinement on sub-band basis is specified as requirements on transmitter side in-band emission and EVM requirements and reception performance in presence of other-subband interferer.
- From RAN1 perspective, spectral confinement technique(s) (e.g. filtering, windowing, etc.) for a waveform at the transmitter is transparent to the receiver.

Commented [T20]: [Editor's note] Definition of subband will be revisited if necessary

7.1.2 Performance evaluation of multiple access

Evaluation for multiple access schemes consider the following usage scenario families defined in [TR38.913].

- eMBB: dense urban, urban macro, rural, indoor
- mMTC: urban coverage for massive connection
- URLLC: FFS

Commented [T21]: [Editor's note] Other scenarios (e.g., eV2X) are not precluded

Link-level simulation and system-level simulation are used for multiple access evaluation. Link level simulation is used for feasibility investigation of new multiple access proposals, comparison of different proposals in typical scenarios. System level simulation is used for comparison of proposals, and verification with traffic/scheduling/multi-cell interference dynamics. Note that link level simulation includes link level simulation with optional analytical model. For link level simulation, the following evaluation metrics are considered.

- BLER vs SNR reported for UL and DL calibration
- BS and UE receiver complexity reported
- Sum rate region
- Optional metrics:
  - Sum normalized user throughput (normalized by throughput in orthogonal case); Sum throughput with minimum throughput constraint for some users

Commented [T22]: [Editor's note] This will be moved to Section 7.2 and 7.3 when details are clarified

For system level simulation, the following are used as evaluation metrics

- eMBB: TRP spectrum efficiency and 5th percentile user spectrum efficiency; user experienced data rate and area traffic capacity; signaling overhead
- mMTC: Connection density with "connection efficiency" reported; latency for infrequent small packets; signaling overhead
- URLLC: Reliability for a target latency

General evaluation assumptions are provided in Annex. A.1.

Commented [T23]: [Editor's note] Agreed link level assumptions are provided. System level evaluation assumptions will also be added when agreed.

7.1.3 Performance evaluation of channel coding

Evaluations for channel coding candidates with similar code rates and block sizes.are conducted for each usage case of eMBB, mMTC and URLLC. General evaluation assumptions are provided in Annex. A.1.

LDPC, Polar and Turbo codes are studied and the following observations are made.

- **Performance**
  - The performance of LDPC, Polar and Turbo codes is captured in R1-1610600 (update of R1-1610423).
  - It has not yet been possible to draw conclusions directly from these captured results, owing to different views on the implementation complexities and possible enhancements which are discussed in more detail below.
- **Flexibility for code rate and code block size support**

Petitioners' Exhibit 1003, p. 1240
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- LDPC, Polar and Turbo codes can all deliver acceptable flexibility.

- **Chase- and IR-HARQ support**
  - The proponents of LDPC and Polar have shown schemes for support of both CC- and IR-HARQ in their respective codes
    - Some companies have concerns on the incremental freezing method of HARQ support for Polar codes
    - One company has concerns on the complexity of IR-HARQ for LDPC codes
  - The ability of Turbo codes to support both CC- and IR-HARQ is well known

- **Implementation complexity**
  - LDPC:
    - LDPC codes are widely implemented in commercial hardware supporting several Gbps throughput and attractive area and energy efficiency with some flexibility, but with flexibility and features that are more limited than required for NR; in relation to NR, there are concerns summarised below.
    - The area efficiency reduces for lower coding rates
    - The complexity of LDPC increases with increasing flexibility
    - Proponents consider LDPC codes with limited flexibility to provide the most attractive area and energy efficiency, and that the characteristics of LDPC codes in area and energy efficiency remain advantageous even when supporting full flexibility, while some other companies consider the applicable flexibility to be limited, for example because a flexible switched network (if used) has an impact on increasing the power, area and latency
    - LDPC codes are amenable to parallelisation which can provide better decoding latency
      - Depending on the parity check matrix design, some of this parallelism may not be exploited for all code block lengths for NR, and some companies have a concern with this and its impact on energy and area efficiency
    - Some variants of min-sum based iterative decoders are considered implementable, and allow a trade-off between complexity and performance
    - Two proponents consider quasi-ML decoders (e.g. list 32, ordered stochastic decoding) implementable for codeword sizes up to 1k
    - BP and sum-product decoders are not considered implementable for NR by some companies
    - For LDPC there are concerns that implementation with attractive area and energy efficiency may be challenging when simultaneously targeting the peak throughput and flexibility requirements of NR
  - Polar:
    - Polar codes are implementable, although there are currently no commercial implementations, and in relation to NR, there are some concerns as summarised below.
    - The area efficiency reduces for shorter block lengths and lower coding rates
    - For list decoders, the implementation complexity increases with increasing list size, especially with larger block sizes
      - Some companies consider that a List 32 decoder is implementable up to a codeword size N of at least 1k (with larger codeword sizes requiring a segmented design), although some other companies have concerns on the achievable performance (including area efficiency, hardware throughput)
      - Some companies consider that a List 8 decoder is implementable for codeword sizes N up to 4k (with larger codeword sizes requiring a segmented design)

Petitioners' Exhibit 1003, p. 1241
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- List 4 decoder is considered implementable for codeword sizes N up to at least 2k, with some companies considering it implementable up to 8k (with larger codeword sizes requiring a segmented design)
- List 1 is considered implementable

✧ For decoding hardware that can achieve acceptable latency, performance and flexibility, there are some concerns about the area efficiency and energy efficiency that are achievable with polar codes

➢ Turbo:

✧ Turbo codes are widely implemented in commercial hardware, supporting HARQ and flexibility similar to what is required for NR, but not at the high data rates or low latencies required for NR; in relation to NR, there are concerns summarised below.

✧ Proponents consider some implementations of turbo codes to meet the flexibility requirements of NR with the most attractive area and energy efficiency except at higher throughputs, and particularly at lower code rates and lower block lengths

- Other companies consider that the latency and area and energy efficiency are not adequate for NR, and that the area and energy efficiency reduces at lower block lengths
- Only two of the proponents of turbo codes propose turbo codes for the higher throughputs for NR

✧ In some implementations suitable for lower throughputs, the area and energy efficiency is constant when varying the puncturing and repetition rate.

- Otherwise, this is not the case, e.g. in some implementations designed for higher data rates

✧ The decoding complexity increases linearly with the information block size for a given mother code rate

✧ The decoding complexity increases as the contraint length increases, and to a lesser extent as the mother code rate reduces

✧ For turbo codes, there are concerns that implementation with attractive area and energy efficiency is challenging when targeting the higher throughput requirements of NR

✧ Some advanced turbo decoders are considered implementable, and allow a tradeoff between complexity and performance.

✧ Some companies consider quasi-ML decoders are implementable for shorter information block lengths and codeword sizes up to 1k

✧ The proponents consider that a turbo decoder could be designed that would be capable of decoding both LTE and at least small information block sizes (K<=6144) of NR

- Other companies consider that such reuse would be subject to multiple concerns or would not be possible

- **Latency**

➢ The proponents of all three coding families consider that their respective codes can fulfil the NR latency requirements

✧ Latency-wise, highly-parallelised decoders, as applicable for LDPC, and turbo according to some proponents, can help to reduce latency

✧ Although polar codes are not highly parallelisable, proponents consider that there are other design techniques that can help to reduce latency for polar decoders

✧ Some companies consider that polar codes may be able to achieve lower latency for decoding of small (around 1000 bits) blocks if capability of decoding large blocks is not considered; however, some other companies consider that polar decoders incurs longer latency than turbo decoders

- **Other considerations**

Petitioners' Exhibit 1003, p. 1242
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Turbo and LDPC are similarly well established, while Polar is less well established, being the newest among the three. All of the code families require effort at least in specification design, in order to meet the NR requirements. Some companies consider that less well established technologies require more effort.

7.2 Analysis of UE complexity

7.3 Analysis of Node B impacts

8 UL concepts

Editor's notes: FDD and TDD, and licensed and unlicensed bands will be considered. If there are specific transmission schemes or technical features for the specific usage case, new section(s) and/or subsection(s) will be created.

8.1 Basic transmission scheme

The uplink transmission scheme is based on OFDM.

Commented [T24]: [Editor's note] Additional low PAPR/CM technique(s), if specified, are added when agreed. Also, the waveform above 40GHz and for mMTC is to be added if agreed.

8.1.1 Modulation scheme

QPSK, 16QAM, 64QAM and 256QAM (with the same constellation mapping as in LTE) are supported.

Commented [T25]: [Editor's note] Nnot precluding other constellation mappings. Note that there might be possibility to exclude some of above constellation mapping based on the further study

8.1.2 Physical layer channel

8.1.2.1 Data channel

8.1.2.2 Control channel

At least two ways of transmissions are supported for NR UL control channel

- UL control channel can be transmitted in short duration around the last transmitted UL symbol(s) of a slot. UL control channel is time-division-multiplexed and/or frequency-division-multiplexed with UL data channel within a slot. For UL control channel in short duration, transmission over one symbol duration of a slot is supported.
- UL control channel can be transmitted in long duration over multiple UL symbols to improve coverage. UL control channel is frequency-division-multiplexed with UL data channel within a slot.

In frequency-domain, a PRB (or multiple PRBs) is the minimum resource unit size for UL control channel. The frequency resource and hopping, if hopping is used, may not spread over the carrier bandwidth. UE-specific RS is used for NR-PUCCH transmission.

At least UL transmission of at least single HARQ-ACK bit is supported.

Mechanism enabling frequency-diversity is supported.

8.1.3 Waveform

OFDM-based waveform is supported. At least up to 40 GHz for eMBB and URLLC services, CP-OFDM based waveform supports spectral utilization of Y greater than that of LTE (assuming Y=90% for LTE) where Y (%) is defined as transmission bandwidth configuration / channel bandwidth * 100%.

DFT-S-OFDM based waveform is also supported, complementary to CP-OFDM waveform at least for eMBB uplink for up to 40GHz. CP-OFDM waveform can be used for a single-stream and multi-stream (i.e. MIMO) transmissions, while DFT-S-OFDM based waveform is limited to a single stream transmissions (targeting for link budget limited cases). Network can decide and communicate to the UE which one of CP-OFDM and DFT-S-OFDM based waveforms to use Note that both CP-OFDM and DFT-S-OFDM based waveforms are mandatory for UEs.

Petitioners' Exhibit 1003, p. 1243
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

8.1.4 Multiple access scheme

Synchronous/scheduling-based orthogonal multiple access is at least supported for UL transmissions, at least targeting for eMBB. Note that synchronous means that timing offset between UEs is within cyclic prefix by e.g. timing alignment.

8.1.5 Channel coding

8.1.6 Multi-antenna scheme

8.1.6.1 Beam management

8.1.6.2 MIMO schemes

The following aspects for UL MIMO transmission should be supported. Transmission schemes/methods for reciprocity calibrated UEs, reciprocity non-calibrated UEs, and non-reciprocity/partial reciprocity cases are considered.

- At least one of the following candidate schemes/methods is to be supported
  - Candidate 1: Codebook based transmission
  - Candidate 2: Non-codebook based transmission

Dynamic switching between transmission methods/schemes is supported.

UL DMRS based spatial multiplexing (SU-MIMO/MU-MIMO) is supported. At least a maximum of 4 layers uplink SU-MIMO transmission is supported.

At least one of precoded and non-precoded SRS based UL link adaptation procedure is supported in NR, with at least following three different procedures:

- UL data scheduling (MCS/precoder/rank) is based on non-precoded SRS transmission by UE
  - Configurable number of SRS ports are 1, 2, 4, or [8].
- UL data scheduling (MCS/precoder/rank) is based on precoded SRS(s) transmission by UE
  - Configurable number of SRS ports are 1, 2, or 4.
  - Multiple precoded SRS resources (if supported) can be configured.
  - At least one of the following is supported
    - Precoder for SRS can be determined by UE based on measurement on DL RS and
    - Precoder for SRS can be indicated by gNB
- UL data scheduling (MCS/precoder/rank) is based on a combination of non-precoded and precoded SRS transmission by UE

Note that some parts of above procedures might be transparent to UE.

8.1.6.3 Reference signal related to multi-antenna scheme

The following RSs are at least supported for NR uplink.

- SRS: Reference signal with main functionalities of CSI acquisition, beam management
- DM-RS: Reference signal with main functionalities of data and control demodulation
- Reference signal for phase tracking

Petitioners' Exhibit 1003, p. 1244
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

8.1.6.3.1 SRS

Configurable SRS bandwidth is supported. Partial band size and full band size can be configured. Partial-band is smaller than the largest transmission bandwidth supported by the UE. Within a partial-band the PRBs for SRS transmission can at least be consecutive in the frequency domain. For the full band size, the size is equal to the largest transmission bandwidth supported by the UE.

Aperiodic SRS transmission triggered by the network is supported.

8.2 Physical layer procedure

8.2.1 Random access procedure

8.2.1.1 Preamble

NR supports multiple RACH preamble formats, including at least RACH preamble formats with longer preamble length and shorter preamble length. Multiple/repeated RACH preambles in a RACH resource are supported. Numerology for RACH preamble can be different depending on frequency ranges. Numerology for RACH preamble can be different or the same from that for the other UL data/control channels.

8.2.1.2 Procedure

RACH procedure including RACH preamble (Msg. 1), random access response (Msg. 2), message 3, and message 4 is assumed for NR from physical layer perspective.

RACH resource is defined as a time-frequency resource to send RACH preamble. Whether UE needs to transmit one or multiple/repeated preamble within a subset of RACH resources can be informed by broadcast system information, e.g., to cover gNB RX beam sweeping in case of NO Tx/Rx reciprocity at the gNB.

Regardless of whether Tx/Rx reciprocity is available or not at gNB at least for multiple beams operation, the following RACH procedure is considered for at least UE in idle mode. Association between one or multiple occasions for DL broadcast channel/signal and a subset of RACH resources is informed to UE by broadcast system information or known to UE. Based on the DL measurement and the corresponding association, UE selects the subset of RACH resources. When Tx/Rx reciprocity is available at gNB, the DL Tx beam for the UE can be obtained based on the detected RACH preamble and would be also applied to Message 2. Then, UL grant in message 2 may indicate the transmission timing of message 3.

Commented [T26]: [Editor's note] The case when Tx/Rx reciprocity is not available is FFS.

8.2.2 Scheduling

NR supports both data and control with the same numerology. The same-slot and cross-slot scheduling for UL is supported. Timing relationship between UL assignment and corresponding UL data transmission can be dynamically indicated by L1 signaling (e.g., DCI), semi-statically indicated to a UE via higher layer, or a combination of indication by higher layers and dynamic L1 signaling (e.g., DCI). For slot-based scheduling, UL assignment in slot N and corresponding uplink data transmission in slot $N+K2$ is to be specified.

Commented [T27]: [Editor's note] one or more of, FFS which ones

8.2.3 HARQ

Operation of more than one UL HARQ processes is supported for a given UE while operation of one UL HARQ process is also supported for some UEs. Asynchronous and adaptive UL HARQ is supported at least for eMBB.

Petitioners' Exhibit 1003, p. 1245
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

8.3 Physical layer measurements

9 Evaluation of UL techniques

9.1 Performance evaluation

9.1.1 Performance evaluation of waveform

Evaluation cases, i.e., Case 3 and 4, and performance metrics for the uplink are described in Section 7.1.1. General evaluation assumptions are provided in Annex. A.1.

Evaluation observations for the uplink are summarized as below.

- Some evaluations in RAN1 show that Y for a NR carrier can be up to 98% of the evaluated channel bandwidths for both DL and UL without complexity and latency constraints [R1-166093]
- For in-band frequency multiplexing of different numerologies, it is expected that spectrum confinement on sub-band basis is specified as requirements on transmitter side in-band emission and EVM requirements and reception performance in presence of other subband interferer.
- From RAN1 perspective, spectral confinement technique(s) (e.g. filtering, windowing, etc.) for a waveform at the transmitter is transparent to the receiver.

Commented [T28]: [Editor's note] Definition of subband will be revisited if necessary

9.1.2 Performance evaluation of multiple access

Evaluation cases and performance metrics for the uplink are followed by those for the downlink described in Section 7.1.2. For link level simulation, the following evaluation metrics are considered.

- BLER vs SNR reported for UL and DL calibration
- BS and UE receiver complexity reported
- Sum throughput v.s. SNR at given BLER level under different overloading factor.
  - Overload factor is defined as
    - For spreading case: number of data layers (users) / spreading length (number of REs)
    - For non-spreading case: number of data layers (users) on each RE
- Link budget (MCL with specific data rate)
- Other metrics FFS (e.g., Maximum overloading factor v.s. SNR at given user throughput)

Commented [T29]: [Editor's note] This will be moved to Section 9.2 and 9.3 when details are clarified

For system level simulation, the same evaluation metrics described in Section 9.1.2 are applicable. General evaluation assumptions are provided in Annex. A.1. For the SLS evaluation for grant-free UL multiple access schemes applied to mMTC, packet drop rate vs. packet arrival rate per cell curve is used, where grant-free UL multiple access schemes has the following characteristics

- A transmission from UE does not need the dynamic and explicit scheduling grant from eNB
- Multiple UEs can share the same time and frequency resources

and packet drop rate is defined as (Number of packet in outage) / (number of generated packets), where a packet is in outage if this packet failed to be successfully received by destination receiver beyond "Packet dropping timer" The UL traffic model to use for evaluation of grant-free UL multiple access applied to mMTC is also shown in Annex A.2.

A MA physical resource for "grant-free" UL transmission is comprised of a time-frequency block. Note that spatial dimension is not considered as a physical resource in this context. A MA resource is comprised of a MA physical resource and a MA signature, where a MA signature includes at least one of the following:

Commented [T30]: [Editor's note] Details on MA physical resource and MA signature resource FFS

Petitioners' Exhibit 1003, p. 1246
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Codebook/Codeword
- Sequence
- Interleaver and/or mapping pattern
- Demodulation reference signal
- Preamble
- Spatial-dimension
- Power-dimension
- Others are not precluded

The baseline multiple access scheme to assess the candidate techniques is described in Table A.9.1.2-1.

Table 9.1.2-1: Baseline scheme of calibration purpose for evaluation of grant-free UL multiple access schemes.

Attributes	Assumptions
Waveform	CP-OFDM as the UL waveform • UL DMRS overhead, 1 OFDM symbol out of 7 OFDM symbols
Resource allocation	A UE selects a MA physical resource randomly from a pool of orthogonal MA physical resources There is no partial overlapping between the MA physical resources selected by more than one UE All orthogonal MA physical resources are of same size Total allocated bandwidth: 6RB, 4RB (optional) for calibration purpose only Bandwidth per user per transmission: 1 RB
Receiver	MMSE-IRC, assuming ideal channel estimation for calibration purpose only • 2Rx • No blind decoding assumed
MCS	Same for all UEs • Derived by the bandwidth per user of 1 RB and TB size of 160 bits per transmission • QPSK
Power control	Open loop power control: Alpha=1, P0= -90 dBm
Packet size	Fixed by 20 bytes TB size with CRC included
HARQ retransmission	No. of transmission is 1 (i.e., no repetition or retransmission)
Traffic model	FTP 3 with fixed TB size
Average no. of users per sector	20 assuming 3 sectors/cell, total 57 sectors
Channel code	LTE Turbo

Commented [T31]: [Editor's note] Companies are encouraged to provide calibration results for both values, Either value can be used for later evaluation of the proposed MA scheme

Commented [T32]: [Editor's note] A few companies share different views. This power control setting for evaluation can be discussed later.

All proposed non-orthogonal MA schemes studied for UL transmission share the following common features:

- At the transmitter side: using MA signature(s)
- At the receiver side: allowing multi-user detector

All proposed non-orthogonal MA schemes for UL transmission on a high level follow the following basic diagram as shown in Figure 9.1.2-1. Note that the basic diagram is not intended to capture all the details or to be a complete diagram.

Petitioners' Exhibit 1003, p. 1247
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

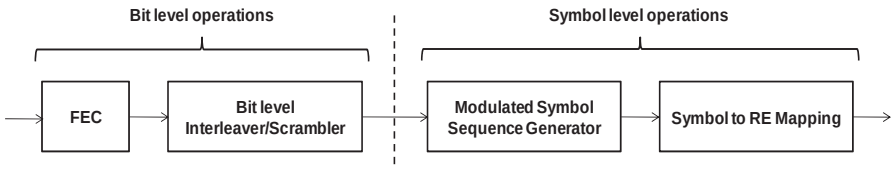


Figure 9.1.2-1: High level block diagram for UL non-orthogonal MA schemes.

Table 9.1.2-2 and 9.1.2-3 provides the link-level simulation assumptions for evaluating various UL non-orthogonal multiple access schemes. Table 9.1.2-4 – Table 9.1.2-6 provides summary of link level simulation results comparing non-orthogonal multiple access schemes with OFDMA. In the table, each source corresponds to the following references.

Commented [T33]: [Editor's note] The resutls are to be added according to the outcome of email discussion.

- Source1: R1-164037, R1-166094, R1-1608853, R1-162153
- Source2: R1-166404, R1-1608953
- Source3: R1-167870, R1-1608755
- Source4: R1-164329, R1-166670, R1-1610478
- Source5: R1-163992, R1-166750, R1-1609041, R1-1612574
- Source6: R1-164557, R1-166876, R1-1609223
- Source7: R1-167340, R1-1609548
- Source8: R1-1610078
- Source9: R1-167537, R1-167536, R1-1609332, R1-167872, R1-1609613, R1-1609333, R1-167872
- Source10: R1-167602, R1-165287, R1-167602
- Source11: R1-167700, R1-1609497, R1-1610918, R1-1610375
- Source12: R1-167105
- Source13: R1-1610118
- Source14: R1-165019, R1-1609651
- Source15: R1-165435, R1-165435

Based on the contributions and the assumptions listed in Table 9.1.2-2, evaluation results shown in Table 9.1.2-3, and also the link level simulation results summary template in [R1-1610530], it is observed

- Non-orthogonal MA, in some of the evaluated scenarios, provides significant gain in terms of UL link-level sum throughput and overloading capability with ideal and realistic channel estimation.
- Some non-orthogonal MA results combined with narrowband and/or repetition operations can reach -164 dB MCL @160bps data rate, which meets the coverage requirement for NR.
- Non-orthogonal MA schemes using an advanced receiver have little or no performance loss due to MA signature (except RS) collision.

Table 9.1.2-2: Link-level evaluation assumptions

Parameters	Values or assumptions	Further specified values reported
Carrier Frequency	2 GHz	
Waveform	OFDM /SC-FDMA Other waveform is not precluded	OFDMA with equal bandwidth and distributed subcarrier allocation or OFDMA with orthogonal Walsh code

Petitioners' Exhibit 1003, p. 1248
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Numerology	Same as Release 13	
System Bandwidth	10 MHz	Allocated bandwidth reported: 4RB, 6RB, 12RB The same for non-orthogonal MA and OFDMA
Target spectral efficiency	Proponents report per UE spectral efficiency and the number of UEs multiplexed if multi-UEs LLS is assumed	The same target per UE spectral efficiency for non-orthogonal MA and OFDMA Without short-term (per TTI) MCS adaptation Detail of reported target SE per user and the number of users are listed in Table 3
BS antenna configuration	2/4 Rx as baseline 8Rx optional	See Table 3
UE antenna configuration	1Tx	
Transmission mode	TM1 (refer to TS36.213)	
SNR distribution of Multiple UEs	Proponents report if single-user or multi-user LLS is used, and what SNR distribution is assumed.	Either equal long-term SNR and/or unequal long-term SNR has been considered Detail of assumptions listed in Table 3
Propagation channel & UE velocity	TDL for in TR38.900 as mandatory EPA, EVA, ETU as optional 3km/h, 30km/h, 120km/h	See Table 3
Max number of HARQ transmission	1, 4	1
Channel estimation		Either ideal and/or realistic channel estimation has been considered Detail of assumptions listed in Table 3
MA signature allocation		Either fixed and/or random MA signature (e.g., codebook, sequence, interleaver, etc.) allocation has been considered Detail of assumptions listed in Table 3
Timing/frequency offset		Frequency offset not considered Timing offset of either within CP and/or beyond CP has been considered Detail of assumptions listed in Table 3
SNR definition		SNR is either defined at the transmitter per layer or at the receiver as the sum per RE

Petitioners' Exhibit 1003, p. 1249
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 9.1.2-3: Assumptions of preliminary link-level simulation results for non-orthogonal multiple access schemes comparing with OFDMA

Source	Source 1, Source 10, Source 12, Source 15	Source 2	Source 3, Source 10, Source 15	Source 4	Source 5	Source 6	Source 7	Source 8, Source 9	Source 9	Source 9	Source 11	Source 9	Source 13	Source 14
Multiple access scheme	SCMA	MUSA	PDMA	LDS-SVE	IGMA	NCMA	LSSA	NOMA	GOCA	RDMA	LCRS	MU-MIMO	RSMA	NOCA
Spectral efficiency (Bit/RE per UE)	0.05~0.5	0.125, 0.25	0.0417,0.0833, 0.2083, 0.3333	0.33, 0.35	0.083,0.171, 0.222	0.0625, 0.25	0.0833, 0.0926, 0.111, 0.166, 0.375	0.144, 0.25, 0.5	0.157, 0.222	0.157, 0.222	0.001~0.33	1.25, 0.625	0.25, 0.375. 0.5, 0.75, 1	0.069
Number of UEs	4, 6, 8, 12	4~40	4, 8, 12	6	6,8 (10~16 not compared with OFDMA)	4, 6, 8	4, 6, 8, 12, 24	2, 4, 8, 12	6, 8, 12	6, 8, 12	1, 8	2	4	12, 18
Channel Type	TDL-A, TDL-C, EPA	TDL-A, TDL-C	TDL-A, TDL-C, EPA	TDL-A, TDL-B, TDL-C	TDL-A, TDL-C,	TDL-C	TDL-C	TDL-C	TDL-A,TDL-C	TDL-A,TDL-C	EPA, EVA,TDL-A, TDL-C	TDL-C	TDL-A,TDL-C	TDL-A,TDL-C
Antenna Config.	1T2R	1T2R	1T2R	1T2R	1T2R	1T2R	1T2R	1T2R	1T2R	1T2R	1T2R	1T2R	1T2R, 1T4R	1T2R
SNR distribution	Equal /unequal	Equal /unequal	Equal	Equal	Equal	Equal	Equal	Equal /unequal	Equal /unequal	Equal /unequal	Equal	Equal	Equal /unequal	Equal / unequal
MA signature allocation	Fixed /random	Random, No dedicate RS	Fixed	Fixed	Fixed /random	Fixed	Fixed	Fixed	Fixed /random	Fixed /random	Fixed	Fixed	Fixed	Fixed
Channel estimation	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal /realistic	Ideal	Ideal /realistic
Timing offset	Within CP	Within CP	Within CP	Within CP	Within CP	Within CP	Within CP	Within CP	Within CP	Within CP	Within CP	Within CP	Within CP	Within CP

Petitioners' Exhibit 1003, p. 1250
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 9.1.2-4: Range of SNR gain of non-orthogonal multiple access over OFDMA with ideal channel estimation

Source		Source 1]	Source 3	Source 9	Source 9	Source 4	Source 6	Source 13	Source 2	Source 5]	Source 7]	Source 11	Source 9	Source 8	Source 14
Multiple access scheme		SCMA	PDMA	GOCA	RDMA	LDS-SVE	NCMA	RSMA	MUSA	IGMA	LSSA	LCRS	MU-MIMO	NOMA	NOCA
Receiver type		MPA	MPA	MF-based SIC	MF-based SIC	MPA w/o iterative decoding	MMSE-IRC w/ SIC	Iterative Demapper	MMSE-SIC	Chip-by chip MAP	Iterative MMSE-PIC	MMSE-PIC	SIC	MMSE-CWIC	MMSE-PIC
whether CRC is included		excluded	excluded	excluded	excluded	excluded	excluded	excluded	excluded	excluded	included	excluded	excluded	excluded	excluded
MA signature setting		fixed & random	fixed	Fixed	fixed	fixed	fixed	fixed	random	fixed	fixed	fixed	fixed	fixed	fixed
# of UEs	**SE Range (bits/RE per UE)**	**Range/value of SNR gain (dB)**													
2	(0.2, 1.0]												[0.1, 3.7)		
4	[0.05, 0.1]	[0.0, 0.8]	0.3[SE = 0.0833]	-	-	-	0.7	-		-	-				
	(0.1, 0.2]	[1.3, 1.8]	0.3[SE =0.2083]	-	-	-	-	-		-	-				
	(0.2, 1.0]	[1.9, 2.5]	0.8 [SE = 0.3333]	-	-	-	1.7	[0.9, 6.5]	[0, 0.1]	-	-	[0.5, 2.2]			
6	[0.05, 0.1]	[0.1, 1.5]	-	-	-	-	0.7	-		0.8	-				
	(0.1, 0.2]	[2.5, 2.7]	-	-	-	-	-	-		1.6	-				
	(0.2, 1.0]	[3.3, 4.9]	-	[0.9, 1.8]	[0.7, 2.0]	1	2.8	-	[0.8,1]	2.5	-				
8	[0.05, 0.1]	[0.6, 2.6]	1.1 [SE = 0.0833]	-	-	-	0.6	-		0.9	-				
	(0.1, 0.2]	[3.4, 4.7]	2.6[SE =0.2083]	[0.8, 2.0]	[0.8, 2.2]	-	-	-		3.1	-				
	(0.2, 1.0]	[3.4, 7.0]	3.2 [SE = 0.3333]	[0.7, 2.2]	[0.6, 2.1]	-	3.6	-	[2.3,2.5]	-	-				
12	[0.05, 0.1]	[1.4, 4.2]	-	-	-	-	-	-		-	-				2.5, 2.7 (SE=0.069)
	(0.1, 0.2]	[5.2, 6.4]	4.5[SE =0.2083]	[1.3, 2.7]	[1.0, 2.7]	-	-	-		-	-				

Petitioners' Exhibit 1003, p. 1251
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

	(0.2, 1.0]	[6.3, 12.3]	5.0[SE = 0.3333]	-	-	-	-	-	4.1	-	-				
18	[0.05, 0.1]	-	-	-	-	-	-	-		-	3.5				-0.3, 0.29 (SE=0.069)
	(0.1, 0.2]	-	-	-	-	-	-	-		-	3.1				
	(0.2, 1.0]	-	-	-	-	-	-	-		-	-				
20	[0.2,1.0]								[5.6,8.4]						
40	[0.2,1.1]								14.6						
Note 1: SNR is defined as total received SNR per RE per Rx antenna at eNB. Note 2: The empty entries in the table are due to absence of simulation data.															

Petitioners' Exhibit 1003, p. 1252
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 9.1.2-5: Range of SNR gain of non-orthogonal multiple access over OFDMA with realistic channel estimation

Source		Source 1	Source 3	Source 9	Source 9	Source 4	Source 6	Source 2	Source 5	Source 7	Source 8	Source 9	Source 11
Multiple access scheme		SCMA	PDMA	GOCA	RDMA	LDS-SVE	NCMA	MUSA	IGMA	LSSA	NOMA	NB-IoT MU	LCRS
Receiver type		MPA	MPA	MF-based SIC	MF-based SIC	MPA w/o iterative decoding	MMSE-IRC w/ SIC	MMSE-SIC	Chip-by chip MAP	Iterative MMSE-PIC	MMSE-CWIC	SIC	MMSE-PIC
whether CRC is included		excluded	excluded	excluded	excluded	excluded	excluded	excluded	Excluded	included	excluded	excluded	excluded
MA signature setting		fixed & random	fixed	fixed	fixed	fixed	fixed	random	Fixed	fixed	fixed	fixed	fixed
# of UEs	**SE Range (bits/RE per UE)**	**Range/value of SNR gain (dB)**											
2	(0.2, 1.0]											[-1.3, 3.3]	
4	[0.05, 0.1]	[0, 0.4]	0.1[SE = 0.0833]	-	-	-	-1.4		-	-	-		
	(0.1, 0.2]	[0.8, 1.4]	0.2[SE = 0.2083]	-	-	-	-	[0.6,1]	-	-	0.2		
	(0.2, 1]	[1.6, 2.2]	0.5[SE = 0.3333]	-	-	-	0.3		-	-	-		[0.5, 1.5]
6	[0.05, 0.1]	[0, 1.1]	-	-	-	-	-1.7		0	-	-		
	(0.1, 0.2]	[2.2, 2.4]	-	-	-	-	-	[1.1,2.5]	0.6	-	-		
	(0.2, 1]	[3.1, 4.5]	-	[0.4, 0.8]	[0.2, 0.6]	[0.8,1.2]	1.1		1.7	-	-		
8	[0.05, 0.1]	[0.1, 1.8]	0.5[SE = 0.0833]	-	-	-	-1.9		0.4	-	-		
	(0.1, 0.2]	[2.5, 3.4]	2.2[SE = 0.2083]	[0.1, 0.7]	[-0.1, 0.5]	-	-	[0.5,1]	1.9	-	4.6		
	(0.2, 1]	[2.9, 6.7]	2.9[SE = 0.3333]	[0.5, 1.2]	[0.2, 0.8]	-	1.7		-	-	-		
12	[0.05, 0.1]	[1.0, 2.7]	-	-	-	-	-		-	-	-		
	(0.1, 0.2]	[5.1, 6.0]	-	[0.6, 1.5]	[0.1, 1.1]	-	-	[0.5,2.2]	-	-	4.6		
	(0.2, 1]	[7.2, 13.2]	-	-	-	-	-		-	-	-		
18	[0.05, 0.1]	-	-	-	-	-	-		-	4.6	-		
	(0.1, 0.2]	-	-	-	-	-	-		-	4.2	-		
	(0.2, 1]	-	-	-	-	-	-		-	-	-		
24	[0,1,0.2]							[0.9,1.4]					
26	[0.1, 0.2]							[1.6,1.7]					

Note 1: SNR is defined as total received SNR per RE per Rx antenna at eNB.
Note 2: The empty entries in the table are due to absence of simulation data.

Petitioners' Exhibit 1003, p. 1253
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 9.1.2-6: MCL calculation of multiple access schemes with ideal and/or realistic channel estimation

Source	Multiple access scheme	number of supported UEs	SE region (bits/RE)	Antenna Configuration	Bandwidth (KHz)	MCL range (dB) (Ideal Channel Estimation)	MCL range (dB) (Realistic Channel Estimation)
Source 9	NB-IoT OFDMA	1	0.072/1.23/1.77	1T2R	3.75		165.13/155.07/151.18
		1	0.01/0.43/1.77	1T2R	15		164.18/154.19/145.26
		1	0.375/0.625	1T2R	180	143.1/139.4	142.0/138.0
		1	0.375/0.625	1T2R	45	147.3/143.3	146.1/141.6
Source 9	NB-IoT MU MIMO	2	0.375/0.625	1T2R	90	147.3/145.8	141.4/144.8
		2	0.3750.625	1T2R	180	145.8/143.3	144.3/141.3
Source 1	SCMA	4	0.0133	1T2R	15	-	[165.24, 166.84]
Source 9	GOCA	6	0.222	1T2R	1080	135.77	135.27
		8	0.222	1T2R	1080	135.27	134.67
		8	0.157	1T2R	1080	137.27	136.57
		12	0.157	1T2R	1080	136.57	135.87
Source 9	RDMA	6	0.222	1T2R	1080	135.57	135.07
		8	0.222	1T2R	1080	134.87	134.27
		8	0.157	1T2R	1080	137.07	136.37
		12	0.157	1T2R	1080	136.17	135.37
Source 4	LDS-SVE	6	0.33	1T2R	360	[134.24, 134.44]	[132.84, 133.34]
		6	0.35	1T2R	1080	[129.87, 130.87]	[128.97, 129.27]
Source 6	NCMA	4	0.0625	1T2R	720	145.13	-
		6	0.0625	1T2R	720	145.03	-
		8	0.0625	1T2R	720	144.93	-
		4	0.25	1T2R	720	138.83	-
		6	0.25	1T2R	720	138,66	-
		8	0.25	1T2R	720	138.43	-
Source 13	RSMA	2	0.5	1T2R	360	136.14	-
		2	0.75	1T2R	360	133.64	-
		2	1	1T2R	360	131.64	-
Source 2	MUSA	20	0.0078	1T2R	15	-	165.74
		20	0.0313	1T2R	15	-	159.74
		20	0.125	1T2R	180	-	142.95
		24	0.0156	1T4R	15	-	165.74
		24	0.125	1T4R	15	-	156.74
		24	0.125	1T4R	180	-	145.95
Source 7	LSSA	4	0.166	1T2R	960	140.21	-
		8	0.166	1T2R	2160	139.16	-
		12	0.375	1T2R	480	138.19	-
		12	0.0011	1T2R	180	166.23	-
Source 11	LCRS	1	[0.00163, 0.208]	1T2R	180	[142.55, 167.35]	[142.25, 161.75]
		8	[0.00163, 0.208]	1T2R	180	[141.85, 167.45]	[141.45, 161.75]
Source 8	NOMA	4	0.144	1T2R	180	-	143.89
Source 5	IGMA	6	0.083	1T2R	1080	141.17	
		6	0.014	1T2R	1080	143.47	
		6	0.0313	1T2R	15	164.04	
Source 3	PDMA	8	0.0417	1T2R	720	137.03	136.48
		8	0.0833	1T2R	720	135.33	134.53
		8	0.2083	1T2R	720	131.53	130.88
		8	0.3333	1T2R	720	128.38	127.53
Source 14	NOCA	12	0.069	1T2R	2160	137.15 / 137.95	136.45/136.02
		18	0.069	1T2R	2160	137.04/137.72	136.04/135.12

Petitioners' Exhibit 1003, p. 1254
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 9.1.2-7 provide summary of system level simulation results for non-orthogonal multiple access schemes. The candidate PHY abstraction methods can be found in [R1-168076 and R1-1610626]. In the table, each source corresponds to the following references.

Commented [T34]: [Editor's note] The resutls are to be added according to the outcome of email discussion.

- Source1: R1-1608854
- Source2: R1-1608952
- Source3: R1-1608756
- Source5: R1-1609042
- Source6: R1-1609224
- Source7: R1-1609549, R1-1611023
- Source8: R1-1610078, R1-1610077
- Source9: R1-1609334, R1-1609335
- Source10: R1-1609581
- Source11: R1-1611008

Source13: R1-1610120

Based on system-level simulation results and assumptions summarized in [R1-1610531], it is observed that

- All simulated non-orthogonal MA schemes with grant-free with advanced receivers (some with ideal channel estimation while others with realistic channel estimation) provide significant capacity gain in terms of packets arrivals rate (packets/s/sector) at a given system outage (e.g, 1% target packet drop rate), compared to a respective grant-free reference scheme assumed by each company.
- Evaluation simulators have been calibrated with agreed simulation assumptions (R1-1609442)

Petitioners' Exhibit 1003, p. 1255
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table A.9.1.2-7: System-level evaluation results

Commented [T35]: [Editor's note] The resutls are to be added according to the outcome of email discussion.

Source	Source 1	Source 13	Source 2	Source 3	Source 5	Source 10	Source 11	Source 7	Source 8	Source 9	Source 14	Source 6
Multiple access scheme	SCMA	RSMA	MUSA	PDMA	IGMA	SCMA	LCRS	LSSA	NOMA	RDMA, GOCA	NOCA	NCMA
Inter-BS distance	1732m	1732m	1732m	1732m	1732m	1732m	1732m	1732m	1732m	1732m	ISD=500m	200m, 1732m
Simulation bandwidth	6 PRB	1.08MHz	6 PRB	4 PRB	6PRB	4 PRB	6PRB	6RB	6PRB	6PRB	72 PRBs	6PRB
BS antenna tilt	92 degrees	6 degrees	No Mechanical downtilt	12 degree	6 degrees	100 degree	96 degree	102 degree	No Mechanical downtilt	96 degree	_	102 degree
BS antenna element gain + connector loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable loss	8 dBi, including 3dB cable los
BS antenna configuration	(M,N,P,Mg,Ng) = (10,1,2,1,1), dv = dh = 0.5 λ, 2 TXRU, TXRU to antenna element mapping: (MTXRU, N, P, Mg, Ng) = (1, 1, 2, 1,1)	1x2 (M,N,P,Mg, Ng) = (10, 1, 2,1,1), 2 TXRU, one TXRU maps to 10 antenna element (50% indoor users has additional 10dB penetration loss)	(M,N,P,Mg,Ng) = (1,1,2,1,1), 2 TXRU, one TXRU maps to one antenna element	(M,N,P,Mg, Ng) = (10,1,2,1,1), TXRU to antenna element mapping: (M, N, P, Mg, Ng) = (10, 1, 1, 1,1)	(M,N,P,Mg,Ng) = (10,1,2,1,1), dv = dh = 0.5 λ 2 TXRU, TXRU to antenna element mapping: (MTXRU, N, P, Mg, Ng) = (1, 1, 2, 1,1)	1x2 (M,N,P,Mg,Ng) = (10, 1, 2,1,1), 2 TXRU, one TXRU maps to 10 antenna element	(M,N,P,Mg, Ng) = (1,1,2,1,1), 2 TXRU, one TXRU maps to one antenna element	M,N,P,Mg,Ng) = (1,1,2,1,1), 2 TXRU, one TXRU maps to one antenna element	(M,N,P,Mg,Ng) = (1,1,2,1,1), 2 TXRU, one TXRU maps to one antenna element	1x2 (M,N,P,Mg,Ng) = (10, 1, 2,1,1), 2 TXRU, one TXRU maps to 10 antenna element	(M,N,P,Mg, Ng) = (1,1,2,1,1), 2 TXRU, one TXRU maps to one antenna element	M,N,P,Mg,Ng) = (1,1,2,1,1), 2 TXRU, one TXRU maps to one antenna element
UE antenna gain	-4dBi	-4dBi	-4dBi	-4dBi	-4dBi	-4dBi	-4dBi	-4dBi	-4dBi	-4dBi	-4dBi	-4dBi
UL power control	P0= -97.8dBm, alpha=0.9	P0 = -126.4dBm , Alpha = 1	Po = -100 dBm, alpha = 1	P0=-95dBm and alpha = 1	P0=-90 dBm, alpha=1	OFDMA: alpha=1, P0= -90 dBm SCMA: alpha = 1, P0=-95dBm	Alpha = 0.8, fixed target SNR = 3 dB	Alpha=1, P0= -90 dBm	Alpha=0.7, P0= -60 dBm	Alpha = 1, P0 = -95dBm	Alpha = 0.8, P0 = -80dBm	Alpha=1, P0= -90 dBm
Channel estimation	Ideal | realistic	ideal	ideal	ideal	ideal, realistic	ideal	ideal	ideal	ideal, realistic	ideal	ideal	ideal
Packet size	Fixed to 40 bytes as TBS, and the reference scheme is segmented to 2 packets	Follow TR45.820, TBS of 200 bit is used to segment the packet	Fixed 40 bytes, with segmentation to 2 packets	Fixed 40 bytes, with segmentation to 2 packets for ODFMA and PDMA.	Fixed by 40 bytes, No segmentation	Fixed by 20 bytes	20 bytes	20 bytes	20~200 Bytes based on TR45.820; Fixed packet size 40 Bytes (segmentation unknown)	Fixed 40 Bytes, segmented into 2 20Bytes packets.	100bytes by using 72 PRB	20 bytes (no segmentation)

Petitioners' Exhibit 1003, p. 1256
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Packet dropping timer	1s		10s	1s	_	1s and 10s		_	128ms	_	1s and 10s	1 s	_	-
NoMA receiver type	MPA		MMSE-IRC	MMSE-SIC	MPA	Chip-by-chip MAP		MPA	MMSE-PIC	MMSE-PIC (selective)	MMSE-IRC + SIC	MF-SIC+MMSE-IRC	MMSE PIC	MMSE IRC+SIC
HARQ signaling combining or not?	Yes		Yes	No HARQ combine	Yes	Yes (repetition and combining)		No HARQ combine	HARQ combining used	combined	Yes/No	No HARQ combine	No HARQ combine	No HARQ combining
HARQ/Repetition	Maximum repetition/retransmissions of 32		HARQ till packet dropping timer to mimic the TTI bundling.	HARQ with random back-off until the fixed dropping timer.	Maximal number of HARQ transmissions is 16.	HARQ until the fixed dropping timer		No repetition or retransmission	Max of 15 HARQ retransmission; synchronous HARQ	Max. 2 HARQ retransmission for comparison	HARQ/no HARQ random back-off	HARQ random back-off until the fixed dropping timer.	No HARQ combining	Max. number of retrial : 10
OFDMA PAR at target PDR (Packets/ms/sector)	ICE 0.6 (@PDR = 1%)	RCE 0.5 (@PDR = 1%)	_	0.18 (@PDR = 1%)	0.6 (@PDR = 1%)	0.052 (@PDR = 10%, 1s dropping timer) Reference scheme is only with ideal CE		0.1 (@PDR = 1%)	0.9 @PDR 4%	0.25 @ PDR 1%	_	PDR floor at 2.5%	1.2 (PDR@ 10%)	ISD 200m: 4.1 (PDR@1%); ISD 1732m: - (PDR@10%)
Reported scheme PAR at target PDR (Packets/ms/sector)	2.1 (@PDR = 1%)	1.5 (@PDR = 1%)	0.68 (@PDR = 1%)	without secondary spreading: 2, with secondary spreading: 8 (@PDR = 1%)	1.8 (@PDR = 1%)	ICE 0.116 (@PDR = 1%, 1s); 0.44 (@PDR = 10%, 1s)	RCE 0.08 (@PDR = 1%, 1s); 0.34 (@PDR = 10%, 1s)	0.2 (@PDR = 1%)	2.5 @PDR 4%	0.8 @ PDR 1%	0.1 (@PDR = 1%, 1s dropping timer); 0.25 (@PDR = 1%, 10s dropping timer)	RDMA:0.7 (PDR@ 1%); GOCA: 0.75 (PDR@ 1%)	6.2 (PDR@ 10%)	ISD 200m: 7.3 (PDR@1%); ISD 1732m: 1.3 (PDR@10%)
MA signature setting	Random		Random	Random	Random	Random		Random	Random	Random	Random	Random		Random
Gain (reported scheme divided by its reference scheme)	350%	300%	_	without secondary spreading: 1100%, with secondary spreading: 4400%	300%	860%@PDR 10% with ICE of IGMA; 680%@PDR 10% with RCE of IGMA;		200% (@PDR = 1%) 250% (@PDR = 10%)	278%	320% @ PDR 1%	_	RDMA: 215% (@PDR 10%) GOCA: 218% (@PDR 10%)	516% @PDR 10%	ISD 200m: 178% (PDR@1%) ISD 1732m: - (PDR@10%)
Note 1: The empty entries in the table are due to absence of simulation data.														

Petitioners' Exhibit 1003, p. 1257
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

9.1.3 Performance evaluation of channel coding

9.2 Analysis of UE complexity

9.3 Analysis of Node B impacts

10 SL concepts

Editor's notes: FDD and TDD, and licensed and unlicensed bands will be considered. If there are specific transmission schemes or technical features for the specific usage case, new section(s) and/or subsection(s) will be created.

10.1 Basic transmission scheme

Efficient same frequency operation is supported between the access link and backhaul link. Efficient operation where the backhaul link and access link are on different frequencies is also considered, including operation of backhaul link and access link on different frequencies in the same band and operation of backhaul link and access link in different bands.

10.2 Physical layer procedure

10.3 Physical layer measurements

11 Evaluation of SL techniques

11.1 Performance evaluation

11.2 Analysis of UE complexity

11.3 Analysis of Node B impacts

12 Evaluation common for UL/DL

12.1 Performance evaluation related to eMBB

12.2 Performance evaluation related to URLLC

Evaluation metric and evaluation method for URLLC are defined as follows.

Petitioners' Exhibit 1003, p. 1258
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- User plane latency :
  - Definition: Follow the definition in TR38.913, target value is 0.5ms one way, without reliability requirement.
  - Evaluation method: Analytical; re-transmission is considered, but scheduling / queuing delay is not included in analytical evaluation
- Reliability
  - Definition: Reliability is defined as the success probability R of transmitting X bits within L seconds, which is the time it takes to deliver a small data packet from the radio protocol layer 2/3 SDU ingress point to the radio protocol layer 2/3 SDU egress point of the radio interface, at a certain channel quality Q (e.g., coverage-edge).
    - Denoted as R(L, Q, SE), where SE is the required spectral efficiency and SE=X/L/B where B (in Hz) is the user bandwidth that is allocable to one device.
    - The latency bound L includes transmission latency, processing latency, retransmission latency and queuing/scheduling latency (including scheduling request and grant reception if any)
  - Evaluation method: Link level simulation as start point
- URLLC capacity and URLLC / eMBB multiplexing capacity
  - Definition: URLLC system capacity is calculated as follows:
    - C(L, R) is the maximum offered cell load under which Y% of UEs in a cell operate with target link reliability R under L latency bound
    - X = (100 – Y) % is the percentage of UEs in outage
    - A UE in outage is defined as the UE can not meet latency L and link reliability R bound
    - Companies report their assumption on X
  - Evaluation method: System level evaluation method is used for URLLC system capacity study to analyze impact from inter-cell interference, queueing and scheduling latency, multiplexing with other services.

The corresponding evaluation assumptions are provided in Annex A.2.

12.3 Performance evaluation related to high speed train

12.4 Performance evaluation related to mMTC

12.5 Performance evaluation related to eV2X

13 UE capability

Petitioners' Exhibit 1003, p. 1259
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Annex A: simulation scenarios and assumptions

A.1 Link level simulation assumptions

A.1.1 Simulation assumption for evaluation of waveform

This section describes the link level simulation assumptions used for evaluating waveform candidates. The link level simulation assumption at the carrier frequencies of 4GHz is provided in Table A.1.1-1 and A.1.1-2 and that for 30GHz and 70GHz is also given in Table A.1.1-3. The evaluation assumptions for high speed scenario is provided in Table A.1.1-4.

Table A.1.1-1: Evaluation assumptions for waveform (4GHz, Cases 1a, 1b and 2)

Assumptions	Value
Carrier frequency	4GHz
Duplex	FDD/TDD
System Bandwidth	10 MHz
TTI length	1 ms as baseline, other TTI length is FFS (e.g. short TTI)
Subcarrier spacing	Single numerology case: 15KHz as baseline, Mixed numerology case: one is 15KHz, and the other subcarrier spacing should be selected by companies from the agreed numerologies (30 kHz for calibration purpose).
Guard time interval	4.7us (interval of LTE normal CP) as baseline, other interval is FFS
FFT size	e.g. 1024 for 15KHz subcarrier spacing
Data transmission bandwidth	Single numerology case: 4※ and/or 1 PRBs for the bandwidth of target UE in case 1b Mixed numerology case: At least two candidate BWs for target UE. At least two candidate BWs for interfering subband At least two numerologies. The values are FFS
Guard tone number	[0~12] subcarriers for the mixed numerology case (60 kHz for calibration)
Antenna configuration	1T1R or 2T2R or 4T4R, other is not precluded
MIMO mode	If companies bring results for MIMO, it is recommended to use at least one constant modulus precoding scheme in cases 1a, 1b and 2. Other precoding scheme is not precluded. Companies need to provide their CSI and precoding assumptions for MIMO evaluations. MIMO correlation matrices should be low correlation (i.e. uncorrelated) for RAN1#85 in case of MIMO simulations.
Rank per UE	Fixed rank
MCS	Fixed. 16QAM: 1/2 or 2/3; 64QAM: 1/2※ or 3/4; 256 QAM: 1/2 or 3/4
Control Overhead	Zero
Channel estimation *	Ideal
Channel Model **	• All values of DS {10, 30, 100, 300, 1000} ns are evaluated with the selected TDL-DS combinations, i.e. TDL-A for DS {10,30}ns, TDL-B for DS {100 }ns, TDL-C for DS {300 ※ ,1000}ns. Companies are allowed to choose additional combination(s) of other DS values and TDL–A and/or TDL-C in TR38.900. • ETU/EPA/EVA are optional. • Mobility: 3km/h※ or 30 km/h or 120 km/h, higher speed is not precluded.

Table A.1.1-2: Evaluation assumptions for waveform (4GHz, Cases 3 and 4)

Assumptions	Value
Carrier frequency	4GHz
Duplex	FDD /TDD
Subframe duration	1 ms as baseline, other duration is FFS (short duration could be considered)

Petitioners' Exhibit 1003, p. 1260
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Subcarrier spacing	Case 3: 15KHz as baseline, Case 4: Target UE: 15KHz; Interferer pair: {30KHz※, 30KHz※}, {7.5KHz, 7.5KHz} other value for interferers is not precluded.
Guard time interval	6.7% overhead as baseline, other interval is FFS (depend on numerology progress)
System bandwidth & FFT size	10 MHz, 1024 for 15KHz subcarrier spacing
UE bandwidth (data transmission bandwidth plus guard tone bandwidth of the desired UE)	Case3: -720 KHz (48 Subcarriers per user allocated for both target UE and interferer UEs) Case4: Config1※: Target UE: - 720KHz (48 Subcarrier allocated) Interferer users: - 720KHz (per UE) Config2: Target UE: - 2880KHz (192 subcarrier allocated) Interferer users: -2880KHz (per UE)
Bandwidth of guard tones between neighboring UEs	{0, 15, 30, 45, 60※, 90, 120, 180}KHz
Number of uplink users	3 (1 target user and 2 interferer users)
Power offset of the interferer user	0 dB, 5 dB, 10 dB※, 20 dB
Antenna configuration	1T1R※, other configuration that captures MIMO aspect is TBD
MIMO mode	If companies bring results for MIMO, it is recommended to use at least one constant modulus precoding scheme. Companies need to provide their CSI and precoding assumptions for MIMO evaluations. MIMO correlation matrices should be low correlation (i.e. uncorrelated) for RAN1#86 in case of MIMO simulations.
MCS	Fixed. 16QAM: 1/2 or 2/3; 64QAM: 1/2※ or 3/4; other is not precluded
Control overhead	Zero
Time offset of interfering user	Case 3: fixed offset {0, 128※, 512} samples (for 15 KHz subcarrier spacing with 1024 FFT size) Case 4: 0
Channel estimation *	Ideal※, realistic
Channel model **	TDL model All values of DS {10, 30, 100, 300, 1000} ns are evaluated with the selected TDL-DS combinations, i.e. TDL-A for DS {10,30}ns, TDL-B for DS {100 }ns, TDL-C for DS {300※,1000}ns. Companies are allowed to choose additional combination(s) of other DS values and TDL–A and/or TDL-C in TR38.900. ETU/EVA/EPA are optional. Mobility: 3km/h※ or 30 km/h or 120 km/h, higher speed is not precluded.

NOTE: * For realistic channel estimation, the current LTE DL/UL DMRS is recommended, and the applied DMRS pattern as well as CE implementation have to be described. Pilot overheads should be considered into the calculation of user spectrum efficiency.

** Power-delay profiles of TDL-{A,B,C} are scenario agnostic.

※ All marked values are recommended for calibration purpose.

Table A.1.1-3: Evaluation assumptions for waveform (30 GHz and 70 GHz)

Assumptions ,	Value
Carrier frequency	30 GHz & 70 GHz
Duplexing	TDD
Simulation case	Case 1a /1b
System bandwidth	30 GHz: 80 MHz or above, 70 GHz: 640MHz or above, other values are not precluded.
Data bandwidth	DL: 90% of system bandwidth UL: 4PRBs (48 subcarriers) or 90% of system bandwidth
Numerology	FFS: Depend on numerology progress (subframe duration, guard time interval, # of symbols per subframe, subcarrier spacing if needed)
UE antenna model	(M,N,P,Mg,Ng) = (2, 4, 2, 1, 1) or (2, 2, 2, 1, 1)

Petitioners' Exhibit 1003, p. 1261
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

TRP antenna model	(M,N,P,Mg,Ng) = (8, 8, 2, 1, 1) for 30GHz, (8,16,2,1,1) for 70GHz. Option 1: a single TXRU is mapped per panel per polarization. DFT vector is used to map TXRU to antenna elements. Per antenna element pattern is in [1]
Phase noise model	Follow the agreement in R1-165685
Channel coding	LTE Turbo code, other coding scheme is not precluded
Rank per UE	Rank 1 or 2
MCS	BPSK(pi/2) 1/2, QPSK(pi/4) 1/3, QPSK: 1/2, 16QAM: 1/2 or 2/3; 64QAM: 1/2 or 3/4; 256QAM ¾
Channel estimation	Ideal, Realistic* (Pilot pattern to be given in the case of real channel estimation)
Channel model	CDL-{A,B,C} in TR 38.900 with {50, 300***, 800} ns DS, with 15 degrees AoD spread for TRP, 45 degrees AoA for UE 3km/h, 30km/h (optional) Beam forming scheme used for spatial filtering needs to be reported

NOTE: * For realistic channel estimation, the current LTE DL/UL DMRS is recommended. Pilot overheads should be considered into the calculation of user spectrum efficiency.

* * *CDLs are scenario agnostic.*

*** *Recommended for calibration*

[1] TR36.873_v210 table 7.1.1 Antennal element vertical & horizontal radiation pattern

Table A.1.1-4: Evaluation assumptions for high speed scenario for waveform

Assumptions	Value
Carrier frequency	4GHz
Duplex	FDD/TDD
System Bandwidth	10 MHz
TTI length	1 ms
Subcarrier spacing	Single numerology case. Companies should report the selected value
Guard time interval	4.7us (interval of LTE normal CP) as baseline, other interval is not precluded
FFT size	e.g. 1024 for 15KHz subcarrier spacing
Data transmission bandwidth	Single numerology case: 50, 4 PRBs
Antenna configuration	1T1R, 2T2R
MIMO mode	Open loop [Companies should describe precoding scheme]
Rank per UE	Fixed rank
MCS	Fixed. QPSK: 1/2, 16QAM: 1/2
Performance metric	User Spectral efficiency (bps/Hz)*
Control Overhead	Zero
Channel estimation	Ideal, Realistic (describe pilot arrangement)
Channel Model	ITU Rural Macro CDL, other channel models not precluded
Mobility	Up to 500 Km/h

* Computed according to R1-163897

A.1.2 Simulation assumption for evaluation of multiple access

This section describes the link level simulation assumptions used for evaluating multiple access candidates. The general link level simulation assumptions for the uplink and downlink are provided in Tables A.1.2-1 and A1.2-2, respectively.

Table A.1.2-1: Simulation assumptions for UL multiple access scheme

Parameters	Values or assumptions
Carrier Frequency	2 GHz
Waveform	OFDM /SC-FDMA Other waveform is not precluded
Channel coding	LTE Turbo as start point, other coding schemes are not precluded.
Numerology	Same as Release 13
System Bandwidth	10 MHz
Total allocated bandwidth for transmission	Companies need to report this value.

Petitioners' Exhibit 1003, p. 1262
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Overhead	2 DMRS symbols, no SRS, i.e., 144 available RE per RB for data tr ansmission, or equivalent overhead
Target spectral efficiency	Proponents report per UE spectral efficiency and the number of UE s multiplexed if multi-UEs LLS is assumed
BS antenna configuration	2/4 Rx as baseline 8Rx optional
UE antenna configuration	1Tx
Transmission mode	TM1 (refer to TS36.213)
SNR distribution of Multiple UE s	Proponents report if single-user or multi-user LLS is used, and wha t SNR distribution is assumed.
Suggested SNR distribution of multiple UEs	Equal average SNR (short-term variation remains) Unequal average SNR (the SNR distribution is FFS, e.g., uniformly distributed within a range of 3dB, and proponents should report thei r assumption)
Propagation channel & UE velo city NOTE2	TDL for in TR38.900 as mandatory EPA, EVA, ETU as optional 3km/h, 30km/h, 120km/h
Max number of HARQ transmis sion	1, 4
Given BLER level (to calculate sum throughput)	0.1 for 1 transmission as starting point, other numbers not preclude d, e.g., 0.01 for 1 transmission
Overloading factor (Optional, definition refers to R1 -163881)	Some example values: 100%, 150%, 200%, 300%

Table A.1.2-2: Simulation assumptions for DL multiple access scheme

Parameters	Values or assumptions
Carrier Frequency	2 GHz
Waveform	OFDM Other waveform is not precluded
Channel coding	LTE Turbo as starting point, other coding schemes are not precluded.
Numerology	Same as Release 13
System Bandwidth	10 MHz
Total allocated bandwidth for transmission	Companies need to report this value.
Overhead	2 PDCCH symbols, 2 CRS ports for TM2 , i.e., 132 REs per RB for data transmission, or equivalent overhead
Target spectral efficiency	Proponents report per UE spectral efficiency and the number of UEs mu ltiplexed if multi-UEs LLS is assumed
BS antenna configuration	2/4 Tx as baseline 8Tx optional
UE antenna configuration	2 Rx
Transmission mode	TM2 as starting point (refer to TS36.213)
SNR distribution of Multip le UEs	Fixed gap {0, 5, 10, 15, 20} dB between UEs
Number of UEs	2 UEs as start point
SNR of the reference UE	0dB (The SNR of the other UE would be 0, 5, 10, 15, or 20dB)
Power allocation between UEs	Dynamic
Propagation channel & U E velocity NOTE2	CDL in TR38.900 as mandatory EPA, EVA, ETU as optional 3km/h, 30km/h, 120km/h
Max number of HARQ tra nsmission	1, 4
Given BLER level (to calc ulate sum rate region)	0.1 for 1 transmission as starting point

Petitioners' Exhibit 1003, p. 1263
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

A.1.3 Simulation assumption for evaluation of channel coding

This section describes the link level simulation assumptions used for evaluating channel coding candidates. The general link level simulation assumptions for eMBB, mMTC, and URLLC are provided in Tables A.1.3-1 and A.1.3-2 to evaluate the BLER performance versus SNR. The general link level simulation assumptions for control channel for eMBB are also provided in A.1.3-3.

Table A.1.3-1: Simulation assumptions for eMBB

Parameters	Values or assumptions		
Channel*	AWGN		
Modulation	QPSK, 64QAM		
Coding Scheme	Turbo	LDPC	Polar
Code rate	1/5, 1/3, 2/5, 1/2, 2/3, 3/4, 5/6, 8/9		
Decoding algorithm **	Max-log-MAP	min-sum	List-X
Info. block length*** (bits w/o CRC)	100, 400, 1000, 2000, 4000, 6000, 8000 Optional(12K, 16K, 32K, 64K)		

Table A.1.3-2: Simulation assumptions for URLLC and mMTC

Parameters	Values or assumptions			
Channel*	AWGN			
Modulation	QPSK, 16 QAM			
Coding Scheme	Convolutional codes	LDPC	Polar	Turbo
Code rate	1/12, 1/6, 1/3			
Decoding algorithm**	List-X Viterbi	min-sum	List-Y	Max-log-MAP
Info. block length*** (bits w/o CRC)	20, 40, 200, 600, 1000			

Table A.1.3-3: Simulation assumptions for control channel targeting eMBB

Channel	AWGN						
Modulation	QPSK						
Coding Scheme	Repetition	Simplex	TBCC	Turbo	LDPC	Reed-Muller	Polar
Code rate (for evaluation purposes)	1/24*, 1/12, 1/6, 1/3, 1/2, 2/3						
Decoding algorithm**	ML	ML	List-Viterbi	Scaled max log MAP	Adjusted min-sum	FHT	SC list
Info. block length (bits w/o CRC) (for evaluation purposes) ***	1, 2, 4, 8, 16, 32, 48, 64, 80, 120, 200						

* Code rate 1/24 is valid for info block length of 1-2 bits

** Other variants of agreed algorithms can be used for encoding and decoding (Complexity details should be illustrated)

*** Each of these info. block lengths shall be evaluated at at least one of the code rates. Other info. block lengths and code rates are not precluded. Similar info. and encoded block lengths should be used for the evaluation. Total coded bits = info. Block length/code rate. Note: these info. block length and code rate are only for initial performance evaluations. They are not interpreted as design targets or assumptions for complexity analysis.

Commented [T36]: [Editor's note] Fading channels will be simulated in the next stage

Commented [T37]: [Editor's note] These algorithms are starting points for further study. Other variants of agreed algorithms can be used for encoding and decoding (Complexity details should be illustrated)

Commented [T38]: [Editor's note] At least these info. block length and code rate shall be evaluated. Other info. block lengths and code rates are not precluded. Similar info. and encoded block lengths should be used for the evaluation. Total coded bits = info. Block length/code rate. Note: these info. block length and code rate are only for initial performance evaluations. They are not interpreted as design targets or assumptions for complexity analysis.

Commented [T39]: [Editor's note] Fading channels will be simulated in the next stage

Commented [T40]: [Editor's note] These algorithms are starting points for further study. Other variants of agreed algorithms can be used for encoding and decoding (Complexity details should be illustrated)

Commented [T41]: At least these info. block length and code rate shall be evaluated. Other info. block lengths and code rates are not precluded. Similar info and encoded block lengths should be used for the evaluation. Total coded bits = info. Block length/code rate. Note: these info. block length and code rate are only for initial performance evaluations. They are not interpreted as design targets or assumptions for complexity analysis.

Petitioners' Exhibit 1003, p. 1264
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

A.1.4 Simulation assumption related to URLLC evaluation

This section describes the simulation assumptions used for evaluating URLLC capacity.

Table A.1.4-1: Simulation assumptions for URLLC

Attributes	Values or assumptions
Carrier Frequency	700MHz and 4 GHz (FDD and TDD)
Modulation and coding rate	QPSK, 16QAM, 64QAM 1/12, 1/6, 1/3 Other MCS not precluded Comparison should be made for the same spectrum efficiency
User bandwidth	Companies report
Latency bound	1ms Other values are not precluded Companies report delay assumptions according to Table 1 in R1-166485
SINR range	-5dB to 20dB Larger range is not precluded
Sub-carrier spacing	Companies report
TTI length	Companies report
OFDM symbols per TTI	Companies report
Channel model	TDL/CDL in TR38.900; user speed = 3km/h, 15km/h (other user speed is not precluded)
BS antenna configuration	2/4/8 Tx/Rx ports as start point Other values (i.e., up to 256) are not precluded
UE antenna elements	2/4 Tx/Rx ports as start point Other values (i.e., up to 8) are not precluded
Packet arrive rate	Option 1: periodically Option 2: Poisson arrival with arrival rate λ
PHY Packet size	32 byte, 50 byte, 200 byte Other values are not precluded.
ACK Feedback assumption	Ideal as start point NOTE: It is also possible that no ACK feedback is needed,
Channel estimation	Ideal as start point; Realistic is not precluded when RS design is ready
CQI feedback assumption	Companies report the feedback scheme if any

NOTE: control channels including DL assignment/UL grant/ACK/NACK are to be evaluated further.

Commented [T42]: [Editor's note] Proponents are encouraged to report under what SINR the proposed scheme could achieve 99.999% reliability within the latency bound

Commented [T43]: [Editor's note] For calibration purpose only, the entries 1.1 and 1.4 of the Table 1 are assumed to be zero. In addition, each company reports the max number of HARQ re-transmissions

Commented [T44]: [Editor's note] Companies report the used option, and are encouraged to provide how to exploit arrival rate for Option 2

A.1.5 Simulation assumption for evaluation related to initial access

This section describes the link level simulation assumptions used for evaluating physical layer signals/channels related to initial access. The link level evaluations for synchronization signal/channels and RACH are respectively provided in Table A.1.5-1 and Table A.1.5-2.

Table A.1.5-1 can also be used in link level evaluation for DL based mobility at above 6 GHz.

Table A.1.5-1: Simulation assumptions for synchronization signals/channels

	Below 6GHz	Above 6GHz
Carrier Frequency	4 GHz	30, 70 GHz
Channel Model	CDL-C for 4 and 30 GHz, and CDL-D for 70 GHz (other CDL models are not precluded), AWGN • with delay scaling values of 100ns (mandatory), 300ns (optional) and 1000ns (optional) for 4 GHz, 30 ns for 30/70 GHz • with combination of ASA and ASD scaling values in sec. 7.7.5.1 in 38.900, for above 6 GHz cases • ZSA = 5 degree, ZSD = 1 degree • The CDL table is translated so that the strongest cluster's AoD and AoA occur at a random angle for both the antenna panels of TRP and UE in the local coordinate. The value of the random angle is selected to be uniformly	

Petitioners' Exhibit 1003, p. 1265
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

	distributed from +30 to -30 degree. The random value is chosen independently for both AoD and AoA	
Subcarrier Spacing(s)	15, 30, 60, 120, 240, or 480 kHz (to be clarified by each proponent; other values are not precluded)	
SNR range	> -6dB	> -18dB
UE speed	3 km/h and 120 km/h (mandatory) 30km/h and 500km/h (optional)	3 km/h
Search window	The time window to search (correlate) NR-PSS. It depends on the periodicity of NR-SS transmission. The value needs to be provided by each proponent	
Antenna Configuration at the TRP	(1,1,2) with omni-directional antenna element	(4,8,2), with directional antenna element (HPBW=65 degrees, directivity 8dB) Optional: (M,N,P,Mg,Ng) = (4,8,2,2,2). (d_V,d_H) = (0.5, 0.5)λ. $(d_{g,V},d_{g,H})$ = (2.0, 4.0)λ
Antenna Configuration at the UE	(1,1,2) with omni-directional antenna element	(2,4,2), with directional antenna element (HPBW=90 degrees , directivity 5dB)
Antenna port virtualization	Clarified by each proponent in simulation assumptions (e.g. the beamforming method, beam directions, number of beams)	
Frequency Offset	o Initial acquisition o TRP: uniform distribution +/- 0.05 ppm o UE: uniform distribution +/- 5, 10, 20 ppm (each company to choose one) o Non-initial acquisition o TRP: uniform distribution +/- 0.05 ppm o UE: uniform distribution +/- 0.1 ppm	
Number of interfering TRPs	1. 0 TRP: mandatory 2. 2 interfering TRPs (1st SIR = 0dB, 2nd SIR = -3dB; SIR is defined as the ratio of power between a reference cell and interfered cell) – timing arrival differences from TRPs are provided by each proponent: optional	1. 0 TRP

Table A.1.5-2: Simulation assumptions for RACH

	Below 6GHz	**Above 6GHz**
Carrier Frequency	4 GHz	30, 70 GHz
Channel Model	CDL-C for 4 and 30GHz, CDL-D for 70 GHz (other CDL models are not precluded), AWGN • with delay scaling values of 100ns(mandatory) for 4 GHz, 30ns (optional), and 1000ns(optional) for 30/70 GHz • with combination of ASA and ASD scaling values in sec. 7.7.5.1 in 38.900, for above 6 GHz cases • ZSA = 5 degree, ZSD = 1 degree • The CDL table is translated so that the strongest cluster's AoD and AoA occur at a random angle for both the antenna panels of TRP and UE in the local coordinate. The value of the random angle is selected to be uniformly distributed from +30 to -30 degree. The random value is chosen independently for both AoD and AoA	
Antenna Configuration at the TRP	(1,1,2) with omni-directional antenna element	(4,8,2), with directional antenna element (HPBW=650, directivity 8dB) Optional: (M,N,P,Mg,Ng) = (4,8,2,2,2). (d_V,d_H) = (0.5, 0.5)λ. $(d_{g,V},d_{g,H})$ = (2.0, 4.0)λ
Antenna Configuration at the UE	(1,1,2) with omni-directional antenna element	(2,4,2), with directional antenna element (HPBW=900, directivity 5dB)
Antenna port virtualization	Clarified by each proponent in simulation assumptions (e.g. the beamforming method, beam directions, number of beams)	
Frequency Offset	o +/- 0.05 ppm at TRP , +/-0.1 ppm at UE	
UE speed	o 3km/h, 120km/h(mandatory) o 30km/h, 500km/h(optional)	o 3km/h o Other values are not precluded
UE movement modeling	o FFS	
Initial timing Offset	o Timing uncertainty derived from cell radius o (e.g. for below 6 GHz, [-10us, +10us] for 3km cell radius) o Companies report the assumed cell radius	

Petitioners' Exhibit 1003, p. 1266
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

A.2 System level simulation assumptions

A.2.1 General assumption

This section describes the reference deployment scenarios for the different system evaluations. The general system evaluation assumptions for Indoor hotspot, Dense urban, Rural, Urban macro, and High-speed train are provided in Tables A.2.1-1, A.2.1-2, and A2.1-3.

The BS and UE antenna configurations are also provided in Table A.2.1-4 - A2.1-8.

For Indoor hotspot, ceiling mounted TRP deployment is adopted. The following three options can be considered.

- Option 1 (baseline at least for calibration): Boresight direction is perpendicular to the ceiling. Antenna model is taken from Wall-mount (90 degree HPBW in azimuth and zenith) in Table A.2.1.7.
  - The number of sites is 3 and 12. Placement of 12 sites is the same as TR 38.900. Placement of 3 sites is according to Figure A.2.1-1.
  - Antenna array baseline configuration:
    - (M,N,P,Mg,Ng) = (4, 4, 2, 1, 1) , dH = dV = 0.5 lambda for 4GHz
    - (M,N,P,Mg,Ng) = (4, 8, 2, 1, 1) , dH = dV = 0.5 lambda for 30GHz
    - (M,N,P,Mg,Ng) = (8, 16, 2, 1, 1), dH = dV = 0.5 lambda for 70 GHz
- Option 2: Three sectors (example below). Antenna model is taken from 3-sector in Table A.2.1.7. (65 degree HPBW in Azimuth and zenith).
  - Used antenna tilt should be reported by each company.
  - The number of sites is 3 and 12. Placement of 12 sites is the same as TR 38.900. Placement of 3 sites is according to Figure A.2.1-1.
  - Antenna array baseline configuration:
    - Same as Option 1
    - Boresight direction is according to TR 38.900
- Option 3 : Boresight direction is perpendicular to the ceiling. Omni antenna model is applied for 4 GHz.
  - The number of sites is 3 and 12. Placement of 12 sites is the same as TR 38.900. Placement of 3 sites is according to Figure A.2.1-1.
  - Antenna array baseline configuration:
  - (M,N,P,Mg,Ng) = (1, 1, 2, 1, 1) for 4GHz.

For Dense urban, the following Option 1 and Option 2 are adopted with one sector deployment for micro cell TRP deployment in dense urban scenario, i.e.,

- Option 1 : Omni in horizontal, directional in vertical (5dBi gain, HPBW 400, vertical tilt 900, Am=20dB, SLAv=30dB)
  - Dropping in the center of the hotspot area
- Option 2: Directional in horizontal, directional in vertical (8dBi gain, HPBW = 650, vertical tilt 900 , Am=30dB, SLAv=30dB)
  - One-sector deployment

Petitioners' Exhibit 1003, p. 1267
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Dropping of TRP and TRP antenna orientation according to TR 36.897 (non co-channel hetnet deployment)

- Number of Tx antennas at micro cell TRP:
  - Baseline: (M,N,P,Mg,Ng) = (8,8,2,1,1), (0.5, 0.8)λ for 4GHz

The distance (d_{in}+d_{out}) from a UE to the closest TRP shall not exceed R (UE dropping radius). The minimum distance between Macro TRP and UE is 10m and that between Micro TRP and UE is 10m. The minimum distance between TRPs and UE cluster radius are also defined in Table A.2.1-9.

Table A.2.1-1: System level evaluation assumptions for Indoor hotspot, Dense urban, Rural, and Urban macro

Parameters	Indoor hotspot	Dense urban	Rural	Urban macro
Layout	Single layer Indoor floor: (12BSs per 120m x 50m) Candidate TRP numbers: 3, 6, 12	Single layer: Macro layer: Hex. Grid Two layer Macro layer: Hex. Grid Micro layer: Random drop (All micro BSs are all outdoor) - 3 micro BSs per macro BS - 6, or 9 micro BSs per macro BS (optional) See Figures A.2.1-3, A.2.1-4 and Table A.2.1-8	Single layer Macro layer: Hex. Grid	Single layer Macro layer: Hex. Grid
Inter-BS distance	20m	Macro layer: 200m	1732m for 4GHz and 1732m and 5km for 700 MHz	500m
Carrier frequency	4GHz, 30GHz, and 70GHz	Macro layer: 4GHz and 30GHz Micro layer: 30GHz and 4GHz; 70 GHz (optional)	4GHz and 700MHz	4 GHz and 30GHz
Aggregated system bandwidth	4GHz: Up to 200MHz (DL+UL) 30GHz or 70GHz: Up to 1GHz (DL+UL)	4GHz: Up to 200MHz (DL+UL) 30GHz and 70 GHz: Up to1GHz (DL+UL)	700MHz: Up to 20MHz(DL+UL) 4GHz: Up to 200MHz (DL+UL) (Consider larger aggregated system bandwidth if 20MHz cannot meet requirement)	4GHz: Up to 200 MHz (DL+UL) 30GHz: Up to 1GHz (DL+UL)
Simulation bandwidth	20MHz per CC below 6GHz and 80 MHz per CC above 6GHz Note: For FDD, simulation BW is split equally between UL and DL Note: UE TX power scaling will impact final results			
Channel model	Below 6GHz: ITU InH Above 6 GHz: 5GCM office Note: When 5GCM is found to be applicable to below 6GHz, 5GCM should be used	Below 6GHz: 3D UMa (Macro layer) and 3D UMi (Micro layer) Above 6GHz: 5GCM UMa (Macro layer) and UMi-Street canyon (Micro layer) Note: When 5GCM is found to be applicable to below 6GHz, 5GCM should be used	ITU Rural	Below 6GHz: 3D UMa 6 GHz: 5GCM UMa Note: When 5GCM is found to be applicable to below 6GHz, 5GCM should be used

Petitioners' Exhibit 1003, p. 1268
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

BS Tx power	Below 6GHz: 24dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 24dBm Above 6GHz: 23 dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 23dBm EIRP should not exceed 58 dBm(*)	Macro layer: Below 6GHz: 44 dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 44 dBm Above 6GHz: 40 dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 40 dBm Micro layer: 4 GHz: 33dBm for 20MHz system bandwidth Above 6GHz: 33 dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 33 dBm. EIRP should not exceed 73 dBm and 68 dBm for the macro and micro layers respectively(*)	49dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 49dBm	Below 6GHz: 49dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 49dBm Above 6GHz: 43dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 43dBm EIRP should not exceed 78 dBm (*)
UE Tx power	Below 6GHz: 23dBm 30GHz: 23dBm 70GHz: 21dBm EIRP should not exceed 43 dBm (*)			
BS antenna configurations	See Table A.2.1-4.			
BS antenna height	3m	25m for macro cells and 10m for micro cells	35 m	25 m
BS antenna element gain + connector loss	See Table A.2.1-4			
BS receiver noise figure	Below 6GHz: 5dB Above 6GHz: 7dB			
UE antenna configuration	See Table A.2.1-4.			
UE antenna height	Follow TR36.873			
UE antenna gain	Follow the modeling of TR36.873			
UE receiver noise figure	Below 6GHz: 9dB Above 6GHz: 13dB (baseline performance), 10dB (high performance)			
Traffic model	Full buffer and FTP model 1/2/3 with packet size 0.1 and 0.5Mbytes (other value is not precluded). Other traffic models are not precluded.			
Traffic load (Resource utilization)	For baseline scheme: 25, 50 and 80% (other value is not precluded)			
UE distribution	100% Indoor, 3km/h, 10 users per BS for full buffer traffic	**Step1 (**):** Uniform/macro TRP (10 users per TRP for full buffer traffic) **Step2 (**):** Uniform/macro TRP + Clustered/micro TRP (10 users per TRP associated with macro cell geographical area for full buffer traffic. 2/3 users randomly and uniformly dropped within the clusters, 1/3 users randomly and	50% outdoor vehicles (120km/h) and 50% indoor (3km/h) 10 users per TRP for full buffer traffic User distribution: Uniform	20% Outdoor in cars: 30km/h, 80% Indoor in houses: 3km/h 10 users per TRP for full buffer traffic (10 users per TRP is the baseline with full buffer traffic. 20 users per TRP with full buffer traffic is not precluded.)

Petitioners' Exhibit 1003, p. 1269
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

		uniformly dropped throughout the macro geographical area for FTP model 1/2/3, and 60 users for FTP model 2/3) (***) - 80% indoor (3km/h), 20% outdoor (30km/h) - In the case of full buffer, 10 users per TRP is the baseline. 20 users per TRP is not precluded. - In case of outdoor (30km/h), penetration loss in-car is 9 dB (LN, σ = 5 dB). Mix of O2I penetration loss models for higher carrier frequency • Option1 – Low loss model – 80% – High-loss model – 20% • Option2 – Low loss model – 50% – High-loss model – 50%		Mix of O2I penetration loss models for higher carrier frequency • Option1 – Low loss model – 80% – High-loss model – 20% • Option2 – Low loss model – 50% – High-loss model – 50%
UE receiver	MMSE-IRC as the baseline receiver Note: Advanced receiver is not precluded.			
Feedback assumption	Realistic			
Channel estimation	Realistic			

(*): See Appendix in R1-164383 and R1-167533 for the derivation of maximum allowed EIRP. EIRP limit is only used for evaluation purpose in RAN1.

(**): Step 1 shall be used for the evaluation of spectral efficiency KPIs. Step2 shall be used for the evaluation of the other deployment scenario dependant KPIs.

(***): Companies are encouraged to investigate the ratio of UEs between the macro and micro cell geographical area depending on options for micro cell dropping (See Figures A.2.1-3 and A.2.1-4 and Table A.2.1-8)

Table A.2.1-2: System level evaluation assumptions for High-speed train, Urban grid for eV2X, and Highway for eV2X

Parameters	High Speed Train	Urban grid for eV2X	Highway for eV2X
Layout	Option 1: Macro only （Dedicated linear deployment along railway line） Option 2: Macro + relay nodes （Dedicated linear deployment along railway line） Option 1 is prioritized for evaluation. Parameter values related to train: Train length: 400m Num of users per train: 1000 UE distribution: Uniform in train For Option 1 and Option 2, both SFN scenario and non-SFN scenario are considered.	Option 1: Macro only (with the road configuration in Figure 6.1.10-1 in TR38.913) Option 2: Macro + RSUs (with the road configuration in Figure 6.1.10-1 in TR38.913) Note: An RSU can be a BS type RSU or UE type RSU Out of coverage can be evaluated assuming eNB or RSU to be disabled. Sidelink evaluation with partly out of coverage UEs and partly in coverage UEs are FFS.	Option 1: Macro only (straightline eNB placement with Road configuration in TR36.885) Option 2: Macro + RSUs (straightline eNB with Road configuration in TR36.885) Note: An RSU can be a BS type RSU or UE type RSU Out of coverage can be evaluated assuming eNB or RSU to be disabled. Sidelink evaluation with partly out of coverage UEs and partly in coverage UEs are FFS.

Petitioners' Exhibit 1003, p. 1270
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

	For Option1 or Option 2 Alt.1, 4GHz Parameter Value for SFN scenario: RRH Railway track distance: 100m Num of RRHs connected to one BBU: 6 Parameter Value for non-SFN scenario: RRH Railway track distance: 100m Num of RRHs connected to one BBU: 2 For Option 2 Alt. 2, For BS to relay 30GHz, SFN/non-SFN RRH Railway track distance: 5m Num of RRHs connected to one BBU: 3 See Figure A.2.1-5 and A.2.1-6 Note: The key characteristics of high speed train scenario are consistent user experience with very high mobility.		
Inter-BS distance	1732m NOTE: For Option1 or Option 2 Alt.1, 4GHz - 1732m between RRH For Option 2 Alt. 2, For BS to relay 30GHz, SFN/non-SFN - 1732m between BBU, (3RRHs in a cell connected to 1 BBU, inter RRH distance (580, 580, 572))	Inter Macro: 500m Inter RSU: RSU is dropped at each intersection	Inter Macro: 1732m, 500m (optional) Inter RSU: Uniform allocation with 100m spacing in the middle of the highway
Carrier frequency	4 GHz for macro only, 4GHz and 30GHz for BS to relay	Macro to/from vehicle/pedestrian UE : 4 GHz Between vehicle/pedestrian UE: 6 GHz BS-type-RSU to/from vehicle/pedestrian UE : 4 GHz UE-type-RSU to/from vehicle/pedestrian UE: 6 GHz Note: Agreed value does not mean non-ITS band is precluded for real deployment for sidelink	Macro to/from vehicle/pedestrian UE : 2 GHz or 4GHz Between vehicle/pedestrian UE: 6 GHz BS-type-RSU to/from vehicle/pedestrian UE : 4 GHz UE-type-RSU to/from vehicle/pedestrian UE: 6 GHz Note: Agreed value does not mean non-ITS band is precluded for real deployment for sidelink
Aggregated system bandwidth	4GHz: Up to 200 MHz (DL+UL) 30GHz or 70GHz: Up to 1GHz (DL+UL)	Up to 200 MHz (DL+UL) Up to 100 MHz (SL)	Up to 200 MHz (DL+UL) Up to 100 MHz (SL)
Simulation bandwidth	Option 2: 80 MHz Other values greater than 80MHz can be considered	20 or 40 MHz (DL+UL) 10 or 20 MHz (SL)	20 or 40 MHz (DL+UL) 10 or 20 MHz (SL)
Channel model	Option 1, Option 2 Alt 1: ITU Rural as the starting point. Note: When 5GCM is found to be applicable, 5GCM should be used. Option 2 Alt 2: - CDL-D, with DS=10 ns and K-factor = {7, 13.3}* dB with the following scaling angle spreads - Parameter set #1: 5(ASD), 5(ASA), 1(ZSA), 1(ZSD) - Parameter set #2: 5(ASD), 15(ASA), 5(ZSA), 1(ZSD) - ZoD and ZoA for cluster #1 are	Macro to/from vehicle/pedestrian UE : 3D UMa Between vehicle/pedestrian UE: V2X Channel model in TR36.885 RSU to/from vehicle/pedestrian UE : V2X Channel model in TR36.885	Macro to/from vehicle/pedestrian UE: 3D UMa for 500m ISD 3D RMa for 1732m ISD (2D RMa may be used until 3D RMa is complete) Between vehicle/pedestrian UE: V2X Channel model in TR36.885 RSU to/from vehicle/pedestrian UE : V2X Channel model in TR36.885

Petitioners' Exhibit 1003, p. 1271
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

	fixed at 90 degrees - TDL-D with DS=10ns and K-factor = {7, 13.3}* dB * Other values are not precluded. "K-factor" here refers to K_desired in Section 7.7.6 in TR38.900, or "per-channel K factor" in R1-165440. For other candidate values for K-factor, the values in Table 7.5-6 in TR38.900 can also be used as a reference. Note: The values in the parameter set #1 and #2 are used for AS_desired in the scaling function in Section 7.7.5.1 in TR38.900. Calculation of AS_model in the scaling function is defined in Annex A of TR 25.996. Baseline values for per cluster spread c_{ASD}, c_{ASA}, c_{ZSD}, c_{ZSA} are defined in Table 7.7.1-4 in TR38.900. If different values are selected for the per cluster spreads, companies should provide justification. Examples of CDL-D tables for all combinations are shown in R1-168174		
BS Tx power	BS: Below 6GHz: 49dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 49dBm Above 6GHz: 30dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 30dBm EIRP should not exceed 69dBm (*). Relay： 27dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 27dBm EIRP should not exceed 43dBm (*)	Macro BS: 49dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 49dBm [TBD for TDD] BS-type-RSU: 24dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 24dBm Vehicle/pedestrian UE or UE type RSU: 23dBm Note: 33dBm for RSU is not precluded	Macro BS: 49dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 49dBm [TBD for TDD] BS-type-RSU: 24dBm PA scaled down with simulation BW when system BW is higher than simulation BW. Otherwise, 24dBm Vehicle/pedestrian UE or UE type RSU: 23dBm Note: 33dBm for RSU is not precluded
UE Tx power	Below 6GHz: 23dBm Above 6GHz: 21dBm EIRP should not exceed 43dBm (*)	Vehicle/pedestrian UE or UE type RSU: 23dBm Note: 33dBm is not precluded	Vehicle/pedestrian UE or UE type RSU: 23dBm Note: 33dBm is not precluded
BS antenna configurations	See Table A.2.1-5.		
BS antenna height	For Option1 or Option 2 Alt.1, 4GHz, 35m For Option 2 Alt. 2, 30GHz, SFN/non-SFN, RRH 2.5m, relay 2.5m	Macro BS: 25m BS-type-RSU: 5m	Macro BS: 35m for ISD 1732m 25m for ISD 500m BS-type-RSU: 5m
BS antenna element gain + connector loss	See Table A.2.1-5	Macro BS: 8dBi BS-type-RSU: 8dBi	Macro BS: 8dBi BS-type-RSU: 8dBi
BS receiver noise figure	Below 6GHz: 5dB Above 6GHz: 7dB RRH and Relay for option 2 Alt.2: 7dB	Below 6GHz: 5dB Above 6GHz: 7dB	Below 6GHz: 5dB Above 6GHz: 7dB
UE antenna	See Table A.2.1-5		

Petitioners' Exhibit 1003, p. 1272
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

configurations			
UE antenna height	Follow TR36.873	Vehicle/pedestrian UE: 1.5m UE-type-RSU: 5 m	Vehicle/pedestrian UE: 1.5m UE-type-RSU: 5 m
UE antenna gain	Follow the modeling of TR36.873	Vehicle UE: 3dBi Pedestrian UE: 0dBi UE-type RSU: 3dBi	Vehicle UE: 3dBi Pedestrian UE: 0dBi UE-type RSU: 3dBi
UE receiver noise figure	Below 6GHz: 9 dB Above 6GHz: 13dB (baseline performance), 10dB (high performance)		
Traffic model	Full buffer and FTP model 1/2/3 with packet size 0.1 and 0.5 Mbytes (other value is not precluded). Other traffic models are not precluded.	[50 messages] per 1 second with [60km/h], [10 messages] per 1 second with [15km/h] in TR38.913 Note: This value is tentative. After SA1 input, it can be modified.	[50 messages] per 1 second with absolute average speed of [100-250 km/h] (relative speed: 200 – 500km/h) in TR38.913 Note: This value is tentative. After SA1 input, it can be modified.
Traffic load (Resource utilization)	For baseline scheme: 25, 50, and 80% (other value is not precluded)	FFS	FFS
UE distribution	100% of users in train [300] UEs per macro cell (assuming 1000 passengers per high-speed train and at least 30% activity ratio) Maximum mobility speed: 500km/h Note: Physical mobility of UE is to be modeled for option 1, and physical mobility of relay node is to be modelled for option 2 Path loss through external wall: $5-10\log_{10}(0.3)+L_{IRRglass}$ dB and $L_{IRRglass}=23+0.3\,f_c$ Indoor loss: $0.5d_{2D\text{-}in}$ dB Standard deviation: [5.45]	Urban grid model (car lanes and pedestrian/bicycle sidewalks are placed around a road block. 2 lanes in each direction, 4 lanes in total, 1 sidewalk, one block size: 433m x 250m) in TR38.913 Average inter-vehicle distance (between two vehicles′ center) in the same lane is [1sec * average vehicle speed] (average speed [15 – 120km/h]) in TR38.913 Vehicle UE location update in TR36.885 should be used for the evaluation of PRR in sidelink or communication interruption in uplink/downlink. Vehicle UE location update may not be assumed for the evaluation of PRR in uplink/downlink Note: Inter-vehicle distance is tentative. After SA1 input, it can be modified. Pedestrian UE distribution: Inter-pedestrian distance 20m, which is tentative. After SA1 input, it can be modified.	Average inter-vehicle distance (between two vehicles′ center) in the same lane is [0.5 sec or 1sec * average vehicle speed] (average speed: [100-250 km/h]) in TR38.913 Vehicle UE location update in TR36.885 should be used for the evaluation of PRR in sidelink or communication interruption in uplink/downlink. Vehicle UE location update may not be assumed for the evaluation of PRR in uplink/downlink Note: Inter-vehicle distance is tentative. * After SA1 input, only one value will be selected.
UE receiver	MMSE-IRC as the baseline receiver Note: Advanced receiver is not precluded.		
Feedback assumption	Realistic	FFS	FFS
Channel estimation	Realistic		
Others	Option 2, alt. 2 Phase noise model: Follow the agreement in R1-165685		

(*): See Appendix in R1-164383 for the derivation of maximum allowed EIRP

Petitioners' Exhibit 1003, p. 1273
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table A.2.1-3: System level evaluation assumptions for urban coverage for massive connection and extreme long coverage

Parameters	Urban coverage for massive connection (Uplink)	Extreme Long Range
Layout	Single layer - Macro layer: Hex. Grid	Single layer: Isolated Macro cells
Inter-BS distance	1732m, 500m (optional)	N/A since single cell Cell radius 100km Feasibility of Higher Range shall be evaluated through Link level evaluation (for example in some scenarios ranges up to 150-300km may be required).
Carrier frequency	700MHz	700MHz
Aggregated system bandwidth	Companies report aggregated bandwidth used in evaluation	40MHz (DL+UL)
Simulation bandwidth	Companies report simulation bandwidth used in evaluation	40MHz (DL+UL)
Channel model	3D UMa Take 5GCM output into account if applicable	LLS For link level modelling and simple system-level modelling, use TDL-A and CDL-A with the following delay and angle scaling: - DS = [100 ns], ASD = [1°], ASA = [30°], ZSD = [0.1°], ZSA = [1°] - The absolute propagation delay is added to all tap delays SLS PL Model PL = 52.44 + 20*lgo10(d_km) + 20*log(fc_MHz) d_km is distance in km fc_MHz is the carrier frequency in MHz Shadowing model Log normal with standard deviation: 4dB Fast fading channel model Option 1 Use LLS but with the mean AOD,ZOD,AOA,ZOD for each link are determined from the geometry assuming LOS propagation Option 2 2D-RMa
BS Tx power	-	BS: 49dBm
UE Tx power	Max 23dBm or optional 10dBm	23dBm
BS antenna configurations	Rx: 2 and 4 ports (8 as optional)	Up to 256 Tx/Rx Following the modelling of TR36.873
BS antenna height	25m	N/A
BS antenna element gain + connector loss	8 dBi, including 3dB cable loss	8dBi
BS receiver noise figure	Below 6GHz: 5dB Above 6GHz: 7dB	5dB
UE antenna configuration	See Table A.2.1-4.	Up to 8 Tx/Rx
UE antenna height	1.5m	1.5m
UE antenna gain	-4dBi	0dBi

Petitioners' Exhibit 1003, p. 1274
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

UE receiver noise figure	Below 6GHz: 9 dB Above 6GHz: 13dB (baseline performance), 10dB (high performance)	
Traffic model	Non-full buffer small packet. Consider future trend of mMTC traffic NOTE: minimum packet size is [20] bytes	FTP Model 3 with packet size 600kbit, Poisson packet arrival rate of 0.05 packets/second Target user experienced data rate: to be provided based on link budget analysis
Traffic load (Resource utilization)	FFS	-
UE distribution	Follow the modeling of TR36.873	10% UE 160km/h and 90% UE 0km/h 95% of UEs uniformly distributed up to 50 km from the basestation and 5% of UEs at an extreme range distance, 100km. Evaluate how many users can be served per cell site when the range edge users are serviced with the target user experience data rate Target user experienced data rate: up to 2 Mbps DL while stationary and 384 kbps DL while moving
BS receiver	MMSE-IRC as the baseline receiver Note: Advanced receiver is not precluded.-	MMSE-IRC as the baseline receiver Note: Advanced receiver is not precluded.
UE receiver	-	MMSE-IRC as the baseline receiver Note: Advanced receiver is not precluded.
Feedback assumption	-	Realistic
Channel estimation	Realistic	

Table A.2.1-4: Antenna configurations for below and above 6GHz

	Below 6GHz (700MHz, 4GHz)	**Above 6GHz (30GHz, 70GHz)**
TXRU mapping	Per panel, reuse models in TR 36.897. Other mappings are FFS. Consider the following a TXRU to antenna elements mapping as examples 4GHz: the same as TR36.897	Per panel, reuse models in TR 36.897. Other mappings are FFS Consider the following a TXRU to antenna elements mapping as examples 30GHz and 70GHz: Option 1: a single TXRU is mapped per panel per polarization. Option 2: a single TXRU is mapped per panel per subarray per polarization, - E.g., where a subarray consists of consecutive M/2 vertical antennas and N/2 horizontal antennas with the same polarization. - Other subarray configurations are not precluded. Option 3: Fully connected TXRU mapping within a panel per polarization. - Other Fully connected TXRU mapping is not precluded. For evaluating multi beam based approaches at 30GHz and 70GHz, consider the following: - TXRU to antenna mapping weights are adjustable and used to steer the panel beam direction in multi beam based approaches in time domain.
Number of BS antenna elements across all panels	700MHz: Up to 64 Tx /Rx antenna elements 4GHz: Up to 256 Tx /Rx antenna elements Note: Same as TR38.913	30GHz: Up to 256 Tx /Rx antenna elements Note: Same as TR38.913 70GHz: Up to 1024 Tx /Rx antenna elements

Petitioners' Exhibit 1003, p. 1275
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Number of UE antenna elements	**700MHz:** Up to 4 Tx /Rx antenna elements **4GHz:** Up to 8 Tx /Rx antenna elements Note: Same as TR38.913	**30GHz:** Up to 32 Tx /Rx antenna elements **70GHz:** Up to 32 Tx /Rx antenna elements Note: Same as TR38.913
BS (M,N,P,Mg,Ng)	**4GHz:** Dense urban and Urban macro: - Baseline: (M,N,P,Mg,Ng) = (8,8,2,1,1). - Note that for Urban macro, companies are also encouraged optionally to investigate larger panels, e.g. (8,16,2,1,1) Indoor hotspot: - FFS	**30GHz:** Dense urban and Urban macro: - Baseline: (M,N,P,Mg,Ng) = (4,8,2,2,2). Indoor hotspot: - FFS **70GHz:** Dense urban: - Baseline: (M,N,P,Mg,Ng) = (8,16,2,2,2). Indoor hotspot: - FFS
BS (d_H,d_V,$d_{H,g}$,$d_{V,g}$)	**4GHz:** Dense urban and Urban macro: - Baseline: (dH,dV) = (0.5, 0.8)λ. Indoor hotspot: - FFS	**30GHz:** Dense urban and Urban macro: - Baseline: (dH,dV) = (0.5, 0.5)λ. (dg,H,dg,V) = (4.0, 2.0)λ. Indoor hotspot: - FFS **70GHz:** Dense urban: - Baseline: (dH,dV) = (0.5, 0.5)λ. (dg,H,dg,V) = (8.0, 4.0) λ. Indoor hotspot: - FFS
UE antenna model parameters	Panel model 1: Mg = 1, Ng = 1, P =2, d_H=0.5 M, N is FFS	For UE with (Mg, Ng) directional antenna panels. - Introduce (Ωmg,ng, Θmg,ng) for orientation of the panel (mg, ng), 0≤mg<Mg, 0≤ng<Ng, where the orientation of the first panel (Ω0,0, Θ0,0) is the same as UE orientation, Ωmg,ng is the array bearing angle and Θmg,ng is the array downtilt angle defined in [TR 36.873]. - For NR MIMO evaluation: - Config 1: (Mg, Ng) = (1, 2); Θmg,ng=90; Ω0,1=Ω0,0+180; (dgH, dgV)=(0,0) - Config 2: (Mg, Ng) = (1, 4); Θmg,ng=90; Ω0,1=Ω0,0+90; Ω0,2=Ω0,0+180; Ω0,3=Ω0,0+270; (dgH, dgV)=(0,0) - Other configurations can have panel specific position offset (dgH, mg, ng, dgV, mg, ng). Note in this case the notation of (Mg, Ng) does not leads to rectangular shape. - UE orientation for mobile device (Ω0,0, Θ0,0)=(U(0,360), 90); UE orientation for customer premise equipment (CPE) can be optimized - Each antenna array has shape dH=dV=0.5λ - Config 1 can be used with config a/b; Config 2 can be used with config c/d/e - Config a: (M, N, P) = (2, 4, 2), the polarization angles are 0 and 90 - Config b: (M, N, P) = (4, 4, 1) , the polarization angle for even panel is 0 and for odd panel is 90 - Config c: (M, N, P) = (2, 2, 2), the polarization angles are 0 and 90 - Config d: (M, N, P) = (2, 4, 1) , the polarization angle for even panel is 0 and for odd panel is 90 - Config e: (M, N, P) = (1, 4, 2), the polarization angles are 0 and 90 - FFS: Other configurations, e.g. (M, N, P) = (4, 4, 2) or (M, N, P) = (4, 8, 1) can be considered for 70GHz band, without exceeding the limit on the maximum number of UE antenna elements - The antenna elements of the same polarization of the same panel is virtualized into one TXRU - FFS: one TXRU can connect to different subarrays

Petitioners' Exhibit 1003, p. 1276
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

		dynamically - Note: The channel coefficients for each UE panel can be generated using spatial channel model
BS antenna element gain pattern	According to TR36.873	See Table A.2.1-6 and Table A.2.1-7
UE antenna element gain pattern	Omnidirectional	See Table A.2.1-8
Number of TXRUs	FFS	FFS
Others	TXRUs within a panel can be assumed to be synchronized and phase-calibrated (at least to the same level as in LTE). It should be possible as one option to assume QCL between ports of two different panels of the same transmission points Distances (dg,H, dg,V) between panels should be limited to at most [FFS] metres. NR evaluations consider both cases of phase-calibration and no phase-calibration between panels: - Phase offset of non-calibrated panel (either TRP or UE side) is modeled as a uniform distributed random variable between $(-\pi,\pi)$. - Adopt the accumulated phase offset of non-calibrated panel pair in channel coefficients equation (7.21) and (7.26) in TR 38.900.	

Table A.2.1-5: Antenna configurations for high speed train, urban grid for eV2X, and highway for eV2X

	High Speed Train	Urban grid for eV2X	Highway for eV2X
TXRU mapping	-	-	-
Number of BS antenna elements across all panels	For Option 2 Alt. 2 Relay: Up to 256 Tx /Rx antenna elements Note: The antenna of the relay for RRH-to-Relay is located outside of a train RRH: Up to 256 Tx /Rx antenna elements Note: The above values are shown in TR 38.913	Macro BS: Up to 256 TX/RX antenna elements BS-type-RSU: Up to 8 TX/RX antenna elements	Macro BS: Up to 256 TX/RX antenna elements BS-type-RSU: Up to 8 TX/RX antenna elements
Number of UE antenna elements		Vehicle/pedestrian UE: Up to 8 TX/RX antenna elements UE-type RSU: Up to 8 TX/RX antenna elements	Vehicle/pedestrian UE: Up to 8 TX/RX antenna elements. UE-type RSU: Up to 8 TX/RX antenna elements
BS (M,N,P,Mg,Ng) BS (d_H,d_V,$d_{H,g}$,$d_{V,g}$)	The baseline BS antenna configuration at 4GHz in high speed train scenario is (M,N,P,Mg,Ng) =(8,8,2,1,1), where the radiation pattern of antenna elements follows TR 36.873 according to the current agreements. Other antenna configurations are not precluded. For Option 2 Alt. 2 RRH: dH=dV=0.5 - For unidirectional beam: (M,N,P,Mg,Ng) = (8, 16, 2, 1, 1), Other configurations such as (8,8,2,1,1) or (4,8,2,2,2) with dH,g=8.0,dV,g=4.0 are not precluded for unidirectional beam - For bidirectional beam: (M,N,P,Mg,Ng) = (4,8,2,2,2) with dH,g=8.0,dV,g=4.0 Relay:		

Petitioners' Exhibit 1003, p. 1277
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

	dH=dV=0.5 - For unidirectional beam: (M,N,P,Mg,Ng) = (8, 16, 2, 1, 1), Other configurations such as (8,8,2,1,1) or (4,8,2,2,2) with dH,g=8.0,dV,g=4.0 are not precluded for unidirectional beam - For bidirectional beam: (M,N,P,Mg,Ng) = (4,8,2,2,2) with dH,g=8.0,dV,g=4.0		
UE antenna model parameters			
BS antenna element gain pattern	See Table A.2.1-10	Macro BS: Follow the modeling of TR 36.873 BS-type RSU: Follow the modeling of TR 36.873 Note: Further study if needed, e.g., vertical beamforming, vehicle-to-vehicle channel.	Macro BS: Follow the modeling of TR 36.873 BS-type RSU: Follow the modeling of TR 36.873 Note: Further study if needed, e.g., vertical beamforming effect, vehicle-to-vehicle channel.
UE antenna element gain pattern	See Table A.2.1-10	Vehicle/pedestrian UE: Half spherically uniform distribution with upper direction UE-type-RSU: Half spherically uniform distribution with bottom direction Note: directional antenna pattern is not precluded Note: uniform antenna models should be used for 2-D channel models	Vehicle/pedestrian UE: Half spherically uniform distribution with upper direction UE-type-RSU: Half spherically uniform distribution with bottom direction Note: directional antenna pattern is not precluded Note: uniform antenna models should be used for 2-D channel models
Number of TXRUs			
Others	TXRUs within a panel can be assumed to be synchronized and phase-calibrated (at least to the same level as in LTE). It should be possible as one option to assume QCL between ports of two different panels of the same transmission points Distances (dg,H, dg,V) between panels should be limited to at most [FFS] metres. NR evaluations may consider both cases of phase-calibration and no phase-calibration between panels		

Table A.2.1-6: 3-Sector BS antenna radiation pattern for above 6GHz

Parameter	Values
Antenna element vertical radiation pattern (dB)	$A_{E,V}(\theta'') = -\min\left[12\left(\frac{\theta''-90^0}{\theta_{3dB}}\right)^2, SLA_V\right], \theta_{3dB} = 65^0, SLA_V = 30$
Antenna element horizontal radiation pattern (dB)	$A_{E,H}(\varphi'') = -\min\left[12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right], \varphi_{3dB} = 65^0, A_m = 30$
Combining method for 3D antenna element pattern (dB)	$A''(\theta'',\varphi'') = -\min\left\{-\left[A_{E,V}(\theta'') + A_{E,H}(\varphi'')\right], A_m\right\}$
Maximum directional gain of an antenna element $G_{E,max}$	8dBi

Table A.2.1-7: Indoor BS antenna radiation pattern for above 6GHz

Parameter	Values

Petitioners' Exhibit 1003, p. 1278
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Single sector	Antenna element vertical radiation pattern (dB)	$A_{E,V}(\theta'') = -\min\left[12\left(\frac{\theta''-90^0}{\theta_{3dB}}\right)^2, SLA_V\right], \theta_{3dB} = 65^0, SLA_V = 25$
	Antenna element horizontal radiation pattern (dB)	$A_{E,H}(\varphi'') = 0$
	Combining method for 3D antenna element pattern (dB)	$A''(\theta'',\varphi'') = A_{E,V}(\theta'')$
	Maximum directional gain of an antenna element GE,max	[5dBi]
	Electric tilting	FFS
3-sector	Antenna element vertical radiation pattern (dB)	$A_{E,V}(\theta'') = -\min\left[12\left(\frac{\theta''-90^0}{\theta_{3dB}}\right)^2, SLA_V\right], \theta_{3dB} = 65^0, SLA_V = 25$
	Antenna element horizontal radiation pattern (dB)	$A_{E,H}(\varphi'') = -\min\left[12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right], \varphi_{3dB} = 65^0, A_m = 25$
	Combining method for 3D antenna element pattern (dB)	$A''(\theta'',\varphi'') = -\min\left\{-\left[A_{E,V}(\theta'') + A_{E,H}(\varphi'')\right], A_m\right\}$
	Maximum directional gain of an antenna element GE,max	[8dBi]
	Electric tilting	[110] degree
Wall-mount	Antenna element vertical radiation pattern (dB)	$A_{E,V}(\theta'') = -\min\left[12\left(\frac{\theta''-90^0}{\theta_{3dB}}\right)^2, SLA_V\right], \theta_{3dB} = 90^0, SLA_V = 25$
	Antenna element horizontal radiation pattern (dB)	$A_{E,H}(\varphi'') = -\min\left[12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right], \varphi_{3dB} = 90^0, A_m = 25$
	Combining method for 3D antenna element pattern (dB)	$A''(\theta'',\varphi'') = -\min\left\{-\left[A_{E,V}(\theta'') + A_{E,H}(\varphi'')\right], A_m\right\}$
	Maximum directional gain of an antenna element GE,max	5dBi
	Electric tilting	FFS
Ceiling-mount	Antenna element vertical radiation pattern (dB)	$A_{E,V}(\theta'') = -\min\left[12\left(\frac{\theta''-90^0}{\theta_{3dB}}\right)^2, SLA_V\right], \theta_{3dB} = 130^0, SLA_V = 25$
	Antenna element horizontal radiation pattern (dB)	$A_{E,H}(\varphi'') = -\min\left[12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right], \varphi_{3dB} = 130^0, A_m = 25$
	Combining method for 3D antenna element pattern (dB)	$A''(\theta'',\varphi'') = -\min\left\{-\left[A_{E,V}(\theta'') + A_{E,H}(\varphi'')\right], A_m\right\}$
	Maximum directional gain of an antenna element GE,max	5dBi
	Electric tilting	

Petitioners' Exhibit 1003, p. 1279
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table A.2.1-8: UE antenna radiation pattern model 1

Parameter	Values
Antenna element radiation pattern in θ'' dim (dB)	$A_{E,V}(\theta'') = -\min\left[12\left(\frac{\theta''-90^0}{\theta_{3dB}}\right)^2, SLA_V\right], \theta_{3dB}=90^0, SLA_V=25$
Antenna element radiation pattern in φ'' dim (dB)	$A_{E,H}(\varphi'') = -\min\left[12\left(\frac{\varphi''}{\varphi_{3dB}}\right)^2, A_m\right], \varphi_{3dB}=90^0, A_m=25$
Combining method for 3D antenna element pattern (dB)	$A''(\theta'',\varphi'') = -\min\left\{-\left[A_{E,V}(\theta'')+A_{E,H}(\varphi'')\right], A_m\right\}$
Maximum directional gain of an antenna element $G_{E,max}$	5dBi

Note: (θ'',φ'') are in local coordinate system.

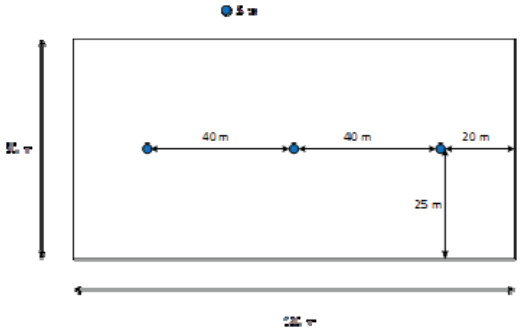


Figure A.2.1-1: Indoor hotspot 3-site deployment.



Figure A.2.1-2: Three sector antenna placement.

Petitioners' Exhibit 1003, p. 1280
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

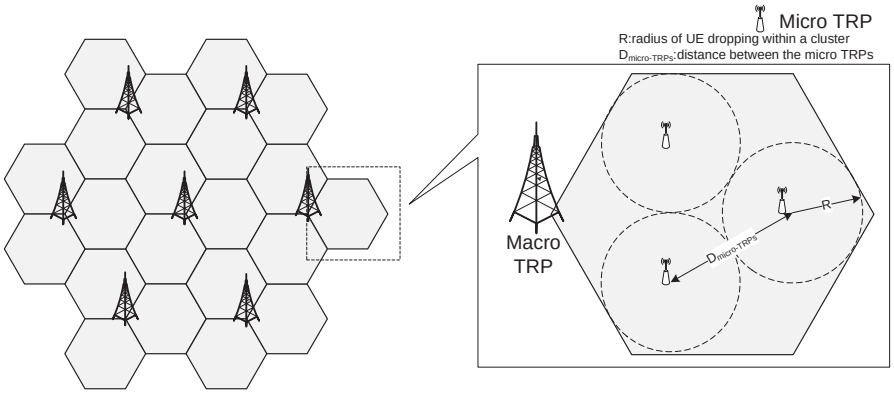


Figure A.2.1-3: Cell layout for dense urban (3 Micro TRPs per Macro TRP)

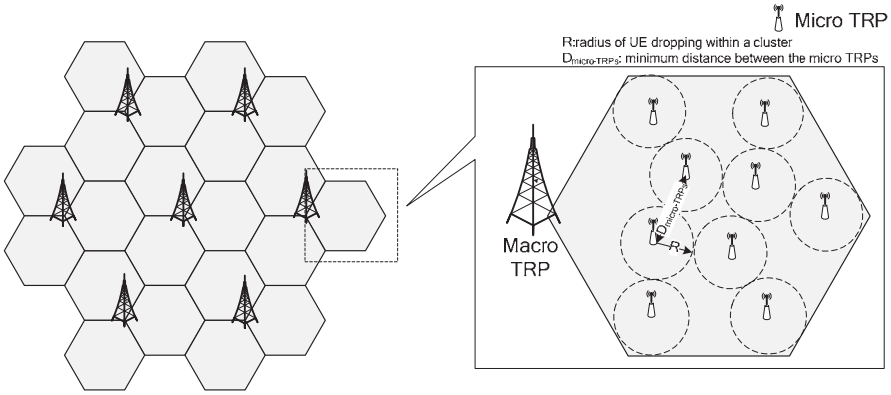


Figure A.2.1-4: Cell layout for dense urban (9 Micro TRPs per Macro TRP)

Table A.2.1-9: Minimum distance between TRPs and UE cluster radius

(a) Option 1

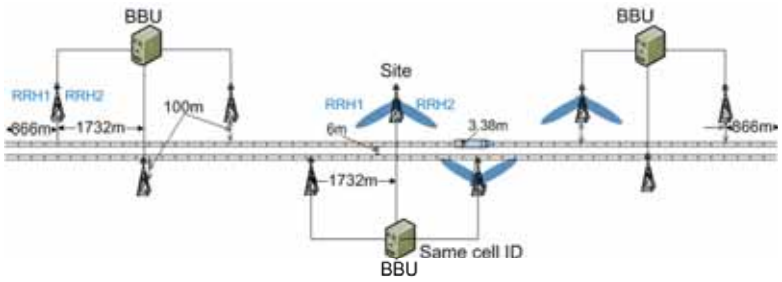
Number of the micro TRPs per macro TRP	Minimum distance between Micro TRPs (m)	Radius of UE dropping within a cluster: R (m)
3	57.9	<28.9
6	42.4	<21.2
9	32	<16

(b) Option 2

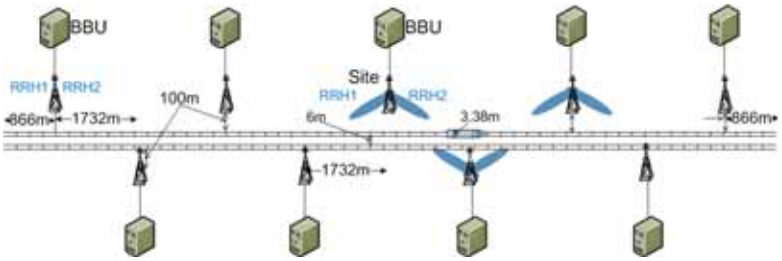
Number of the micro TRPs per macro TRP	Minimum distance between Micro TRPs (m)	Radius of UE dropping within a cluster: R (m)
3	40	50
6	32	50

Petitioners' Exhibit 1003, p. 1281
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

9	25	50

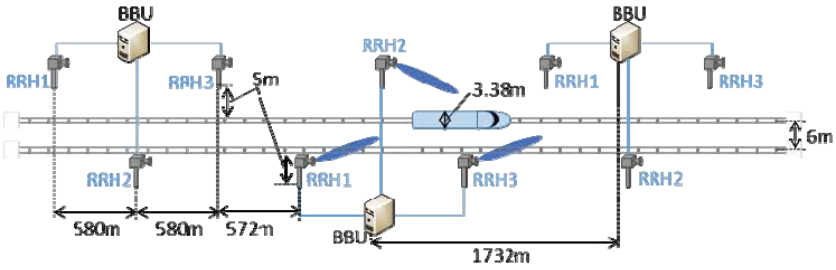


(a) SFN model

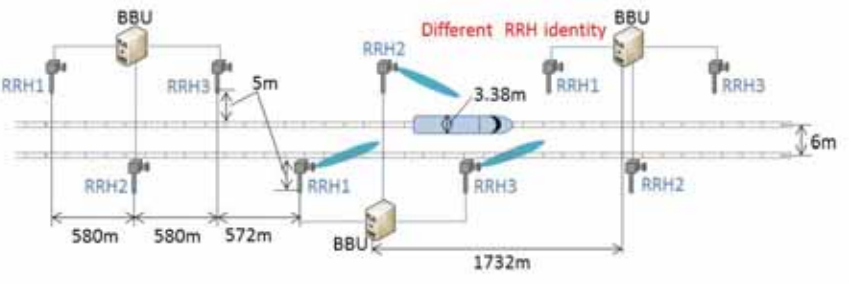


(b) Non-SFN model

Figure A.2.1-5: Cell layout for High Speed Train (4GHz)



(a) SFN model



Petitioners' Exhibit 1003, p. 1282
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

(b) Non-SFN model

Figure A.2.1-6: Cell layout for High Speed Train (30 GHz)

Table A.2.1-10: RRH and Relay antenna radiation pattern for high speed train option 2, alt. 2

Parameter		Values
Antenna element vertical radiation pattern (dB)	RRH	$A_{E,V}(\theta^{\prime\prime}) = -min\left[12\left(\frac{\theta^{\prime\prime}-90^{o}}{\theta_{3dB}}\right)^{2}, SLA_{V}\right], \theta_{3dB} = 65^{o}, SLA_{V} = 30$
	Relay	$A_{E,V}(\theta^{\prime\prime}) = -min\left[12\left(\frac{\theta^{\prime\prime}-90^{o}}{\theta_{3dB}}\right)^{2}, SLA_{V}\right], \theta_{3dB} = 65^{o}, SLA_{V} = 30$
	Relay (Optional)	$A_{E,V}(\theta^{\prime\prime}) = -min\left[12\left(\frac{\theta^{\prime\prime}-90^{o}}{\theta_{3dB}}\right)^{2}, SLA_{V}\right], \theta_{3dB} = 90^{o}, SLA_{V} = 25$
Antenna element horizontal radiation pattern (dB)	RRH	$A_{E,H}(\varphi^{\prime\prime}) = -min\left[12\left(\frac{\varphi^{\prime\prime}}{\varphi_{3dB}}\right)^{2}, A_{m}\right], \varphi_{3dB} = 65^{o}, A_{m} = 30$
	Relay	$A_{E,H}(\varphi^{\prime\prime}) = -min\left[12\left(\frac{\varphi^{\prime\prime}}{\varphi_{3dB}}\right)^{2}, A_{m}\right], \varphi_{3dB} = 65^{o}, A_{m} = 30$
	Relay (Optional)	$A_{E,H}(\varphi^{\prime\prime}) = -min\left[12\left(\frac{\varphi^{\prime\prime}}{\varphi_{3dB}}\right)^{2}, A_{m}\right], \varphi_{3dB} = 90^{o}, A_{m} = 25$
Combining method for 3D antenna element pattern (dB)	RRH	$A^{\prime\prime}(\theta^{\prime\prime}, \varphi^{\prime\prime}) = -min\{-[A_{E,V}(\theta^{\prime\prime}) + A_{E,H}(\varphi^{\prime\prime})], A_{m}\}$
	Relay	$A^{\prime\prime}(\theta^{\prime\prime}, \varphi^{\prime\prime}) = -min\{-[A_{E,V}(\theta^{\prime\prime}) + A_{E,H}(\varphi^{\prime\prime})], A_{m}\}$
	Relay (Optional)	$A^{\prime\prime}(\theta^{\prime\prime}, \varphi^{\prime\prime}) = -min\{-[A_{E,V}(\theta^{\prime\prime}) + A_{E,H}(\varphi^{\prime\prime})], A_{m}\}$
Maximum directional gain of an antenna element GE,max	RRH	8dBi
	Relay	8dBi
	Relay (Optional)	5dBi

The system level evaluation parameters specific to flexible duplex evaluation which are not covered by Table A.2.1-1is also given in Table A.2.1-11.

Table A.2.1-11: Evaluation parameters specific to flexible duplex

Parameters	Dense urban	Urban macro	Indoor hotspot
Minimum BS-UE (2D) distance	Macro-to-UE: 35m [TR36.897] Micro-to-UE: 10m [TR36.897]	35m [TR36.897]	0m [TR38.900]
Minimum UE-UE (2D) distance	3m [TR36.843]		
Carrier frequency	Macro layer: 4 GHz, 30 GHz [TR38.913] Micro layer: 4 GHz, 30 GHz	2GHz [TR38.913], 4 GHz, 30 GHz	4 GHz, 30 GHz
	For 30GHz: Un-paired spectrum is preferred. For 2GHz: paired spectrum is preferred.		

Petitioners' Exhibit 1003, p. 1283
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

	For 4GHz: both paired and un-paired spectrum can be considered.		
Aggregated system bandwidth	4GHz: Up to 200MHz (DL+UL) 30GHz: Up to1GHz (DL+UL)	2GHz: Up to 40 MHz (DL+UL) 4GHz: Up to 200 MHz (DL+UL) 30GHz: Up to 1GHz (DL+UL)	4GHz: Up to 200MHz (DL+UL) 30GHz: Up to 1GHz (DL+UL)
Simulation bandwidth	20MHz per CC below 6GHz and 80 MHz per CC above 6GHz Note: For FDD, simulation BW is split equally between UL and DL Note: UE TX power scaling will impact final results		
Large-scale channel parameters(*)	**Below 6GHz:** - Macro-to-UE: 3D UMa - Micro-to-UE: 3D UMi - Macro-to-Macro: 3D UMa (h_UE=25m) - Macro-to-Micro: 3D UMa (h_UE=10m), FFS additional offset X1 dB - Micro-to-Micro: 3D UMi (h_UE=10m), FFS additional offset X2 dB - UE-to-UE: A.2.1.2 in TR36.843, FFS on penetration loss between UEs **Above 6GHz:** - Macro-to-UE: 5GCM UMa - Micro-to-UE: UMi-Street canyon - Macro-to-Macro: 5GCM UMa (h_UE=25m) - Macro-to-Micro: 5GCM UMa (h_UE=10m) - Micro-to-Micro: UMi-Street canyon (h_UE=10m) - UE-to-UE: UMi-Street canyon (h_BS=1.5m ~ 22.5m), FFS on penetration loss between UEs		**Below 6GHz:** - TRP-to-UE: ITU InH - TRP-to-TRP: ITU InH (h_UE=3m) - UE-to-UE: A.2.1.2 in TR36.843 **Above 6GHz:** - TRP-to-UE: 5GCM Indoor-office - TRP-to-TRP: 5GCM Indoor-office (h_UE=3m) - UE-to-UE: 5GCM Indoor-office (h_BS=1.5m)
Fast fading parameters(*)	**Below 6GHz:** - Macro-to-UE: 3D Uma - Micro-to-UE: 3D Umi - Macro to Macro: 3D UMa O-to-O (h_UE=25m); ASA and ZSA statistics(**) updated to be the same as ASD and ZSD; ZoD offset = 0 - Macro to Micro: 3D Uma O-to-O - Micro to Micro: 3D Umi O-to-O (h_UE=10m); ASA and ZSA statistics updated to be the same as ASD and ZSD; ZoD offset = 0 - UE to UE: InH for indoor to indoor, and 3D Umi for other cases. ASD and ZSD statistics updated to be the same as ASA and ZSA. Dual mobility support. **Above 6GHz:** - Macro-to-UE: 5GCM Uma - Micro-to-UE: UMi-Street canyon - Macro to macro: 5GCM UMa O-to-O (h_UE=25m); ASA and ZSA statistics updated to be the same as ASD and ZSD; ZoD offset = 0 - Macro to micro: 5GCM UMa O-to-O - Micro to Micro: UMi-Street canyon O-to-O (h_UE=10m); ASA and ZSA statistics updated to be the same as ASD and ZSD; ZoD offset = 0 - UE to UE: UMi-Street canyon; ASD and ZSD statistics updated to be the same as ASA and ZSA. Dual mobility support.		**Below 6GHz:** - TRP-to-UE: ITU InH - TRP-to-TRP: ITU InH (h_UE=3m), ASA statistics updated to be the same as ASD - UE-to-UE: A.2.1.2 in TR36.843 (ITU InH), ASD statistics updated to be the same as ASA. **Above 6GHz:** - TRP-to-UE: 5GCM Indoor-office - TRP-to-TRP: 5GCM Indoor-office (h_UE=3m), ASA and ZSA statistics(**) updated to be the same as ASD and ZSD - UE-to-UE: 5GCM Indoor-office (h_BS=1.5m), ASD and ZSD statistics updated to be the same as ASA and ZSA
Traffic model	Baseline: – FTP traffic model 3 with packet size 0.1 and 0.5Mbytes – Ratio of DL/UL traffic = {2:1}, {4:1} and {1: 1} for optional [TR36.828]		

(*): The assumption is used as starting point for flexible duplex evaluation, and further update might be made.

(**): Statistics of ASA/ASD and ZSA/ZSD include its mean, standard variance, correlation distance in the horizontal plane, and in-cluster angular spread (e.g., cluster ASA/ASD).

Table A.2.1-12: Penetration loss for UE-to-UE link for 30GHz specific to flexible duplex

Location of UE_x	Location of UE_y	Sub-scenario	Penetration loss (for around 30GHz)

Petitioners' Exhibit 1003, p. 1284
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Indoor	Indoor	In different building (if inter-user 2D distance > 50m)	$PLoss = PLoss_x + PLoss_y$ $PLoss_i = PL_{tw}^{(i)} + PL_{in}^{(i)} + N^{(i)}(0,\sigma_P^2)$ is the building penetration loss as given by section 7.4.3 in TR 38.900. *i=x, y*
		In the same building (if inter-user 2D distance ≤ 50m)	$PLoss = \lvert n_x - n_y \rvert \times L_{\text{concrete}}$ where L_{concrete} is given by Table 7.4.3-1 in TR 38.900, and n_i is the floor number for UE_i, *i=x, y*.
Indoor	Outdoor	N.A.	$PLoss = PLoss_x + PLoss_y$ $PLoss_x = PL_{tw}^{(x)} + PL_{in}^{(x)} + N^{(x)}(0,\sigma_P^2)$ is the building penetration loss as given by section 7.4.3 in TR 38.900. $PLoss_y = N^{(y)}(\mu,\sigma_P^2)$ is the car penetration loss as given by section 7.4.3 in TR 38.900.
Outdoor	Indoor	N.A.	$PLoss = PLoss_x + PLoss_y$ $PLoss_x = N^{(x)}(\mu,\sigma_P^2)$ is the car penetration loss as given by section 7.4.3 in TR 38.900. $PLoss_y = PL_{tw}^{(y)} + PL_{in}^{(y)} + N^{(y)}(0,\sigma_P^2)$ is the building penetration loss as given by section 7.4.3 in TR 38.900.
Outdoor	Outdoor	N.A.	$PLoss = PLoss_x + PLoss_y$ $PLoss_i = N^{(i)}(\mu,\sigma_P^2)$ is the car penetration loss as given by section 7.4.3 in TR 38.900. *i=x, y*

Note: The assumption is used as starting point for flexible duplex evaluation, and further update might be made.

Table A.2.1-13: Penetration loss for UE-to-UE link for 4GHz and 2GHz specific to flexible duplex

Location of UE_x	Location of UE_y	Sub-scenario	Penetration loss (for around 4GHz and 2GHz)
Indoor	Indoor	In different building (if inter-user 2D distance > 50m)	$PLoss = PLoss_x + PLoss_y$ $PLoss_i = PL_{tw} + 0.5d_{in}^{(i)}$ where PL$_{tw}$=20dB, and $d_{in}^{(i)} \sim U(0,25)$ in meter TR 36.814 is the distance from user to internal wall, *i=x, y,* and *U(a,b)* indicates uniform distribution.
		In the same building (if inter-user 2D distance ≤ 50m)	$PLoss = 18.3dB$ for UEs on different floors TR 36.872; otherwise 0dB.
Indoor	Outdoor	N.A.	$PLoss = PLoss_x + PLoss_y$ $PLoss_x = PL_{tw} + 0.5d_{in}^{(x)}$ with PL$_{tw}$=20dB and $d_{in}^{(i)} \sim U(0,25)$ in meter is the building penetration loss as given by TR 36.814. $PLoss_y = N^{(y)}(\mu,\sigma_P^2)$ is the car penetration loss as given by section 7.4.3 in TR 38.900.
Outdoor	Indoor	N.A.	$PLoss = PLoss_x + PLoss_y$ $PLoss_x = N^{(x)}(\mu,\sigma_P^2)$ is the car penetration loss as given by section 7.4.3 in TR 38.900. $PLoss_y = PL_{tw} + 0.5d_{in}^{(y)}$ with PL$_{tw}$=20dB and $d_{in}^{(i)} \sim U(0,25)$ in meter is the building penetration loss as given by TR 36.814.
Outdoor	Outdoor	N.A.	$PLoss = PLoss_x + PLoss_y$ $PLoss_i = N^{(i)}(\mu,\sigma_P^2)$ is the car penetration loss as given by section 7.4.3 in TR 38.900. *i=x, y*

Note: The assumption is used as starting point for flexible duplex evaluation, and further update might be made.

Petitioners' Exhibit 1003, p. 1285
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

A.2.2 Simulation assumption for evaluation of multiple access scheme

This section describes the system level evaluation assumptions in order to assess multiple access schemes. The system level evaluation assumptions for multiple access schemes are provided in Table A.2.2-1. Table A.2.2-2 provides UL traffic model for mMTC which is only applied to multiple access evaluation.

Table A.2.2-1: Evaluation assumptions for multiple access schemes targeting eMBB

Parameters	Dense urban (eMBB)	Rural
Layout	Signal layer Two layers not precluded	Single layer Macro layer: Hex. Grid
Inter-BS distance	Macro layer: 200m	1732m
Carrier frequency	4 GHz for the single layer	700MHz
BS antenna configuration	4, 8, 16, 32 TXRUs	2, 4, 8 ports
BS scheduler	Both subband and wideband scheduler can be considered	
UE antenna configuration	2, 1 TXUs 2, 4 RXUs	2Tx, 1Tx port 2Rx, 4Rx ports
Traffic model	Full buffer model for spectral efficiency FTP model 1/3 for user experienced data rate NOTE: full buffer evaluation is not used for technical scheme down selection	
Traffic load (Resource utilization)	50%, 80% 25% (optional)	
UE density for full buffer model	10 UE per TRP 20 or other values are not precluded	10 UE per TRP other values are not precluded

Table A.2.2-2: UL traffic model for mMTC applied to multiple access evaluation

Parameters	Values/assumptions
Data packet arrival rate per UE	Poisson arrival with arrival rate λ
Number of UEs per cell	Companies report the number of UEs per cell and companies are encouraged to report λ to achieve the connection density target.
Packet size	Option 1: Follow TR45.820 Option 2: Fix 40 Bytes
Simulation Bandwidth	Companies report the simulation bandwidth
Target packet drop rate	0.01
Packet dropping timer	Baseline: 1s, 10s Other values are not precluded.

Commented [T45]: [Editor's note] Companies report the option used, but are encouraged to evaluate both options. Decide on which option(s) is used to draw the conclusion of MA at RAN1#86bis meeting
Companies report details on packet segmentation assumption

A.2.3 Simulation assumption related to initial access

This section describes the simulation assumptions for evaluating initial access. Table A.2.3-1 shows the evaluation assumption for synchronization signal related to initial access.

Table A.2.3-1: Simulation assumptions for synchronization signals/channels

	Below 6GHz	Above 6GHz
Scenario	Urban Macro (ISD = 500m), Macro only scenario in dense urban (ISD = 200m)	
Carrier Frequency	4 GHz	30, 70 GHz
Channel Model	TR 36.873	TR 38.900
UE dropping	According to TR 36.873 (one or two cellular tiers) Note: Company reports which value for the number (i.e., 1 or 2) of cellular tiers to choose for the evaluation	
Subcarrier Spacing(s)	15, 30, 60, 120, 240, or 480 kHz (to be clarified by each proponent; other values are not precluded)	
Network Synchronization	TRPs are synchronized, propagation delay difference between TRPs is	

Petitioners' Exhibit 1003, p. 1286
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

	modelled based on the free space assumption.	
Search window	The time window to search (correlate) NR-PSS. It depends on the periodicity of NR-SS transmission. The value needs to be provided by each proponent	
Antenna Configuration at the TRP	(8,1,2) with directional antenna element (HPBW=65 degrees, directivity 8dB)	(4,8,2), with directional antenna element (HPBW=65 degrees , directivity 8dB)
Antenna Configuration at the UE	(1,1,2) with omni-directional antenna element	(2,4,2), with directional antenna element (HPBW=90 degrees , directivity 5dB)
Antenna port virtualization	Clarified by each proponent in simulation assumptions (e.g. the beamforming method, beam directions, number of beams)	
Frequency Offset	o Initial acquisition o TRP: uniform distribution +/- 0.05 ppm o UE: uniform distribution +/- 5, 10, 20 ppm (each company to choose one) o Non-initial acquisition o TRP: uniform distribution +/- 0.05 ppm o UE: uniform distribution +/- 0.1 ppm	
PHY Abstraction	No PHY Abstraction. All the links shall be explicitly implemented in the system level platform. Note: Proponents are allowed to provide PHY abstraction details if used	

Tables A.2.3-2 – A.2.3.4 provided the evaluation assumption for evaluation of DL and UL mobility for dense urban, rural and high-speed train scenarios, respectively. Only the parameters which are different from Table A.2.1-1 and Table A.2.1-2 are provided. For dense urban, a UE speed of up to 60km/h is considered for macro-only evaluation while a UE speed of up to 30km/h is considered for dual layer evaluation.

Table A.2.3-2: Simulation assumptions for DL and UL mobility (Dense urban)

Parameters	Values or assumptions
Layout	Two layer Macro layer: Hex. Grid Micro layer: Random drop 9 micro BSs per macro BS
Carrier frequency	4 GHz
BS antenna configurations	(8,1,2) with directional antenna element (HPBW=650, directivity 8dB) other values are not precluded
UE distribution	10 users per macro TRP, 10 users per micro TRP 100% outdoor,30km/h (basleine), 3, 60 km/h (optional) Simultaneous UEs within a slot UE location/movement direction randomly chosen

Table A.2.3-3: Simulation assumptions for DL and UL mobility (Rural)

Parameters	Values or assumptions
Carrier frequency	4GHz
Channel model	3D UMa
BS antenna configurations	(8,1,2) with directional antenna element (HPBW=650, directivity 8dB) other values are not precluded
UE distribution	Outdoor vehicles 120km/h 10 UEs per TRPs UE location/movement direction randomly chosen

Table A.2.3-4: Simulation assumptions for DL and UL mobility (High-speed train)

Parameters	Values or assumptions
BS antenna configurations	(8,1,2) with directional antenna element (HPBW=650, directivity 8dB) other values are not precluded

Petitioners' Exhibit 1003, p. 1287
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

UE distribution	1000 UEs per train and 30% active UEs 100% of users in train at 480 km/h Each company should open how to model network configuration

A.2.4 Simulation assumption for URLLC

This section describes the simulation assumptions for evaluating the aspects related to URLLC. Indoor Hotspot and Urban Macro scenario are considered. Table A.2.4-1 shows the evaluation assumptions where URLLC as well as eMBB traffic models are taken into account.

Table A.2.4-1: Simulation assumptions for URLLC

Parameters	**Urban Macro**	**Indoor Hotspot**
Layout	Single layer Macro layer: Hexagonal Grid	Single-layer Indoor floor: (3,6,12) BSs per 120 m x 50 m
Inter-BS distance	500 m	Follow TRP placement from 38.802
Carrier frequency	4 GHz	4 GHz
Aggregated system bandwidth	4 GHz: Up to 200 MHz (DL+UL)	4 GHz: Up to 200 MHz (DL+UL)
Simulation bandwidth	20 MHz per CC below 6 GHz Note: For FDD, simulation BW is split equally between UL and DL Other bandwidths are not precluded	
Channel model	36.873 3D Uma	Below 6 GHz: ITU InH Note: When 5GCM is found to be applicable to below 6 GHz, 5GCM should be used
BS Tx power	46 dBm per 20 MHz	24 dBm per 20 MHz
UE Tx power	23 dBm	
BS antenna configurations	See 38.802, table A.2.1-4.	
BS antenna height	25 m	3 m
BS antenna element gain + connector loss	See 38.802, table A.2.1-4.	
BS receiver noise figure	Below 6 GHz: 5 dB	
UE antenna configurations	See 38.802, table A.2.1-4.	
UE antenna height	Follow the modelling of TR 36.873	
UE antenna gain	Follow the modelling of TR 36.873	
UE receiver noise figure	9 dB	
Traffic model	Unidirectional and bidirectional (DL or UL). URLLC: Both FTP Model 3 (with Poisson arrival) and periodic packet arrivals with packet size 32, 50, 200 bytes. eMBB: Option 1: Full buffer, Option 2: FTP model 3 with packet size, 0.1Mbytes and 0.5Mbytes	
Traffic load (Resource utilization)	URLLC: Packet arrival to achieve URLLC capacity eMBB: For FTP Model 3, arrival rate is selected to achieve RU of [20, 50] % for the case of no multiplexing with URLLC	
UE distribution	Follow Urban Macro user distribution for both URLLC and eMBB UEs 20% Outdoor in cars: 30 km/h, 80% Indoor: 3 km/h () URLLC: 10 UE/sector eMBB: 0/10 UE/sector Option 1 (DL only) Load only center 1 sector with 10 URLLCC and 0/10 eMBB Load other 56 sectors with 1 eMBB 1 eMBB UE in the other 56 sectors is of the same traffic model as the eMBB UEs in the center sector Option 2 Load all sectors with 10 URLLCC and 0/10 eMBB	Follow Indoor Hotspot user distribution for both URLLC and eMBB UEs 100% Indoor, 3 km/h URLLC: 10 UE/floor/TRP eMBB: 0/10 UE/floor/TRP
BS receiver	Reported by companies, Baseline is MMSE-IRC	

Petitioners' Exhibit 1003, p. 1288
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

UE receiver	Reported by companies, Baseline is MMSE-IRC
Feedback assumption & Link adaptation assumptions	Reported by companies
Channel estimation	Reported by companies, Practical channel estimation
Others	Companies report the assumption on admission control used

Annex B: Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
2016-04	RAN1#84b	R1-163376	-	-	Draft Skeleton TR	-	0.0.1
2016-05	RAN1#85	R1-165216	-	-	Updated version	0.0.1	0.0.2
2016-05	RAN1#85	R1-165889	-	-	Inclusion of agreements made at RAN1#84b on introduction, evaluation assumptions and methodologies	0.0.2	0.0.3
2016-08	RAN1#86	R1-168526	-	-	Inclusion of agreements made at RAN1#85 on forward compatibility, UL multiple access scheme, and updated evaluation assumptions	0.0.3	0.1.0
2016-10	RAN1#86b	R1-1610848	-	-	Inclusion of agreements made at RAN1#86 on duplexing, numerologies, frame structure, DL/UL concepts, multi-antenna scheme, and updated evaluation assumptions	0.1.0	0.3.0
2016-11	RAN1#87	R1-16xxxx			Inclusion of agreements made at RAN1#86b including numerologies, frame structure, DL/UL concepts, aspects related to initial access/mobility, multi-antenna scheme	0.3.0	X.X.X

Petitioners' Exhibit 1003, p. 1289
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

APPENDIX 11

ETSI TS 136 212 V13.1.0 (2016-04)



LTE;
Evolved Universal Terrestrial Radio Access (E-UTRA);
Multiplexing and channel coding
(3GPP TS 36.212 version 13.1.0 Release 13)



Petitioners' Exhibit 1003, p. 1291
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Reference
RTS/TSGR-0136212vd10

Keywords
LTE

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

Important notice

The present document can be downloaded from:
http://www.etsi.org/standards-search

The present document may be made available in electronic versions and/or in print. The content of any electronic and/or print versions of the present document shall not be modified without the prior written authorization of ETSI. In case of any existing or perceived difference in contents between such versions and/or in print, the only prevailing document is the print of the Portable Document Format (PDF) version kept on a specific network drive within ETSI Secretariat.

Users of the present document should be aware that the document may be subject to revision or change of status.
Information on the current status of this and other ETSI documents is available at
http://portal.etsi.org/tb/status/status.asp

If you find errors in the present document, please send your comment to one of the following services:
https://portal.etsi.org/People/CommiteeSupportStaff.aspx

Copyright Notification

No part may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm except as authorized by written permission of ETSI.
The content of the PDF version shall not be modified without the written authorization of ETSI.
The copyright and the foregoing restriction extend to reproduction in all media.

© European Telecommunications Standards Institute 2016.
All rights reserved.

DECT™, **PLUGTESTS**™, **UMTS**™ and the ETSI logo are Trade Marks of ETSI registered for the benefit of its Members.
3GPP™ and **LTE**™ are Trade Marks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners.
GSM® and the GSM logo are Trade Marks registered and owned by the GSM Association.

Petitioners' Exhibit 1003, p. 1292
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Intellectual Property Rights

IPRs essential or potentially essential to the present document may have been declared to ETSI. The information pertaining to these essential IPRs, if any, is publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (https://ipr.etsi.org/).

Pursuant to the ETSI IPR Policy, no investigation, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Foreword

This Technical Specification (TS) has been produced by ETSI 3rd Generation Partnership Project (3GPP).

The present document may refer to technical specifications or reports using their 3GPP identities, UMTS identities or GSM identities. These should be interpreted as being references to the corresponding ETSI deliverables.

The cross reference between GSM, UMTS, 3GPP and ETSI identities can be found under http://webapp.etsi.org/key/queryform.asp.

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Petitioners' Exhibit 1003, p. 1293
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Contents

Intellectual Property Rights 2
Foreword 2
Modal verbs terminology 2
Foreword 5
1 Scope 6
2 References 6
3 Definitions, symbols and abbreviations 6
3.1 Definitions 6
3.2 Symbols 6
3.3 Abbreviations 7
4 Mapping to physical channels 8
4.1 Uplink 8
4.2 Downlink 8
4.3 Sidelink 8
5 Channel coding, multiplexing and interleaving 9
5.1 Generic procedures 9
5.1.1 CRC calculation 9
5.1.2 Code block segmentation and code block CRC attachment 9
5.1.3 Channel coding 11
5.1.3.1 Tail biting convolutional coding 12
5.1.3.2 Turbo coding 13
5.1.3.2.1 Turbo encoder 13
5.1.3.2.2 Trellis termination for turbo encoder 14
5.1.3.2.3 Turbo code internal interleaver 14
5.1.4 Rate matching 16
5.1.4.1 Rate matching for turbo coded transport channels 16
5.1.4.1.1 Sub-block interleaver 16
5.1.4.1.2 Bit collection, selection and transmission 17
5.1.4.2 Rate matching for convolutionally coded transport channels and control information 19
5.1.4.2.1 Sub-block interleaver 20
5.1.4.2.2 Bit collection, selection and transmission 21
5.1.5 Code block concatenation 22
5.2 Uplink transport channels and control information 22
5.2.1 Random access channel 22
5.2.2 Uplink shared channel 22
5.2.2.1 Transport block CRC attachment 23
5.2.2.2 Code block segmentation and code block CRC attachment 24
5.2.2.3 Channel coding of UL-SCH 24
5.2.2.4 Rate matching 24
5.2.2.5 Code block concatenation 24
5.2.2.6 Channel coding of control information 24
5.2.2.6.1 Channel quality information formats for wideband CQI reports 38
5.2.2.6.2 Channel quality information formats for higher layer configured subband CQI reports 42
5.2.2.6.3 Channel quality information formats for UE selected subband CQI reports 54
5.2.2.6.4 Channel coding for CQI/PMI information in PUSCH 61
5.2.2.6.5 Channel coding for more than 11 bits of HARQ-ACK information 62
5.2.2.7 Data and control multiplexing 62
5.2.2.8 Channel interleaver 63
5.2.3 Uplink control information on PUCCH 65
5.2.3.1 Channel coding for UCI HARQ-ACK 66
5.2.3.2 Channel coding for UCI scheduling request 72
5.2.3.3 Channel coding for UCI channel quality information 72

Petitioners' Exhibit 1003, p. 1294
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.2.3.3.1 Channel quality information formats for wideband reports 73
5.2.3.3.2 Channel quality information formats for UE-selected sub-band reports 79
5.2.3.4 Channel coding for UCI channel quality information and HARQ-ACK 88
5.2.4 Uplink control information on PUSCH without UL-SCH data 88
5.2.4.1 Channel coding of control information 89
5.2.4.2 Control information mapping 89
5.2.4.3 Channel interleaver 90
5.3 Downlink transport channels and control information 90
5.3.1 Broadcast channel 90
5.3.1.1 Transport block CRC attachment 91
5.3.1.2 Channel coding 91
5.3.1.3 Rate matching 91
5.3.2 Downlink shared channel, Paging channel and Multicast channel 91
5.3.2.1 Transport block CRC attachment 92
5.3.2.2 Code block segmentation and code block CRC attachment 92
5.3.2.3 Channel coding 93
5.3.2.4 Rate matching 93
5.3.2.5 Code block concatenation 93
5.3.3 Downlink control information 93
5.3.3.1 DCI formats 94
5.3.3.1.1 Format 0 94
5.3.3.1.2 Format 1 95
5.3.3.1.3 Format 1A 97
5.3.3.1.3A Format 1B 99
5.3.3.1.4 Format 1C 100
5.3.3.1.4A Format 1D 101
5.3.3.1.5 Format 2 102
5.3.3.1.5A Format 2A 106
5.3.3.1.5B Format 2B 108
5.3.3.1.5C Format 2C 109
5.3.3.1.5D Format 2D 111
5.3.3.1.6 Format 3 112
5.3.3.1.7 Format 3A 113
5.3.3.1.8 Format 4 113
5.3.3.1.9 Format 5 115
5.3.3.1.10 Format 6-0A 115
5.3.3.1.11 Format 6-0B 116
5.3.3.1.12 Format 6-1A 117
5.3.3.1.13 Format 6-1B 118
5.3.3.1.14 Format 6-2 119
5.3.3.2 CRC attachment 119
5.3.3.3 Channel coding 120
5.3.3.4 Rate matching 120
5.3.4 Control format indicator 120
5.3.4.1 Channel coding 121
5.3.5 HARQ indicator (HI) 121
5.3.5.1 Channel coding 121
5.4 Sidelink transport channels and control information 121
5.4.1 Sidelink broadcast channel 121
5.4.1.1 Transport block CRC attachment 122
5.4.1.2 Channel coding 122
5.4.1.3 Rate matching 122
5.4.2 Sidelink shared channel 123
5.4.3 Sidelink control information 123
5.4.3.1 SCI formats 123
5.4.3.1.1 SCI format 0 123
5.4.4 Sidelink discovery channel 124

Annex A (informative): Change history 125

History 129

Petitioners' Exhibit 1003, p. 1295
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Foreword

This Technical Specification has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

Y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

Petitioners' Exhibit 1003, p. 1296
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

1 Scope

The present document specifies the coding, multiplexing and mapping to physical channels for E-UTRA.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document.*

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TS 36.211: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation".

[3] 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures".

[4] 3GPP TS 36.306: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities".

[5] 3GPP TS36.321, 'Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification'

[6] 3GPP TS36.331, 'Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) protocol specification'

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in [1].

BL/CE: A Bandwidth-reduced Low-complexity or Coverage Enhanced (BL/CE) UE is capable of coverage enhancement mode A support and intends to access a cell in a coverage enhancement mode or is configured in a coverage enhancement mode.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

$N_{\mathrm{RB}}^{\mathrm{DL}}$ Downlink bandwidth configuration, expressed in number of resource blocks [2]

$N_{\mathrm{RB}}^{\mathrm{UL}}$ Uplink bandwidth configuration, expressed in number of resource blocks [2]

$N_{\mathrm{RB}}^{\mathrm{SL}}$ Sidelink bandwidth configuration, expressed in number of resource blocks [2]

Petitioners' Exhibit 1003, p. 1297
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

N_{sc}^{RB}	Resource block size in the frequency domain, expressed as a number of subcarriers
N_{symb}^{PUSCH}	Number of SC-FDMA symbols carrying PUSCH in a subframe
$N_{symb}^{PUSCH\text{-}initial}$	Number of SC-FDMA symbols carrying PUSCH in the initial PUSCH transmission subframe
N_{symb}^{UL}	Number of SC-FDMA symbols in an uplink slot
N_{symb}^{SL}	Number of SC-FDMA symbols in a sidelink slot
N_{SRS}	Number of SC-FDMA symbols used for SRS transmission in a subframe (0 or 1).

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

BCH	Broadcast channel
CFI	Control Format Indicator
CP	Cyclic Prefix
CSI	Channel State Information
DCI	Downlink Control Information
DL-SCH	Downlink Shared channel
EPDCCH	Enhanced Physical Downlink Control channel
FDD	Frequency Division Duplexing
HI	HARQ indicator
LAA	Licensed-Assisted Access
MCH	Multicast channel
MPDCCH	MTC Physical Downlink Control Channel
PBCH	Physical Broadcast channel
PCFICH	Physical Control Format Indicator channel
PCH	Paging channel
PDCCH	Physical Downlink Control channel
PDSCH	Physical Downlink Shared channel
PHICH	Physical HARQ indicator channel
PMCH	Physical Multicast channel
PMI	Precoding Matrix Indicator
PRACH	Physical Random Access channel
PSBCH	Physical Sidelink Broadcast Channel
PSCCH	Physical Sidelink Control Channel
PSDCH	Physical Sidelink Discovery Channel
PSSCH	Physical Sidelink Shared Channel PUCCH Physical Uplink Control channel
PUSCH	Physical Uplink Shared channel
RACH	Random Access channel
RI	Rank Indication
SCI	Sidelink Control Information
SL-BCH	Sidelink Broadcast Channel
SL-DCH	Sidelink Discovery Channel
SL-SCH	Sidelink Shared Channel
SR	Scheduling Request
SRS	Sounding Reference Signal
TDD	Time Division Duplexing
TPMI	Transmitted Precoding Matrix Indicator
UCI	Uplink Control Information
UL-SCH	Uplink Shared channel

Petitioners' Exhibit 1003, p. 1298
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

4 Mapping to physical channels

4.1 Uplink

Table 4.1-1 specifies the mapping of the uplink transport channels to their corresponding physical channels. Table 4.1-2 specifies the mapping of the uplink control channel information to its corresponding physical channel.

Table 4.1-1

TrCH	Physical Channel
UL-SCH	PUSCH
RACH	PRACH

Table 4.1-2

Control information	Physical Channel
UCI	PUCCH, PUSCH

4.2 Downlink

Table 4.2-1 specifies the mapping of the downlink transport channels to their corresponding physical channels. Table 4.2-2 specifies the mapping of the downlink control channel information to its corresponding physical channel.

Table 4.2-1

TrCH	Physical Channel
DL-SCH	PDSCH
BCH	PBCH
PCH	PDSCH
MCH	PMCH

Table 4.2-2

Control information	Physical Channel
CFI	PCFICH
HI	PHICH
DCI	PDCCH, EPDCCH, MPDCCH

4.3 Sidelink

Table 4.3-1 specifies the mapping of the sidelink transport channels to their corresponding physical channels. Table 4.3-2 specifies the mapping of the sidelink control information to its corresponding physical channel.

Table 4.3-1

TrCH	Physical Channel
SL-SCH	PSSCH
SL-BCH	PSBCH
SL-DCH	PSDCH

Table 4.3-2

Control information	Physical Channel
SCI	PSCCH

Petitioners' Exhibit 1003, p. 1299
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5 Channel coding, multiplexing and interleaving

Data and control streams from/to MAC layer are encoded /decoded to offer transport and control services over the radio transmission link. Channel coding scheme is a combination of error detection, error correcting, rate matching, interleaving and transport channel or control information mapping onto/splitting from physical channels.

5.1 Generic procedures

This section contains coding procedures which are used for more than one transport channel or control information type.

5.1.1 CRC calculation

Denote the input bits to the CRC computation by $a_0, a_1, a_2, a_3, ..., a_{A-1}$, and the parity bits by $p_0, p_1, p_2, p_3, ..., p_{L-1}$. A is the size of the input sequence and L is the number of parity bits. The parity bits are generated by one of the following cyclic generator polynomials:

- $g_{CRC24A}(D) = [D^{24} + D^{23} + D^{18} + D^{17} + D^{14} + D^{11} + D^{10} + D^7 + D^6 + D^5 + D^4 + D^3 + D + 1]$ and;
- $g_{CRC24B}(D) = [D^{24} + D^{23} + D^6 + D^5 + D + 1]$ for a CRC length $L = 24$ and;
- $g_{CRC16}(D) = [D^{16} + D^{12} + D^5 + 1]$ for a CRC length $L = 16$.
- $g_{CRC8}(D) = [D^8 + D^7 + D^4 + D^3 + D + 1]$ for a CRC length of $L = 8$.

The encoding is performed in a systematic form, which means that in GF(2), the polynomial:

$$a_0 D^{A+23} + a_1 D^{A+22} + ... + a_{A-1} D^{24} + p_0 D^{23} + p_1 D^{22} + ... + p_{22} D^1 + p_{23}$$

yields a remainder equal to 0 when divided by the corresponding length-24 CRC generator polynomial, $g_{CRC24A}(D)$ or $g_{CRC24B}(D)$, the polynomial:

$$a_0 D^{A+15} + a_1 D^{A+14} + ... + a_{A-1} D^{16} + p_0 D^{15} + p_1 D^{14} + ... + p_{14} D^1 + p_{15}$$

yields a remainder equal to 0 when divided by $g_{CRC16}(D)$, and the polynomial:

$$a_0 D^{A+7} + a_1 D^{A+6} + ... + a_{A-1} D^8 + p_0 D^7 + p_1 D^6 + ... + p_6 D^1 + p_7$$

yields a remainder equal to 0 when divided by $g_{CRC8}(D)$.

The bits after CRC attachment are denoted by $b_0, b_1, b_2, b_3, ..., b_{B-1}$, where $B = A + L$. The relation between a_k and b_k is:

$b_k = a_k$ for $k = 0, 1, 2, \ldots, A-1$

$b_k = p_{k-A}$ for $k = A, A+1, A+2, ..., A+L-1$.

5.1.2 Code block segmentation and code block CRC attachment

The input bit sequence to the code block segmentation is denoted by $b_0, b_1, b_2, b_3, ..., b_{B-1}$, where $B > 0$. If B is larger than the maximum code block size Z, segmentation of the input bit sequence is performed and an additional CRC sequence of $L = 24$ bits is attached to each code block. The maximum code block size is:

- $Z = 6144$.

If the number of filler bits F calculated below is not 0, filler bits are added to the beginning of the first block.

Note that if $B < 40$, filler bits are added to the beginning of the code block.

Petitioners' Exhibit 1003, p. 1300
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The filler bits shall be set to <*NULL*> at the input to the encoder.

Total number of code blocks C is determined by:

if $B \le Z$

$L = 0$

Number of code blocks: $C = 1$

$B' = B$

else

$L = 24$

Number of code blocks: $C = \lceil B/(Z-L) \rceil$.

$B' = B + C \cdot L$

end if

The bits output from code block segmentation, for $C \neq 0$, are denoted by $c_{r0}, c_{r1}, c_{r2}, c_{r3}, ..., c_{r(K_r-1)}$, where r is the code block number, and K_r is the number of bits for the code block number r.

Number of bits in each code block (applicable for $C \neq 0$ only):

First segmentation size: K_+ = minimum K in table 5.1.3-3 such that $C \cdot K \ge B'$

if $C = 1$

the number of code blocks with length K_+ is C_+=1, $K_- = 0$, $C_- = 0$

else if $C > 1$

Second segmentation size: K_- = maximum K in table 5.1.3-3 such that $K < K_+$

$\Delta_K = K_+ - K_-$

Number of segments of size K_-: $C_- = \left\lfloor \frac{C \cdot K_+ - B'}{\Delta_K} \right\rfloor$.

Number of segments of size K_+: $C_+ = C - C_-$.

end if

Number of filler bits: $F = C_+ \cdot K_+ + C_- \cdot K_- - B'$

for k = 0 to F-1 -- Insertion of filler bits

$c_{0k} =$ < *NULL* >

end for

$k = F$

$s = 0$

for r = 0 to C-1

if $r < C_-$

$K_r = K_-$

Petitioners' Exhibit 1003, p. 1301
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

else

$K_r = K_+$

end if

while $k < K_r - L$

$c_{rk} = b_s$

$k = k + 1$

$s = s + 1$

end while

if $C > 1$

The sequence $c_{r0}, c_{r1}, c_{r2}, c_{r3}, ..., c_{r(K_r - L - 1)}$ is used to calculate the CRC parity bits $p_{r0}, p_{r1}, p_{r2}, ..., p_{r(L-1)}$ according to section 5.1.1 with the generator polynomial $g_{CRC24B}(D)$. For CRC calculation it is assumed that filler bits, if present, have the value 0.

while $k < K_r$

$c_{rk} = p_{r(k+L-K_r)}$

$k = k + 1$

end while

end if

$k = 0$

end for

5.1.3 Channel coding

The bit sequence input for a given code block to channel coding is denoted by $c_0, c_1, c_2, c_3, ..., c_{K-1}$, where K is the number of bits to encode. After encoding the bits are denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, d_3^{(i)}, ..., d_{D-1}^{(i)}$, where D is the number of encoded bits per output stream and i indexes the encoder output stream. The relation between c_k and $d_k^{(i)}$ and between K and D is dependent on the channel coding scheme.

The following channel coding schemes can be applied to TrCHs:

- tail biting convolutional coding;
- turbo coding.

Usage of coding scheme and coding rate for the different types of TrCH is shown in table 5.1.3-1. Usage of coding scheme and coding rate for the different control information types is shown in table 5.1.3-2.

The values of D in connection with each coding scheme:

- tail biting convolutional coding with rate 1/3: $D = K$;
- turbo coding with rate 1/3: $D = K + 4$.

The range for the output stream index i is 0, 1 and 2 for both coding schemes.

Table 5.1.3-1: Usage of channel coding scheme and coding rate for TrCHs.

Petitioners' Exhibit 1003, p. 1302
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

TrCH	Coding scheme	Coding rate
UL-SCH	Turbo coding	1/3
DL-SCH		
PCH		
MCH		
SL-SCH		
SL-DCH		
BCH	Tail biting convolutional coding	1/3
SL-BCH		

Table 5.1.3-2: Usage of channel coding scheme and coding rate for control information.

Control Information	Coding scheme	Coding rate
DCI	Tail biting convolutional coding	1/3
CFI	Block code	1/16
HI	Repetition code	1/3
UCI	Block code	variable
	Tail biting convolutional coding	1/3
SCI	Tail biting convolutional coding	1/3

5.1.3.1 Tail biting convolutional coding

A tail biting convolutional code with constraint length 7 and coding rate 1/3 is defined.

The configuration of the convolutional encoder is presented in figure 5.1.3-1.

The initial value of the shift register of the encoder shall be set to the values corresponding to the last 6 information bits in the input stream so that the initial and final states of the shift register are the same. Therefore, denoting the shift register of the encoder by $s_0, s_1, s_2, ..., s_5$, then the initial value of the shift register shall be set to

$$s_i = c_{(K-1-i)}$$

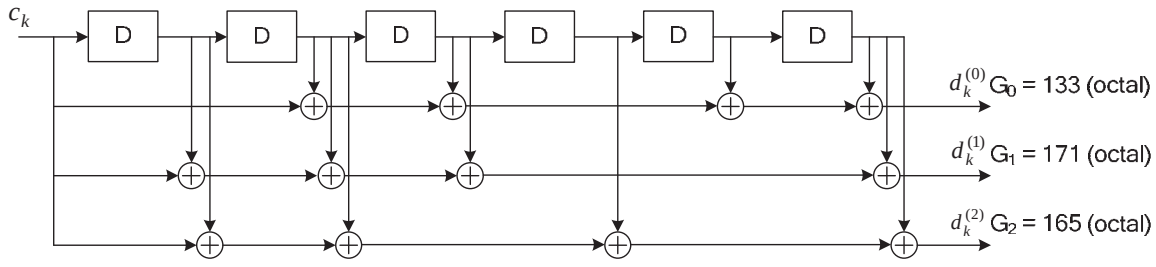


Figure 5.1.3-1: Rate 1/3 tail biting convolutional encoder.

The encoder output streams $d_k^{(0)}$, $d_k^{(1)}$ and $d_k^{(2)}$ correspond to the first, second and third parity streams, respectively as shown in Figure 5.1.3-1.

Petitioners' Exhibit 1003, p. 1303
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.1.3.2 Turbo coding

5.1.3.2.1 Turbo encoder

The scheme of turbo encoder is a Parallel Concatenated Convolutional Code (PCCC) with two 8-state constituent encoders and one turbo code internal interleaver. The coding rate of turbo encoder is 1/3. The structure of turbo encoder is illustrated in figure 5.1.3-2.

The transfer function of the 8-state constituent code for the PCCC is:

$$G(D) = \left[1, \frac{g_1(D)}{g_0(D)}\right],$$

where

$$g_0(D) = 1 + D^2 + D^3,$$

$$g_1(D) = 1 + D + D^3.$$

The initial value of the shift registers of the 8-state constituent encoders shall be all zeros when starting to encode the input bits.

The output from the turbo encoder is

$$d_k^{(0)} = x_k$$

$$d_k^{(1)} = z_k$$

$$d_k^{(2)} = z'_k$$

for $k = 0,1,2,...,K-1$.

If the code block to be encoded is the 0-th code block and the number of filler bits is greater than zero, i.e., $F > 0$, then the encoder shall set c_k, = 0, k = 0,…,(F-1) at its input and shall set $d_k^{(0)} =< NULL >$, k = 0,…,(F-1) and $d_k^{(1)} =< NULL >$, k = 0,…,(F-1) at its output.

The bits input to the turbo encoder are denoted by $c_0, c_1, c_2, c_3, ..., c_{K-1}$, and the bits output from the first and second 8-state constituent encoders are denoted by $z_0, z_1, z_2, z_3, ..., z_{K-1}$ and $z'_0, z'_1, z'_2, z'_3, ..., z'_{K-1}$, respectively. The bits output from the turbo code internal interleaver are denoted by $c'_0, c'_1, ..., c'_{K-1}$, and these bits are to be the input to the second 8-state constituent encoder.

Petitioners' Exhibit 1003, p. 1304
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

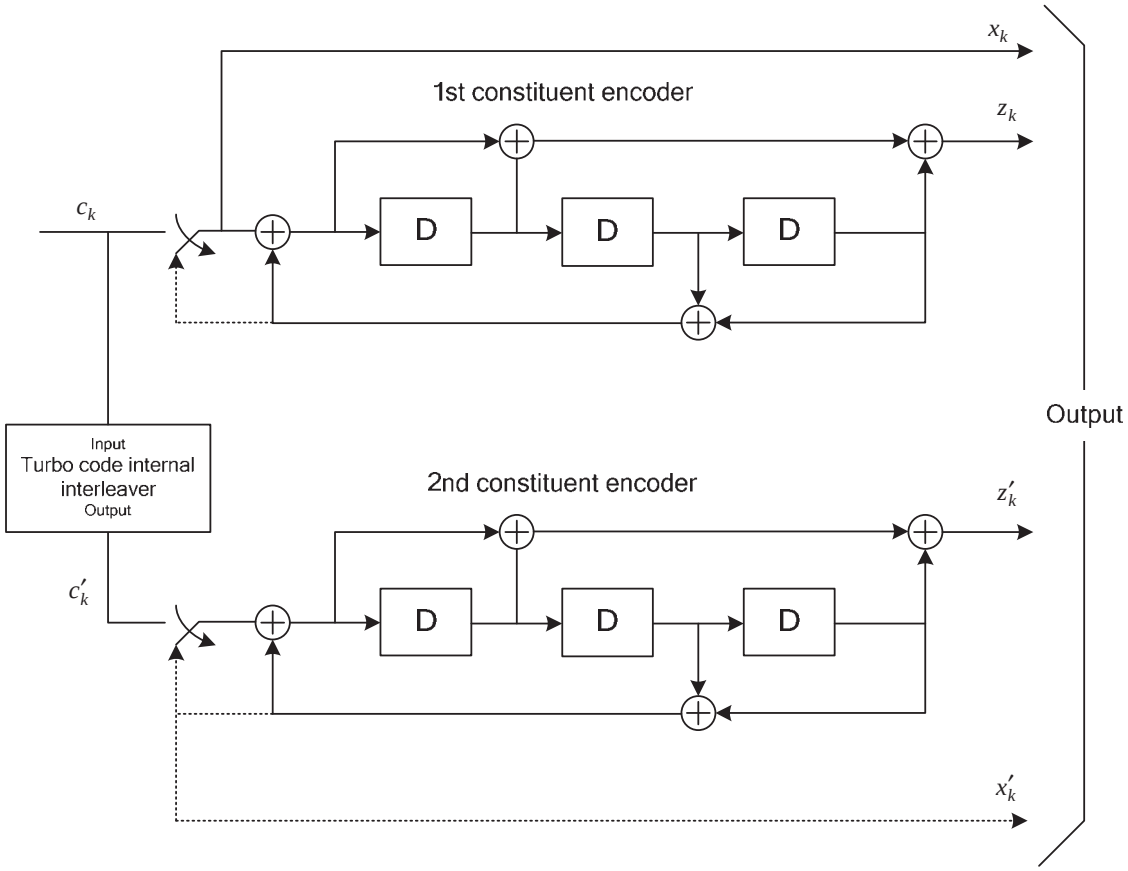


Figure 5.1.3-2: Structure of rate 1/3 turbo encoder (dotted lines apply for trellis termination only).

5.1.3.2.2 Trellis termination for turbo encoder

Trellis termination is performed by taking the tail bits from the shift register feedback after all information bits are encoded. Tail bits are padded after the encoding of information bits.

The first three tail bits shall be used to terminate the first constituent encoder (upper switch of figure 5.1.3-2 in lower position) while the second constituent encoder is disabled. The last three tail bits shall be used to terminate the second constituent encoder (lower switch of figure 5.1.3-2 in lower position) while the first constituent encoder is disabled.

The transmitted bits for trellis termination shall then be:

$d_K^{(0)} = x_K$, $d_{K+1}^{(0)} = z_{K+1}$, $d_{K+2}^{(0)} = x'_K$, $d_{K+3}^{(0)} = z'_{K+1}$

$d_K^{(1)} = z_K$, $d_{K+1}^{(1)} = x_{K+2}$, $d_{K+2}^{(1)} = z'_K$, $d_{K+3}^{(1)} = x'_{K+2}$

$d_K^{(2)} = x_{K+1}$, $d_{K+1}^{(2)} = z_{K+2}$, $d_{K+2}^{(2)} = x'_{K+1}$, $d_{K+3}^{(2)} = z'_{K+2}$

5.1.3.2.3 Turbo code internal interleaver

The bits input to the turbo code internal interleaver are denoted by $c_0, c_1, ..., c_{K-1}$, where K is the number of input bits. The bits output from the turbo code internal interleaver are denoted by $c'_0, c'_1, ..., c'_{K-1}$.

The relationship between the input and output bits is as follows:

$c'_i = c_{\Pi(i)}$, i=0, 1,…, (K-1)

Petitioners' Exhibit 1003, p. 1305
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

where the relationship between the output index *i* and the input index $\Pi(i)$ satisfies the following quadratic form:

$$\Pi(i) = \left(f_1 \cdot i + f_2 \cdot i^2\right) \bmod K$$

The parameters f_1 and f_2 depend on the block size *K* and are summarized in Table 5.1.3-3.

Table 5.1.3-3: Turbo code internal interleaver parameters.

i	*K*	f_1	f_2	*i*	*K*	f_1	f_2	*i*	*K*	f_1	f_2	*i*	*K*	f_1	f_2
1	40	3	10	48	416	25	52	95	1120	67	140	142	3200	111	240
2	48	7	12	49	424	51	106	96	1152	35	72	143	3264	443	204
3	56	19	42	50	432	47	72	97	1184	19	74	144	3328	51	104
4	64	7	16	51	440	91	110	98	1216	39	76	145	3392	51	212
5	72	7	18	52	448	29	168	99	1248	19	78	146	3456	451	192
6	80	11	20	53	456	29	114	100	1280	199	240	147	3520	257	220
7	88	5	22	54	464	247	58	101	1312	21	82	148	3584	57	336
8	96	11	24	55	472	29	118	102	1344	211	252	149	3648	313	228
9	104	7	26	56	480	89	180	103	1376	21	86	150	3712	271	232
10	112	41	84	57	488	91	122	104	1408	43	88	151	3776	179	236
11	120	103	90	58	496	157	62	105	1440	149	60	152	3840	331	120
12	128	15	32	59	504	55	84	106	1472	45	92	153	3904	363	244
13	136	9	34	60	512	31	64	107	1504	49	846	154	3968	375	248
14	144	17	108	61	528	17	66	108	1536	71	48	155	4032	127	168
15	152	9	38	62	544	35	68	109	1568	13	28	156	4096	31	64
16	160	21	120	63	560	227	420	110	1600	17	80	157	4160	33	130
17	168	101	84	64	576	65	96	111	1632	25	102	158	4224	43	264
18	176	21	44	65	592	19	74	112	1664	183	104	159	4288	33	134
19	184	57	46	66	608	37	76	113	1696	55	954	160	4352	477	408
20	192	23	48	67	624	41	234	114	1728	127	96	161	4416	35	138
21	200	13	50	68	640	39	80	115	1760	27	110	162	4480	233	280
22	208	27	52	69	656	185	82	116	1792	29	112	163	4544	357	142
23	216	11	36	70	672	43	252	117	1824	29	114	164	4608	337	480
24	224	27	56	71	688	21	86	118	1856	57	116	165	4672	37	146
25	232	85	58	72	704	155	44	119	1888	45	354	166	4736	71	444
26	240	29	60	73	720	79	120	120	1920	31	120	167	4800	71	120
27	248	33	62	74	736	139	92	121	1952	59	610	168	4864	37	152
28	256	15	32	75	752	23	94	122	1984	185	124	169	4928	39	462
29	264	17	198	76	768	217	48	123	2016	113	420	170	4992	127	234
30	272	33	68	77	784	25	98	124	2048	31	64	171	5056	39	158
31	280	103	210	78	800	17	80	125	2112	17	66	172	5120	39	80
32	288	19	36	79	816	127	102	126	2176	171	136	173	5184	31	96
33	296	19	74	80	832	25	52	127	2240	209	420	174	5248	113	902
34	304	37	76	81	848	239	106	128	2304	253	216	175	5312	41	166
35	312	19	78	82	864	17	48	129	2368	367	444	176	5376	251	336
36	320	21	120	83	880	137	110	130	2432	265	456	177	5440	43	170
37	328	21	82	84	896	215	112	131	2496	181	468	178	5504	21	86
38	336	115	84	85	912	29	114	132	2560	39	80	179	5568	43	174
39	344	193	86	86	928	15	58	133	2624	27	164	180	5632	45	176
40	352	21	44	87	944	147	118	134	2688	127	504	181	5696	45	178
41	360	133	90	88	960	29	60	135	2752	143	172	182	5760	161	120
42	368	81	46	89	976	59	122	136	2816	43	88	183	5824	89	182
43	376	45	94	90	992	65	124	137	2880	29	300	184	5888	323	184
44	384	23	48	91	1008	55	84	138	2944	45	92	185	5952	47	186
45	392	243	98	92	1024	31	64	139	3008	157	188	186	6016	23	94
46	400	151	40	93	1056	17	66	140	3072	47	96	187	6080	47	190
47	408	155	102	94	1088	171	204	141	3136	13	28	188	6144	263	480

Petitioners' Exhibit 1003, p. 1306
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.1.4 Rate matching

5.1.4.1 Rate matching for turbo coded transport channels

The rate matching for turbo coded transport channels is defined per coded block and consists of interleaving the three information bit streams $d_k^{(0)}$, $d_k^{(1)}$ and $d_k^{(2)}$, followed by the collection of bits and the generation of a circular buffer as depicted in Figure 5.1.4-1. The output bits for each code block are transmitted as described in section 5.1.4.1.2.

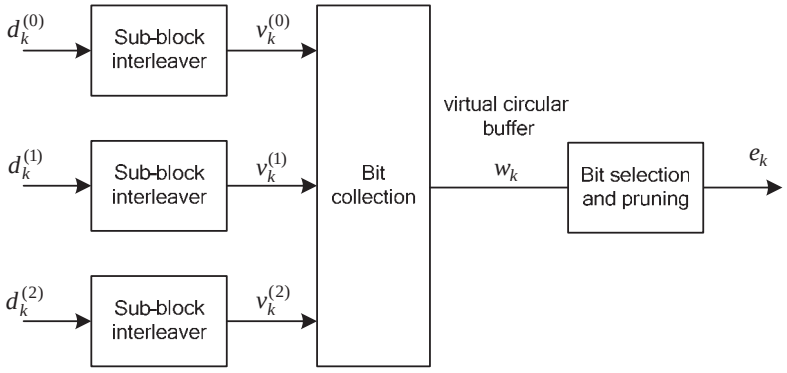


Figure 5.1.4-1. Rate matching for turbo coded transport channels.

The bit stream $d_k^{(0)}$ is interleaved according to the sub-block interleaver defined in section 5.1.4.1.1 with an output sequence defined as $v_0^{(0)}, v_1^{(0)}, v_2^{(0)}, ..., v_{K_\Pi - 1}^{(0)}$ and where K_Π is defined in section 5.1.4.1.1.

The bit stream $d_k^{(1)}$ is interleaved according to the sub-block interleaver defined in section 5.1.4.1.1 with an output sequence defined as $v_0^{(1)}, v_1^{(1)}, v_2^{(1)}, ..., v_{K_\Pi - 1}^{(1)}$.

The bit stream $d_k^{(2)}$ is interleaved according to the sub-block interleaver defined in section 5.1.4.1.1 with an output sequence defined as $v_0^{(2)}, v_1^{(2)}, v_2^{(2)}, ..., v_{K_\Pi - 1}^{(2)}$.

The sequence of bits e_k for transmission is generated according to section 5.1.4.1.2.

5.1.4.1.1 Sub-block interleaver

The bits input to the block interleaver are denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, ..., d_{D-1}^{(i)}$, where D is the number of bits. The output bit sequence from the block interleaver is derived as follows:

(1) Assign $C_{subblock}^{TC} = 32$ to be the number of columns of the matrix. The columns of the matrix are numbered 0, 1, 2,…, $C_{subblock}^{TC} - 1$ from left to right.

(2) Determine the number of rows of the matrix $R_{subblock}^{TC}$, by finding minimum integer $R_{subblock}^{TC}$ such that:

$$D \le \left(R_{subblock}^{TC} \times C_{subblock}^{TC} \right)$$

The rows of rectangular matrix are numbered 0, 1, 2,…, $R_{subblock}^{TC} - 1$ from top to bottom.

Petitioners' Exhibit 1003, p. 1307
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

(3) If $\left(R_{subblock}^{TC} \times C_{subblock}^{TC}\right) > D$, then $N_D = \left(R_{subblock}^{TC} \times C_{subblock}^{TC} - D\right)$ dummy bits are padded such that y_k = <*NULL*> for $k = 0, 1, \ldots, N_D - 1$. Then, $y_{N_D+k} = d_k^{(i)}$, $k = 0, 1, \ldots, D-1$, and the bit sequence y_k is written into the $\left(R_{subblock}^{TC} \times C_{subblock}^{TC}\right)$ matrix row by row starting with bit y_0 in column 0 of row 0:

$$\begin{bmatrix} y_0 & y_1 & y_2 & \cdots & y_{C_{subblock}^{TC}-1} \\ y_{C_{subblock}^{TC}} & y_{C_{subblock}^{TC}+1} & y_{C_{subblock}^{TC}+2} & \cdots & y_{2C_{subblock}^{TC}-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ y_{(R_{subblock}^{TC}-1)\times C_{subblock}^{TC}} & y_{(R_{subblock}^{TC}-1)\times C_{subblock}^{TC}+1} & y_{(R_{subblock}^{TC}-1)\times C_{subblock}^{TC}+2} & \cdots & y_{(R_{subblock}^{TC}\times C_{subblock}^{TC}-1)} \end{bmatrix}$$

For $d_k^{(0)}$ and $d_k^{(1)}$:

(4) Perform the inter-column permutation for the matrix based on the pattern $\langle P(j) \rangle_{j \in \{0,1,\ldots,C_{subblock}^{TC}-1\}}$ that is shown in table 5.1.4-1, where P(*j*) is the original column position of the *j*-th permuted column. After permutation of the columns, the inter-column permuted $\left(R_{subblock}^{TC} \times C_{subblock}^{TC}\right)$ matrix is equal to

$$\begin{bmatrix} y_{P(0)} & y_{P(1)} & y_{P(2)} & \cdots & y_{P(C_{subblock}^{TC}-1)} \\ y_{P(0)+C_{subblock}^{TC}} & y_{P(1)+C_{subblock}^{TC}} & y_{P(2)+C_{subblock}^{TC}} & \cdots & y_{P(C_{subblock}^{TC}-1)+C_{subblock}^{TC}} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ y_{P(0)+(R_{subblock}^{TC}-1)\times C_{subblock}^{TC}} & y_{P(1)+(R_{subblock}^{TC}-1)\times C_{subblock}^{TC}} & y_{P(2)+(R_{subblock}^{TC}-1)\times C_{subblock}^{TC}} & \cdots & y_{P(C_{subblock}^{TC}-1)+(R_{subblock}^{TC}-1)\times C_{subblock}^{TC}} \end{bmatrix}$$

(5) The output of the block interleaver is the bit sequence read out column by column from the inter-column permuted $\left(R_{subblock}^{TC} \times C_{subblock}^{TC}\right)$matrix. The bits after sub-block interleaving are denoted by $v_0^{(i)}, v_1^{(i)}, v_2^{(i)}, \ldots, v_{K_\Pi-1}^{(i)}$, where $v_0^{(i)}$ corresponds to $y_{P(0)}$, $v_1^{(i)}$ to $y_{P(0)+C_{subblock}^{TC}}$ … and $K_\Pi = \left(R_{subblock}^{TC} \times C_{subblock}^{TC}\right)$.

For $d_k^{(2)}$:

(4) The output of the sub-block interleaver is denoted by $v_0^{(2)}, v_1^{(2)}, v_2^{(2)}, \ldots, v_{K_\Pi-1}^{(2)}$, where $v_k^{(2)} = y_{\pi(k)}$ and where

$$\pi(k) = \left(P\left(\left\lfloor \frac{k}{R_{subblock}^{TC}} \right\rfloor \right) + C_{subblock}^{TC} \times \left(k \bmod R_{subblock}^{TC}\right) + 1 \right) \bmod K_\Pi$$

The permutation function *P* is defined in Table 5.1.4-1.

Table 5.1.4-1 Inter-column permutation pattern for sub-block interleaver.

Number of columns $C_{subblock}^{TC}$	**Inter-column permutation pattern** $< P(0), P(1), \ldots, P(C_{subblock}^{TC}-1) >$
32	< 0, 16, 8, 24, 4, 20, 12, 28, 2, 18, 10, 26, 6, 22, 14, 30, 1, 17, 9, 25, 5, 21, 13, 29, 3, 19, 11, 27, 7, 23, 15, 31 >

5.1.4.1.2 Bit collection, selection and transmission

The circular buffer of length $K_w = 3K_\Pi$ for the *r*-th coded block is generated as follows:

$w_k = v_k^{(0)}$ for $k = 0, \ldots, K_\Pi - 1$

$w_{K_\Pi+2k} = v_k^{(1)}$ for $k = 0, \ldots, K_\Pi - 1$

$w_{K_\Pi+2k+1} = v_k^{(2)}$ for $k = 0, \ldots, K_\Pi - 1$

Petitioners' Exhibit 1003, p. 1308
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Denote the soft buffer size for the transport block by N_{IR} bits and the soft buffer size for the r-th code block by N_{cb} bits. The size N_{cb} is obtained as follows, where C is the number of code blocks computed in section 5.1.2:

- $N_{cb} = \min\left(\left\lfloor \frac{N_{IR}}{C} \right\rfloor, K_w\right)$ for DL-SCH and PCH transport channels

- $N_{cb} = K_w$ for UL-SCH, MCH, SL-SCH and SL-DCH transport channels

For UE category 0, for DL-SCH associated with SI-RNTI and RA-RNTI and PCH transport channel, N_{cb} is always equal to K_w.

where N_{IR} is equal to:

$$N_{IR} = \left\lfloor \frac{N_{soft}}{K_C \cdot K_{\text{MIMO}} \cdot \min\left(M_{\text{DL\_HARQ}}, M_{\text{limit}}\right)} \right\rfloor$$

where:

If the UE signals *ue-CategoryDL-r12* indicating UE category 0, or if the UE signals *ue-CategoryDL-r12* indicating UE category 14 and is configured by higher layers with *altCQI-Table-r12* for the DL cell, N_{soft} is the total number of soft channel bits according to the UE category indicated by *ue-CategoryDL-r12*. Otherwise, if the UE signals *ue-Category-v11a0*, and is configured by higher layers with *altCQI-Table-r12* for the DL cell, N_{soft} is the total number of soft channel bits according to the UE category indicated by *ue-Category-v11a0*. Otherwise, if the UE signals *ue-Category-v1020*, and is configured with transmission mode 9 or transmission mode 10, or is configured with transmission mode 3 or transmission mode 4 and the higher layer parameter *maxLayersMIMO-r10* is configured to fourLayers, for the DL cell, N_{soft} is the total number of soft channel bits [4] according to the UE category indicated by *ue-Category-v1020* [6]. Otherwise, N_{soft} is the total number of soft channel bits [4] according to the UE category indicated by *ue-Category* (without suffix) [6].

If N_{soft} = 35982720 or 47431680,

K_C= 5,

elseif N_{soft} = 7308288 and the UE is configured by higher layers with *altCQI-Table-r12*,

if the UE is capable of supporting no more than a maximum of two spatial layers for the DL cell in the transmission mode configured for the UE, or if the configured maximum number of layers indicated by the *maxLayersMIMO-r10* field is no more than two,

K_C = 3

else

K_C = 3/2

end if.

elseif N_{soft} = 3654144 and the UE is capable of supporting no more than a maximum of two spatial layers for the DL cell, or if the configured maximum number of layers indicated by the *maxLayersMIMO-r10* field is no more than two,

K_C = 2

else

K_C = 1

End if.

K_{MIMO} is equal to 2 if the UE is configured to receive PDSCH transmissions based on transmission modes 3, 4, 8, 9 or 10 as defined in section 7.1 of [3], and is equal to 1 otherwise. For BL/CE UE K_{MIMO} is equal to 1.

$M_{\text{DL\_HARQ}}$ is the maximum number of DL HARQ processes as defined in section 7 of [3].

Petitioners' Exhibit 1003, p. 1309
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

M_{limit} is a constant equal to 8.

Denoting by E the rate matching output sequence length for the r-th coded block, and rv_{idx} the redundancy version number for this transmission (rv_{idx} = 0, 1, 2 or 3), the rate matching output bit sequence is e_k, $k = 0,1,\ldots, E-1$.

Define by G the total number of bits available for the transmission of one transport block.

Set $G' = G/(N_L \cdot Q_m)$ where Q_m is equal to 2 for QPSK, 4 for 16QAM, 6 for 64QAM and 8 for 256QAM, and where

- For transmit diversity:
  - N_L is equal to 2,
- Otherwise:
  - N_L is equal to the number of layers a transport block is mapped onto

Set $\gamma = G' \bmod C$, where C is the number of code blocks computed in section 5.1.2.

if $r \le C - \gamma - 1$

set $E = N_L \cdot Q_m \cdot \lfloor G'/C \rfloor$

else

set $E = N_L \cdot Q_m \cdot \lceil G'/C \rceil$

end if

Set $k_0 = R_{subblock}^{TC} \cdot \left(2 \cdot \left\lceil \frac{N_{cb}}{8R_{subblock}^{TC}} \right\rceil \cdot rv_{idx} + 2 \right)$, where $R_{subblock}^{TC}$ is the number of rows defined in section 5.1.4.1.1.

Set k = 0 and j = 0

while { $k < E$ }

if $w_{(k_0+j) \bmod N_{cb}} \neq <NULL>$

$e_k = w_{(k_0+j) \bmod N_{cb}}$

$k = k + 1$

end if

$j = j + 1$

end while

5.1.4.2 Rate matching for convolutionally coded transport channels and control information

The rate matching for convolutionally coded transport channels and control information consists of interleaving the three bit streams, $d_k^{(0)}$, $d_k^{(1)}$ and $d_k^{(2)}$, followed by the collection of bits and the generation of a circular buffer as depicted in Figure 5.1.4-2. The output bits are transmitted as described in section 5.1.4.2.2.

Petitioners' Exhibit 1003, p. 1310
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

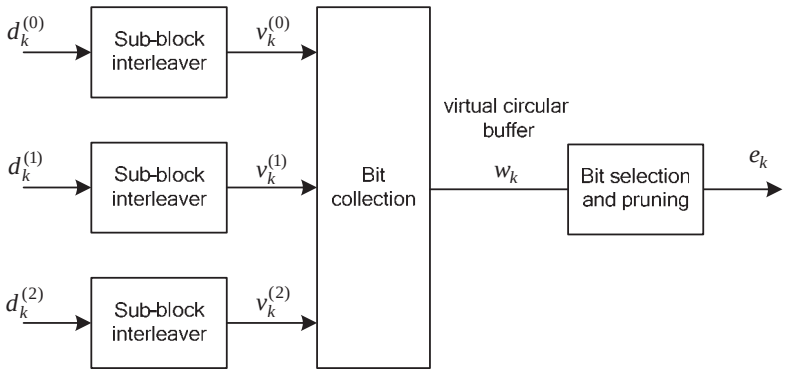


Figure 5.1.4-2. Rate matching for convolutionally coded transport channels and control information.

The bit stream $d_k^{(0)}$ is interleaved according to the sub-block interleaver defined in section 5.1.4.2.1 with an output sequence defined as $v_0^{(0)}, v_1^{(0)}, v_2^{(0)}, ..., v_{K_\Pi-1}^{(0)}$ and where K_Π is defined in section 5.1.4.2.1.

The bit stream $d_k^{(1)}$ is interleaved according to the sub-block interleaver defined in section 5.1.4.2.1 with an output sequence defined as $v_0^{(1)}, v_1^{(1)}, v_2^{(1)}, ..., v_{K_\Pi-1}^{(1)}$.

The bit stream $d_k^{(2)}$ is interleaved according to the sub-block interleaver defined in section 5.1.4.2.1 with an output sequence defined as $v_0^{(2)}, v_1^{(2)}, v_2^{(2)}, ..., v_{K_\Pi-1}^{(2)}$.

The sequence of bits e_k for transmission is generated according to section 5.1.4.2.2.

5.1.4.2.1 Sub-block interleaver

The bits input to the block interleaver are denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, ..., d_{D-1}^{(i)}$, where D is the number of bits. The output bit sequence from the block interleaver is derived as follows:

(1) Assign $C_{subblock}^{CC} = 32$ to be the number of columns of the matrix. The columns of the matrix are numbered 0, 1, 2,…, $C_{subblock}^{CC} - 1$ from left to right.

(2) Determine the number of rows of the matrix $R_{subblock}^{CC}$, by finding minimum integer $R_{subblock}^{CC}$ such that:

$$D \le \left(R_{subblock}^{CC} \times C_{subblock}^{CC}\right)$$

The rows of rectangular matrix are numbered 0, 1, 2,…, $R_{subblock}^{CC} - 1$ from top to bottom.

(3) If $\left(R_{subblock}^{CC} \times C_{subblock}^{CC}\right) > D$, then $N_D = \left(R_{subblock}^{CC} \times C_{subblock}^{CC} - D\right)$ dummy bits are padded such that y_k = <*NULL*> for k = 0, 1,…, N_D - 1. Then, $y_{N_D+k} = d_k^{(i)}$, k = 0, 1,…, D-1, and the bit sequence y_k is written into the $\left(R_{subblock}^{CC} \times C_{subblock}^{CC}\right)$ matrix row by row starting with bit y_0 in column 0 of row 0:

$$\begin{bmatrix} y_0 & y_1 & y_2 & \cdots & y_{C_{subblock}^{CC}-1} \\ y_{C_{subblock}^{CC}} & y_{C_{subblock}^{CC}+1} & y_{C_{subblock}^{CC}+2} & \cdots & y_{2C_{subblock}^{CC}-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ y_{(R_{subblock}^{CC}-1)\times C_{subblock}^{CC}} & y_{(R_{subblock}^{CC}-1)\times C_{subblock}^{CC}+1} & y_{(R_{subblock}^{CC}-1)\times C_{subblock}^{CC}+2} & \cdots & y_{(R_{subblock}^{CC}\times C_{subblock}^{CC}-1)} \end{bmatrix}$$

Petitioners' Exhibit 1003, p. 1311
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

(4) Perform the inter-column permutation for the matrix based on the pattern $\langle P(j) \rangle_{j \in \{0,1,\ldots,C^{CC}_{subblock}-1\}}$ that is shown in table 5.1.4-2, where P(*j*) is the original column position of the *j*-th permuted column. After permutation of the columns, the inter-column permuted $\left(R^{CC}_{subblock} \times C^{CC}_{subblock}\right)$ matrix is equal to

$$\begin{bmatrix} y_{P(0)} & y_{P(1)} & y_{P(2)} & \cdots & y_{P(C^{CC}_{subblock}-1)} \\ y_{P(0)+C^{CC}_{subblock}} & y_{P(1)+C^{CC}_{subblock}} & y_{P(2)+C^{CC}_{subblock}} & \cdots & y_{P(C^{CC}_{subblock}-1)+C^{CC}_{subblock}} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ y_{P(0)+(R^{CC}_{subblock}-1)\times C^{CC}_{subblock}} & y_{P(1)+(R^{CC}_{subblock}-1)\times C^{CC}_{subblock}} & y_{P(2)+(R^{CC}_{subblock}-1)\times C^{CC}_{subblock}} & \cdots & y_{P(C^{CC}_{subblock}-1)+(R^{CC}_{subblock}-1)\times C^{CC}_{subblock}} \end{bmatrix}$$

(5) The output of the block interleaver is the bit sequence read out column by column from the inter-column permuted $\left(R^{CC}_{subblock} \times C^{CC}_{subblock}\right)$matrix. The bits after sub-block interleaving are denoted by $v^{(i)}_0, v^{(i)}_1, v^{(i)}_2, \ldots, v^{(i)}_{K_\Pi-1}$, where $v^{(i)}_0$ corresponds to $y_{P(0)}$, $v^{(i)}_1$ to $y_{P(0)+C^{CC}_{subblock}}$ … and $K_\Pi = \left(R^{CC}_{subblock} \times C^{CC}_{subblock}\right)$

Table 5.1.4-2 Inter-column permutation pattern for sub-block interleaver.

Number of columns $C^{CC}_{subblock}$	**Inter-column permutation pattern** $< P(0), P(1), \ldots, P(C^{CC}_{subblock}-1) >$
32	< 1, 17, 9, 25, 5, 21, 13, 29, 3, 19, 11, 27, 7, 23, 15, 31, 0, 16, 8, 24, 4, 20, 12, 28, 2, 18, 10, 26, 6, 22, 14, 30 >

This block interleaver is also used in interleaving PDCCH modulation symbols. In that case, the input bit sequence consists of PDCCH symbol quadruplets [2].

5.1.4.2.2 Bit collection, selection and transmission

The circular buffer of length $K_w = 3K_\Pi$ is generated as follows:

$w_k = v^{(0)}_k$ for $k = 0,\ldots, K_\Pi - 1$

$w_{K_\Pi + k} = v^{(1)}_k$ for $k = 0,\ldots, K_\Pi - 1$

$w_{2K_\Pi + k} = v^{(2)}_k$ for $k = 0,\ldots, K_\Pi - 1$

Denoting by *E* the rate matching output sequence length, the rate matching output bit sequence is e_k, $k = 0,1,\ldots, E-1$.

Set $k = 0$ and $j = 0$

while { $k < E$ }

if $w_{j \bmod K_w} \neq <NULL>$

$e_k = w_{j \bmod K_w}$

$k = k + 1$

end if

$j = j + 1$

end while

Petitioners' Exhibit 1003, p. 1312
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.1.5 Code block concatenation

The input bit sequence for the code block concatenation block are the sequences e_{rk}, for $r = 0,..., C-1$ and $k = 0,..., E_r - 1$. The output bit sequence from the code block concatenation block is the sequence f_k for $k = 0,..., G-1$.

The code block concatenation consists of sequentially concatenating the rate matching outputs for the different code blocks. Therefore,

Set $k = 0$ and $r = 0$

while $r < C$

Set $j = 0$

while $j < E_r$

$f_k = e_{rj}$

$k = k + 1$

$j = j + 1$

end while

$r = r + 1$

end while

5.2 Uplink transport channels and control information

If the UE is configured with a Master Cell Group (MCG) and Secondary Cell Group (SCG) [6], the procedures described in this clause are applied to the MCG and SCG, respectively. When the procedures are applied to a SCG, the term primary cell refers to the primary SCell (PSCell) of the SCG.

If the UE is configured with a PUCCH SCell [6], the procedures described in this clause are applied to the group of DL cells associated with the primary cell and the group of DL cells associated with the PUCCH SCell, respectively. When the procedures are applied to the group of DL cells associated with the PUCCH SCell, the term primary cell refers to the PUCCH SCell.

If the UE is configured with a LAA SCell, the procedures described in this clause are applied assuming the LAA SCell is an FDD SCell.

5.2.1 Random access channel

The sequence index for the random access channel is received from higher layers and is processed according to [2].

5.2.2 Uplink shared channel

Figure 5.2.2-1 shows the processing structure for the UL-SCH transport channel on one UL cell. Data arrives to the coding unit in the form of a maximum of two transport blocks every transmission time interval (TTI) per UL cell. The following coding steps can be identified for each transport block of an UL cell:

- Add CRC to the transport block
- Code block segmentation and code block CRC attachment
- Channel coding of data and control information
- Rate matching

Petitioners' Exhibit 1003, p. 1313
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

– Code block concatenation

– Multiplexing of data and control information

– Channel interleaver

The coding steps for one UL-SCH transport block are shown in the figure below. The same general processing applies for each UL-SCH transport block on each UL cell with restrictions as specified in [3].

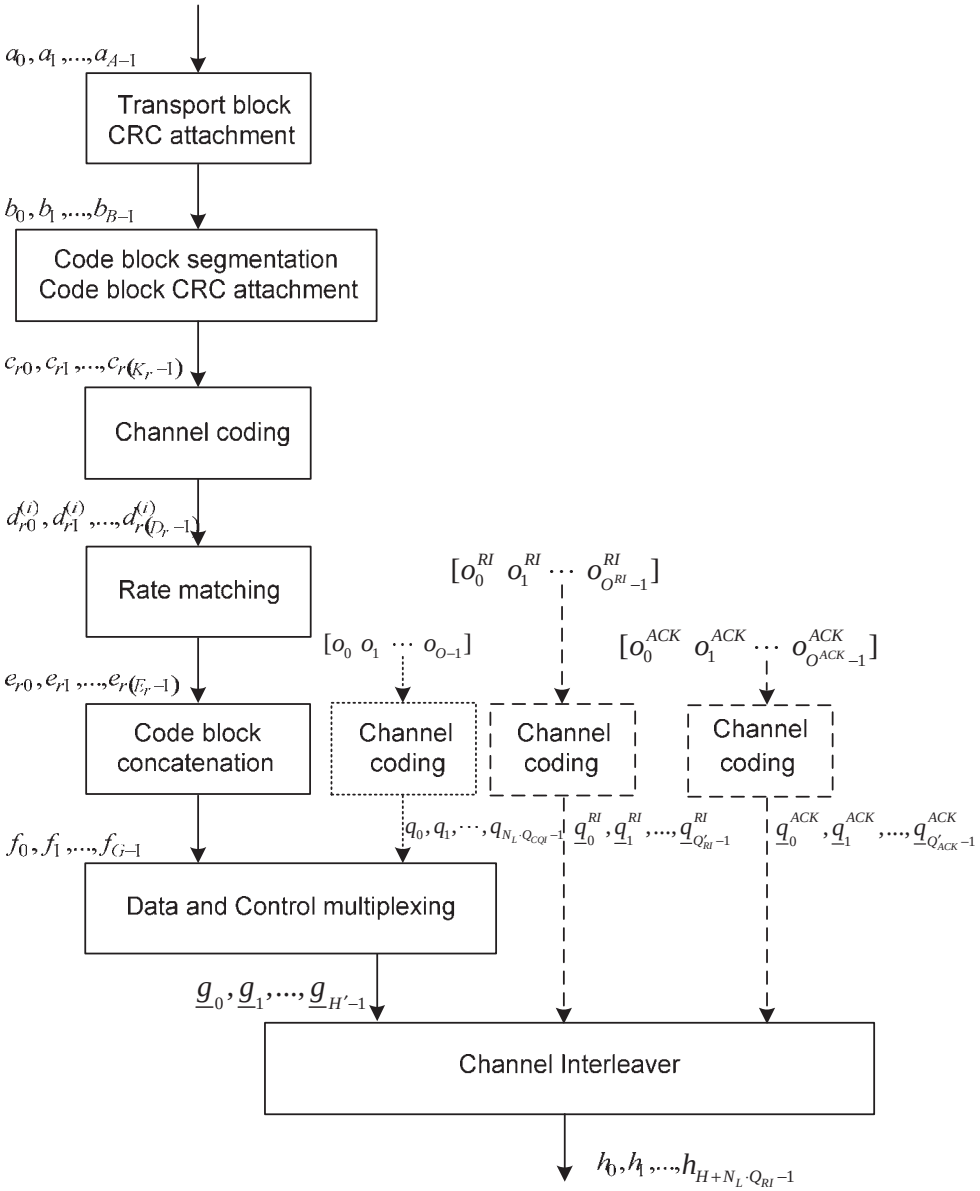


Figure 5.2.2-1: Transport block processing for UL-SCH.

5.2.2.1 Transport block CRC attachment

Error detection is provided on each UL-SCH transport block through a Cyclic Redundancy Check (CRC).

The entire transport block is used to calculate the CRC parity bits. Denote the bits in a transport block delivered to layer 1 by $a_0, a_1, a_2, a_3, \ldots, a_{A-1}$, and the parity bits by $p_0, p_1, p_2, p_3, \ldots, p_{L-1}$. A is the size of the transport block and L is the number of parity bits. The lowest order information bit a_0 is mapped to the most significant bit of the transport block as defined in section 6.1.1 of [5].

Petitioners' Exhibit 1003, p. 1314
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The parity bits are computed and attached to the UL-SCH transport block according to section 5.1.1 setting L to 24 bits and using the generator polynomial $g_{CRC24A}(D)$.

5.2.2.2 Code block segmentation and code block CRC attachment

The bits input to the code block segmentation are denoted by $b_0, b_1, b_2, b_3, ..., b_{B-1}$ where B is the number of bits in the transport block (including CRC).

Code block segmentation and code block CRC attachment are performed according to section 5.1.2.

The bits after code block segmentation are denoted by $c_{r0}, c_{r1}, c_{r2}, c_{r3}, ..., c_{r(K_r-1)}$, where r is the code block number and K_r is the number of bits for code block number r.

5.2.2.3 Channel coding of UL-SCH

Code blocks are delivered to the channel coding block. The bits in a code block are denoted by $c_{r0}, c_{r1}, c_{r2}, c_{r3}, ..., c_{r(K_r-1)}$, where r is the code block number, and K_r is the number of bits in code block number r. The total number of code blocks is denoted by C and each code block is individually turbo encoded according to section 5.1.3.2.

After encoding the bits are denoted by $d_{r0}^{(i)}, d_{r1}^{(i)}, d_{r2}^{(i)}, d_{r3}^{(i)}, ..., d_{r(D_r-1)}^{(i)}$, with $i = 0,1,$ and 2 and where D_r is the number of bits on the i-th coded stream for code block number r, i.e. $D_r = K_r + 4$.

5.2.2.4 Rate matching

Turbo coded blocks are delivered to the rate matching block. They are denoted by $d_{r0}^{(i)}, d_{r1}^{(i)}, d_{r2}^{(i)}, d_{r3}^{(i)}, ..., d_{r(D_r-1)}^{(i)}$, with $i = 0,1,$ and 2, and where r is the code block number, i is the coded stream index, and D_r is the number of bits in each coded stream of code block number r. The total number of code blocks is denoted by C and each coded block is individually rate matched according to section 5.1.4.1.

After rate matching, the bits are denoted by $e_{r0}, e_{r1}, e_{r2}, e_{r3}, ..., e_{r(E_r-1)}$, where r is the coded block number, and where E_r is the number of rate matched bits for code block number r.

5.2.2.5 Code block concatenation

The bits input to the code block concatenation block are denoted by $e_{r0}, e_{r1}, e_{r2}, e_{r3}, ..., e_{r(E_r-1)}$ for $r = 0, ..., C-1$ and where E_r is the number of rate matched bits for the r-th code block.

Code block concatenation is performed according to section 5.1.5.

The bits after code block concatenation are denoted by $f_0, f_1, f_2, f_3, ..., f_{G-1}$, where G is the total number of coded bits for transmission of the given transport block over N_L transmission layers excluding the bits used for control transmission, when control information is multiplexed with the UL-SCH transmission.

5.2.2.6 Channel coding of control information

Control data arrives at the coding unit in the form of channel quality information (CQI and/or PMI), HARQ-ACK and rank indication, and CSI-RS resource indication (CRI). Different coding rates for the control information are achieved by allocating different number of coded symbols for its transmission. When control data are transmitted in the PUSCH, the channel coding for HARQ-ACK, rank indication (including RI only, joint report of RI/i1, joint report of CRI/RI, joint report of CRI/RI/ i1,joint report of CRI/RI/PTI, and joint report of RI/PTI), CRI and channel quality information $o_0, o_1, o_2, ..., o_{O-1}$ is done independently.

For the cases with TDD primary cell, the number of HARQ-ACK bits is determined as described in section 7.3 of [3].

Petitioners' Exhibit 1003, p. 1315
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

When the UE transmits HARQ-ACK bits, rank indicator bits or CRI bits, it shall determine the number of coded modulation symbols per layer Q' for HARQ-ACK, rank indicator, or CRI bits as follows.

For the case when only one transport block is transmitted in the PUSCH conveying the HARQ-ACK bits, rank indicator bits or CRI bits:

$$Q' = \min\left(\left\lceil \frac{O \cdot M_{sc}^{PUSCH-initial} \cdot N_{symb}^{PUSCH-initial} \cdot \beta_{offset}^{PUSCH}}{\sum_{r=0}^{C-1} K_r} \right\rceil, 4 \cdot M_{sc}^{PUSCH}\right)$$

where

- O is the number of HARQ-ACK bits, rank indicator bits or CRI bits, and
- M_{sc}^{PUSCH} is the scheduled bandwidth for PUSCH transmission in the current sub-frame for the transport block, expressed as a number of subcarriers in [2], and
- $N_{symb}^{\text{PUSCH-initial}}$ is the number of SC-FDMA symbols per subframe for initial PUSCH transmission for the same transport block, respectively, given by $N_{\text{symb}}^{PUSCH\text{-}initial} = \left(2 \cdot \left(N_{\text{symb}}^{\text{UL}} - 1\right) - N_{\text{SRS}}\right)$, where
  - N_{SRS} is equal to 1
    - if UE configured with one UL cell is configured to send PUSCH and SRS in the same subframe for initial transmission, or
    - if UE transmits PUSCH and SRS in the same subframe in the same serving cell for initial transmission, or
    - if the PUSCH resource allocation for initial transmission even partially overlaps with the cell-specific SRS subframe and bandwidth configuration defined in section 5.5.3 of [2], or
    - if the subframe for initial transmission in the same serving cell is a UE-specific type-1 SRS subframe as defined in Section 8.2 of [3], or
    - if the subframe for initial transmission in the same serving cell is a UE-specific type-0 SRS subframe as defined in section 8.2 of [3] and the UE is configured with multiple TAGs.
  - Otherwise N_{SRS} is equal to 0.
- $M_{sc}^{PUSCH-initial}$, C, and K_r are obtained from the initial PDCCH or EPDCCH or MPDCCH for the same transport block. If there is no initial PDCCH or EPDCCH with DCI format 0 or MPDCCH with DCI format 6-0A/6-0B for the same transport block, $M_{sc}^{PUSCH-initial}$, C, and K_r shall be determined from:
  - the most recent semi-persistent scheduling assignment PDCCH or EPDCCH or MPDCCH, when the initial PUSCH for the same transport block is semi-persistently scheduled, or,
  - the random access response grant for the same transport block, when the PUSCH is initiated by the random access response grant.

For the case when two transport blocks are transmitted in the PUSCH conveying the HARQ-ACK bits, rank indicator bits or CRI bits:

$$Q' = \max\left[\min\left(Q'_{temp}, 4 \cdot M_{sc}^{PUSCH}\right), Q'_{\min}\right] \text{ with}$$

Petitioners' Exhibit 1003, p. 1316
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$$Q'_{temp}=\left\lceil \frac{O \cdot M_{sc}^{PUSCH-initial(1)} \cdot N_{symb}^{PUSCH-initial(1)} \cdot M_{sc}^{PUSCH-initial(2)} \cdot N_{symb}^{PUSCH-initial(2)} \cdot \beta_{offset}^{PUSCH}}{\sum_{r=0}^{C^{(1)}-1} K_r^{(1)} \cdot M_{sc}^{PUSCH-initial(2)} \cdot N_{symb}^{PUSCH-initial(2)} + \sum_{r=0}^{C^{(2)}-1} K_r^{(2)} \cdot M_{sc}^{PUSCH-initial(1)} \cdot N_{symb}^{PUSCH-initial(1)}} \right\rceil$$

where

- O is the number of HARQ-ACK bits, rank indicator bits or CRI bits, and
- $Q'_{\min}=O$ if $O\le 2$, $Q'_{\min}=\lceil 2O/Q'_m \rceil$ if $3\le O\le 11$ with $Q'_m=\min\left(Q_m^1, Q_m^2\right)$ where $Q_m^x, x=\{1,2\}$ is the modulation order of transport block 'x', and $Q'_{\min}=\lceil 2O_1/Q'_m \rceil+\lceil 2O_2/Q'_m \rceil$ if $O>11$ with $O_1=\lceil O/2 \rceil$ and $O_2=O-\lceil O/2 \rceil$.
- $M_{\text{sc}}^{PUSCH\text{-}initial(x)}, x=\{1,2\}$ are the scheduled bandwidths for PUSCH transmission in the initial sub-frame for the first and second transport block, respectively, expressed as a number of subcarriers in [2], and
- $N_{\text{symb}}^{PUSCH\text{-}initial(\text{x})}, x=\{1,2\}$ are the number of SC-FDMA symbols per subframe for initial PUSCH transmission for the first and second transport block given by $N_{\text{symb}}^{PUSCH\text{-}initial(x)}=\left(2\cdot\left(N_{\text{symb}}^{\text{UL}}-1\right)-N_{\text{SRS}}^{(x)}\right), x=\{1,2\}$, where
  - $N_{SRS}^{(x)}, x=\{1,2\}$ is equal to 1
    - if UE configured with one UL cell is configured to send PUSCH and SRS in the same subframe for initial transmission, or
    - if UE transmits PUSCH and SRS in the same subframe in the same serving cell for initial transmission of transport block 'x', or
    - if the PUSCH resource allocation for initial transmission of transport bock 'x' even partially overlaps with the cell-specific SRS subframe and bandwidth configuration defined in section 5.5.3 of [2] , or
    - if the subframe for initial transmission of transport block 'x' in the same serving cell is a UE-specific type-1 SRS subframe as defined in Section 8.2 of [3], or
    - if the subframe for initial transmission of transport block 'x' in the same serving cell is a UE-specific type-0 SRS subframe as defined in section 8.2 of [3] and the UE is configured with multiple TAGs.
  - Otherwise $N_{SRS}^{(x)}, x=\{1,2\}$ is equal to 0.
- $M_{sc}^{PUSCH-initial(x)}, x=\{1,2\}$, $C^{(x)}, x=\{1,2\}$, and $K_r^{(x)}, x=\{1,2\}$ are obtained from the initial PDCCH or EPDCCH for the corresponding transport block.

For HARQ-ACK, $Q_{ACK}=Q_m\cdot Q'$ and $\beta_{offset}^{PUSCH}=\beta_{offset}^{HARQ-ACK}$, where Q_m is the modulation order of a given transport block. For UEs configured with no more than five DL cells, $\beta_{offset}^{HARQ-ACK}$ shall be determined according to [3] depending on the number of transmission codewords for the corresponding PUSCH. For UEs configured with more than five DL cells, $\beta_{offset}^{HARQ-ACK}$ shall be determined according to [3] depending on the number of transmission codewords for the corresponding PUSCH and and the number of HARQ-ACK feedback bits.

For rank indication or CRI, $Q_{RI}=Q_m\cdot Q'$, $Q_{CRI}=Q_m\cdot Q'$ and $\beta_{offset}^{PUSCH}=\beta_{offset}^{RI}$, where Q_m is the modulation order of a given transport block, and β_{offset}^{RI} shall be determined according to [3] depending on the number of transmission codewords for the corresponding PUSCH, and on the uplink power control subframe set for the corresponding PUSCH when two uplink power control subframe sets are configured by higher layers for the cell.

For HARQ-ACK

Petitioners' Exhibit 1003, p. 1317
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Each positive acknowledgement (ACK) is encoded as a binary "1" and each negative acknowledgement (NACK) is encoded as a binary "0"

- If HARQ-ACK feedback consists of 1-bit of information, i.e., $[o_0^{ACK}]$, it is first encoded according to Table 5.2.2.6-1.

- If HARQ-ACK feedback consists of 2-bits of information, i.e., $[o_0^{ACK}\ o_1^{ACK}]$ with o_0^{ACK} corresponding to HARQ-ACK bit for codeword 0 and o_1^{ACK} corresponding to that for codeword 1, or if HARQ-ACK feedback consists of 2-bits of information as a result of the aggregation of HARQ-ACK bits corresponding to two DL cells with which the UE is configured by higher layers, or if HARQ-ACK feedback consists of 2-bits of information corresponding to two subframes for TDD, it is first encoded according to Table 5.2.2.6-2 where $o_2^{ACK} = (o_0^{ACK} + o_1^{ACK}) \bmod 2$.

Table 5.2.2.6-1: Encoding of 1-bit HARQ-ACK.

Q_m	Encoded HARQ-ACK
2	$[o_0^{ACK}$ y]
4	$[o_0^{ACK}$ y x x]
6	$[o_0^{ACK}$ y x x x x]

Table 5.2.2.6-2: Encoding of 2-bit HARQ-ACK.

Q_m	Encoded HARQ-ACK
2	$[o_0^{ACK}\ o_1^{ACK}\ o_2^{ACK}\ o_0^{ACK}\ o_1^{ACK}\ o_2^{ACK}]$
4	$[o_0^{ACK}\ o_1^{ACK}$ x x $o_2^{ACK}\ o_0^{ACK}$ x x $o_1^{ACK}\ o_2^{ACK}$ x x]
6	$[o_0^{ACK}\ o_1^{ACK}$ x x x x $o_2^{ACK}\ o_0^{ACK}$ x x x x $o_1^{ACK}\ o_2^{ACK}$ x x x x]

- If HARQ-ACK feedback consists of $3 \le O^{ACK} \le 11$ bits of information as a result of the aggregation of HARQ-ACK bits corresponding to one or more DL cells with which the UE is configured by higher layers, i.e., $o_0^{ACK}\ o_1^{ACK},...,o_{O^{ACK}-1}^{ACK}$, then a coded bit sequence $\tilde{q}_0^{ACK}\ \tilde{q}_1^{ACK},...,\tilde{q}_{31}^{ACK}$ is obtained by using the bit sequence $o_0^{ACK}\ o_1^{ACK},...,o_{O^{ACK}-1}^{ACK}$ as the input to the channel coding block described in section 5.2.2.6.4. In turn, the bit sequence $q_0^{ACK}, q_1^{ACK}, q_2^{ACK},..., q_{Q_{ACK}-1}^{ACK}$ is obtained by the circular repetition of the bit sequence $\tilde{q}_0^{ACK}\ \tilde{q}_1^{ACK},...,\tilde{q}_{31}^{ACK}$ so that the total bit sequence length is equal to Q_{ACK}.

- If HARQ-ACK feedback consists of $11 < O^{ACK} \le 22$ bits of information as a result of the aggregation of HARQ-ACK bits corresponding to one or more DL cells with which the UE is configured by higher layers, i.e., $o_0^{ACK}\ o_1^{ACK},...,o_{O^{ACK}-1}^{ACK}$, then the coded bit sequence $q_0^{ACK}, q_1^{ACK}, q_2^{ACK},..., q_{Q_{ACK}-1}^{ACK}$ is obtained by using the bit sequence $o_0^{ACK}\ o_1^{ACK},...,o_{O^{ACK}-1}^{ACK}$ as the input to the channel coding block described in section 5.2.2.6.5.

- If HARQ-ACK feedback consists of $O^{ACK} > 22$ bits of information as a result of the aggregation of HARQ-ACK bits corresponding to one or more DL cells with which the UE is configured by higher layers, the coded bit sequence is denoted by $q_0^{ACK}, q_1^{ACK}, q_2^{ACK},..., q_{Q_{ACK}-1}^{ACK}$. The CRC attachment, channel coding and rate matching of the HARQ-ACK bits are performed according to sections 5.1.1 setting L to 8 bits, 5.1.3.1 and 5.1.4.2, respectively. The input bit sequence to the CRC attachment operation is $o_0^{ACK}\ o_1^{ACK},...,o_{O^{ACK}-1}^{ACK}$. The output bit sequence of the CRC attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.

The 'x' and 'y' in Table 5.2.2.6-1 and 5.2.2.6-2 are placeholders for [2] to scramble the HARQ-ACK bits in a way that maximizes the Euclidean distance of the modulation symbols carrying HARQ-ACK information.

Petitioners' Exhibit 1003, p. 1318
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

For FDD or TDD HARQ-ACK multiplexing or the aggregation of more than one DL cell including at least one cell using FDD and at least one cell using TDD when HARQ-ACK consists of one or two bits of information, the bit sequence $q_0^{ACK}, q_1^{ACK}, q_2^{ACK}, ..., q_{Q_{ACK}-1}^{ACK}$ is obtained by concatenation of multiple encoded HARQ-ACK blocks where Q_{ACK} is the total number of coded bits for all the encoded HARQ-ACK blocks. The last concatenation of the encoded HARQ-ACK block may be partial so that the total bit sequence length is equal to Q_{ACK}.

For UEs configured by higher layers with *codebooksizeDetermination-r13 = 0*, the bit sequence $\tilde{o}_0^{ACK}\ \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ is determined according to the Downlink Assignment Index (DAI) as in Table 5.3.3.1.1-2 and as defined in [3]. Otherwise, the bit sequence $\tilde{o}_0^{ACK}\ \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ is determined as below.

For FDD when HARQ ACK consists of 2 or more bits of information as a result of the aggregation of more than one DL cell, the bit sequence $\tilde{o}_0^{ACK}\ \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ is the result of the concatenation of HARQ-ACK bits for the multiple DL cells according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

Set N_{cells}^{DL} to the number of cells configured by higher layers for the UE

while $c < N_{cells}^{DL}$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ – 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK}$ = HARQ-ACK bit of this cell

$j = j + 1$

else

if the UE is not configured with spatial bundling on PUSCH by higher layers $\tilde{o}_j^{ACK}$ = HARQ-ACK bit corresponding to the first codeword of this cell

$j = j + 1$

$\tilde{o}_j^{ACK}$ = HARQ-ACK bit corresponding to the second codeword of this cell

$j = j + 1$

else

$\tilde{o}_j^{ACK}$ = binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell

$j = j + 1$

end if

end if

$c = c + 1$

end while

For the aggregation of more than one DL cell including a primary cell using FDD and at least one secondary cell using TDD, the bit sequence $\tilde{o}_0^{ACK}\ \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ is the result of the concatenation of HARQ-ACK bits for one or multiple DL cells. Define N_{cells}^{DL} as the number of cells configured by higher layers for the UE and B_c^{DL} as the number of subframes for which the UE needs to feed back HARQ-ACK bits in UL subframe n for the *c*-th serving cell. For a

Petitioners' Exhibit 1003, p. 1319
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

cell using TDD, the subframes are determined by the DL-reference UL/DL configuration if the UE is configured with higher layer parameter *eimta-HARQ-ReferenceConfig*, and determined by the UL/DL configuration otherwise. For a cell using TDD, $B_c^{DL}=1$ if subframe n-4 in the cell is a DL subframe or a special subframe with special subframe configurations 1/2/3/4/6/7/8/9 and normal downlink CP or a special subframe with special subframe configurations 1/2/3/5/6/7 and extended downlink CP, and $B_c^{DL}=0$ otherwise. For a cell using FDD, $B_c^{DL}=1$.

The bit sequence $\tilde{o}_0^{ACK}\ \tilde{o}_1^{ACK},\ldots,\tilde{o}_{O^{ACK}-1}^{ACK}$ is performed according to the following pseudo-code:

Set c = 0 – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set j = 0 – HARQ-ACK bit index

while $c < N_{cells}^{DL}$

if $B_c^{DL}=1$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ – 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK}$ = HARQ-ACK bit of this cell

$j = j + 1$

else

if the UE is not configured with spatial bundling on PUSCH by higher layers $\tilde{o}_j^{ACK}$ = HARQ-ACK bit corresponding to the first codeword of this cell

$j = j + 1$

$\tilde{o}_j^{ACK}$ = HARQ-ACK bit corresponding to the second codeword of this cell

$j = j + 1$

else

$\tilde{o}_j^{ACK}$ = binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell

$j = j + 1$

end if

end if

end if

$c = c + 1$

end while

For the cases with TDD primary cell when HARQ-ACK is for the aggregation of one or more DL cells and the UE is configured with PUCCH format 3, PUCCH format 4 or PUCCH format 5 [3], the bit sequence $\tilde{o}_0^{ACK}\ \tilde{o}_1^{ACK},\ldots,\tilde{o}_{O^{ACK}-1}^{ACK}$ is the result of the concatenation of HARQ-ACK bits for the one or more DL cells configured by higher layers and the multiple subframes as defined in [3].

Define N_{cells}^{DL} as the number of cells configured by higher layers for the UE and B_c^{DL} as the number of subframes for which the UE needs to feed back HARQ-ACK bits as defined in Section 7.3 of [3].

Petitioners' Exhibit 1003, p. 1320
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The number of HARQ-ACK bits for the UE to convey if it is configured with PUCCH format 3, PUCCH format 4 or PUCCH format 5 is computed as follows:

Set k = 0 – counter of HARQ-ACK bits

Set c=0 – cell index: lower indices correspond to lower RRC indices of corresponding cell

while c < N_{cells}^{DL}

set l = 0;

while l < B_c^{DL}

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ -- 1 bit HARQ-ACK feedback for this cell

$k = k + 1$

else

$k = k + 2$

end if

$l = l+1$

end while

$c = c + 1$

end while

When PUCCH format 3 is configured, if $k \leq 20$ when TDD is used in all the configured serving cell(s) of the UE, or if $k \leq 21$ when FDD is used in at least one of the configured serving cells with TDD primary cell; or when PUCCH format 4 or PUCCH format 5 is configured and when the UE is not configured with spatial bundling on PUSCH by higher layers, the multiplexing of HARQ-ACK bits is performed according to the following pseudo-code:

Set c = 0 – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set j = 0 – HARQ-ACK bit index

while c < N_{cells}^{DL}

set l = 0;

while l < B_c^{DL}

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ -- 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ HARQ-ACK bit of this cell as defined in Section 7.3 of [3]

$j = j + 1$

else

$[\tilde{o}_j^{ACK}, \tilde{o}_{j+1}^{ACK}] = [o_{c,2l}^{ACK}, o_{c,2l+1}^{ACK}]$ HARQ-ACK bits of this cell as defined in Section 7.3 of [3]

$j = j + 2$

end if

$l = l+1$

end while

Petitioners' Exhibit 1003, p. 1321
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$c = c + 1$

end while

When PUCCH format 3 is configured, if $k > 20$ when TDD is used in all the configured serving cell(s) of the UE, or if $k > 21$ when FDD is used in at least one of the configured serving cells with TDD primary cell, spatial bundling is applied to all subframes in all cells; or when PUCCH format 4 or PUCCH format 5 is configured and when the UE is configured with spatial bundling on PUSCH by higher layers, the multiplexing of HARQ-ACK bits is performed according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

while c < N_{cells}^{DL}

set $l = 0$;

while $l <$ B_c^{DL}

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ – 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ HARQ-ACK bit of this cell as defined in Section 7.3 of [3]

$j = j + 1$

else

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell as defined in Section 7.3 of [3]

$j = j + 1$

end if

$l = l+1$

end while

$c = c + 1$

end while

For $O^{ACK} \le 11$ or $O^{ACK} > 22$, the bit sequence $o_0^{ACK}\ o_1^{ACK},...,o_{O^{ACK}-1}^{ACK}$ is obtained by setting $o_i^{ACK} = \tilde{o}_i^{ACK}$.

For $11 < o^{ACK} \le 22$, the bit sequence $o_0^{ACK}\ o_1^{ACK},...,o_{O^{ACK}-1}^{ACK}$ is obtained by setting $o_{i/2}^{ACK} = \tilde{o}_i^{ACK}$ if i is even and $o_{\lceil O^{ACK}/2 \rceil + (i-1)/2}^{ACK} = \tilde{o}_i^{ACK}$ if i is odd.

For the cases with TDD primary cell when HARQ-ACK is for the aggregation of two DL cells and the UE is configured with PUCCH format 1b with channel selection, the bit sequence $o_0^{ACK}\ o_1^{ACK},...,o_{O^{ACK}-1}^{ACK}$ is obtained as described in section 7.3 of [3].

For TDD HARQ-ACK bundling, a bit sequence $\tilde{q}_0^{ACK}, \tilde{q}_1^{ACK}, \tilde{q}_2^{ACK},..., \tilde{q}_{Q_{ACK}-1}^{ACK}$ is obtained by concatenation of multiple encoded HARQ-ACK blocks where Q_{ACK} is the total number of coded bits for all the encoded HARQ-ACK blocks. The last concatenation of the encoded HARQ-ACK block may be partial so that the total bit sequence length is equal to Q_{ACK}. A scrambling sequence $\left[w_0^{ACK}\ w_1^{ACK}\ w_2^{ACK}\ w_3^{ACK}\right]$ is then selected from Table 5.2.2.6-A with index $i = (N_{bundled} - 1) \bmod 4$, where N_{bundled} is determined as described in section 7.3 of [3]. The bit sequence

Petitioners' Exhibit 1003, p. 1322
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$q_0^{ACK}, q_1^{ACK}, q_2^{ACK}, ..., q_{Q_{ACK}-1}^{ACK}$ is then generated by setting $m = 1$ if HARQ-ACK consists of 1-bit and $m = 3$ if HARQ-ACK consists of 2-bits and then scrambling $\tilde{q}_0^{ACK}, \tilde{q}_1^{ACK}, \tilde{q}_2^{ACK}, ..., \tilde{q}_{Q_{ACK}-1}^{ACK}$ as follows

Set i ,k to 0

while $i < Q_{ACK}$

if $\tilde{q}_i^{ACK} = y$ // place-holder repetition bit

$$q_i^{ACK} = \left(\tilde{q}_{i-1}^{ACK} + w_{\lfloor k/m \rfloor}^{ACK}\right) \bmod 2$$

$$k = (k+1) \bmod 4m$$

else

if $\tilde{q}_i^{ACK} = x$ // a place-holder bit

$$q_i^{ACK} = \tilde{q}_i^{ACK}$$

else // coded bit

$$q_i^{ACK} = \left(\tilde{q}_i^{ACK} + w_{\lfloor k/m \rfloor}^{ACK}\right) \bmod 2$$

$$k = (k+1) \bmod 4m$$

end if

$$i = i + 1$$

end while

Table 5.2.2.6-A: Scrambling sequence selection for TDD HARQ-ACK bundling.

i	$\left[w_0^{ACK} w_1^{ACK} w_2^{ACK} w_3^{ACK}\right]$
0	[1 1 1 1]
1	[1 0 1 0]
2	[1 1 0 0]
3	[1 0 0 1]

When HARQ-ACK information is to be multiplexed with UL-SCH at a given PUSCH, the HARQ-ACK information is multiplexed in all layers of all transport blocks of that PUSCH, For a given transport block, the vector sequence output of the channel coding for HARQ-ACK information is denoted by $\underline{q}_0^{ACK}, \underline{q}_1^{ACK}, ..., \underline{q}_{Q'_{ACK}-1}^{ACK}$, where $\underline{q}_i^{ACK}$, $i = 0, ..., Q'_{ACK} - 1$ are column vectors of length $(Q_m \cdot N_L)$ and where $Q'_{ACK} = Q_{ACK} / Q_m$ is obtained as follows:

Set i ,k to 0

while $i < Q_{ACK}$

$\hat{\underline{q}}_k^{ACK} = [q_i^{ACK} \; ... q_{i+Q_m-1}^{ACK}]$ -- temporary row vector

$\underline{q}_k^{ACK} = [\overbrace{\hat{\underline{q}}_k^{ACK} \cdots \hat{\underline{q}}_k^{ACK}}^{N_L}]^T$ -- replicating the row vector $\hat{\underline{q}}_k^{ACK}$ N_L times and transposing into a column vector

Petitioners' Exhibit 1003, p. 1323
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$i = i + Q_m$

$k = k + 1$

end while

where N_L is the number of layers onto which the UL-SCH transport block is mapped.

For rank indication (RI) (RI only, joint report of RI and i1, joint report of CRI and RI, joint report of CRI,RI and i1,joint report of CRI,RI, and PTI, and joint report of RI and PTI) or CRI

- The corresponding bit widths for CRI feedback for PDSCH transmissions are given by Tables 5.2.2.6.2-3A, 5.2.2.6.3-3A, 5.2.3.3.1-3E, and 5.2.3.3.2-4E,
- The corresponding bit widths for RI feedback for PDSCH transmissions are given by Tables 5.2.2.6.1-2, 5.2.2.6.1-2A, 5.2.2.6.2-3, 5.2.2.6.2-3B, 5.2.2.6.3-3, 5.2.2.6.3-3B, 5.2.3.3.1-3, 5.2.3.3.1-3A, 5.2.3.3.1-3B, 5.2.3.3.1-3C, 5.2.3.3.1-3D, 5.2.3.3.2-4, and 5.2.3.3.2-4A, 5.2.3.3.2-4B, 5.2.3.3.2-4C, 5.2.3.3.2-4D which are determined assuming the maximum number of layers as follows:
  - If the *maxLayersMIMO-r10* is configured for the DL cell, the maximum number of layers is determined according to *maxLayersMIMO-r10* for the DL cell
  - Else,
    - If the UE is configured with transmission mode 9, and the *supportedMIMO-CapabilityDL-r10* field is included in the *UE-EUTRA-Capability*, the maximum number of layers is determined according to the minimum of the configured number of CSI-RS ports and the maximum of the reported UE downlink MIMO capabilities for the same band in the corresponding band combination.
    - If the UE is configured with transmission mode 9, and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and RI and CRI are transmitted in the same reporting instance, and the supportedMIMO-CapabilityDL-r10 field is included in the UE-EUTRA-Capability, the maximum number of layers is determined according to the minimum of the maximum of number of antenna port of the configured CSI-RS resources and the maximum of the reported UE downlink MIMO capabilities for the same band in the corresponding band combination,.
    - If the UE is configured with transmission mode 9, and the *supportedMIMO-CapabilityDL-r10* field is not included in the *UE-EUTRA-Capability*, the maximum number of layers is determined according to the minimum of the configured number of CSI-RS ports and *ue-Category* (without suffix).
    - If the UE is configured with transmission mode 9, and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and RI and CRI are transmitted in the same reporting instance, and the supportedMIMO-CapabilityDL-r10 field is not included in the UE-EUTRA-Capability, the maximum number of layers is determined according to the minimum of the maximum of number of antenna port of the configured CSI-RS resources and ue-Category (without suffix).
    - If the UE is configured with transmission mode 10, and the *supportedMIMO-CapabilityDL-r10* field is included in the *UE-EUTRA-Capability*, the maximum number of layers for each CSI process is determined according to the minimum of the configured number of CSI-RS ports for that CSI process and the maximum of the reported UE downlink MIMO capabilities for the same band in the corresponding band combination.
    - If the UE is configured with transmission mode 10, and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and RI and CRI are transmitted in the same reporting instance, and the supportedMIMO-CapabilityDL-r10 field is included in the UE-EUTRA-Capability, the maximum number of layers for each CSI process is determined according to the minimum of the maximum of number of antenna port of the configured CSI-RS resources in that CSI process and the maximum of the reported UE downlink MIMO capabilities for the same band in the corresponding band combination.
    - If the UE is configured with transmission mode 10, and the *supportedMIMO-CapabilityDL-r10* field is not included in the *UE-EUTRA-Capability*, the maximum number of layers for each CSI process is determined according to the minimum of the configured number of CSI-RS ports for that CSI process and *ue-Category* (without suffix).

Petitioners' Exhibit 1003, p. 1324
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- If the UE is configured with transmission mode 10, and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and RI and CRI are transmitted in the same reporting instance, and the supportedMIMO-CapabilityDL-r10 field is not included in the UE-EUTRA-Capability, the maximum number of layers for each CSI process is determined according to the minimum of the maximum of number of antenna port of the configured CSI-RS resources in that CSI process and ue-Category (without suffix).
- Otherwise the maximum number of layers is determined according to the minimum of the number of PBCH antenna ports and *ue-Category* (without suffix).

- If RI feedback consists of 1-bit of information, i.e., $[o_0^{RI}]$, it is first encoded according to Table 5.2.2.6-3. The $[o_0^{RI}]$ to RI mapping is given by Table 5.2.2.6-5.
- If RI feedback consists of 2-bits of information, i.e., $[o_0^{RI}\ o_1^{RI}]$ with o_0^{RI} corresponding to MSB of 2-bit input and o_1^{RI} corresponding to LSB, it is first encoded according to Table 5.2.2.6-4 where $o_2^{RI} = (o_0^{RI} + o_1^{RI}) \bmod 2$. The $[o_0^{RI}\ o_1^{RI}]$ to RI mapping is given by Table 5.2.2.6-6.

Table 5.2.2.6-3: Encoding of 1-bit RI.

Q_m	Encoded RI
2	$[o_0^{RI}$ y]
4	$[o_0^{RI}$ y x x]
6	$[o_0^{RI}$ y x x x x]

Table 5.2.2.6-4: Encoding of 2-bit RI.

Q_m	Encoded RI
2	$[o_0^{RI}\ o_1^{RI}\ o_2^{RI}\ o_0^{RI}\ o_1^{RI}\ o_2^{RI}]$
4	$[o_0^{RI}\ o_1^{RI}$ x x $o_2^{RI}\ o_0^{RI}$ x x $o_1^{RI}\ o_2^{RI}$ x x]
6	$[o_0^{RI}\ o_1^{RI}$ x x x x $o_2^{RI}\ o_0^{RI}$ x x x x $o_1^{RI}\ o_2^{RI}$ x x x x]

Table 5.2.2.6-5: o_0^{RI} to RI mapping.

o_0^{RI}	RI
0	1
1	2

Table 5.2.2.6-6: o_0^{RI}, o_1^{RI} to RI mapping.

o_0^{RI}, o_1^{RI}	RI
0, 0	1
0, 1	2
1, 0	3
1, 1	4

Table 5.2.2.6-7: o_0^{RI}, o_1^{RI}, o_2^{RI} to RI mapping.

Petitioners' Exhibit 1003, p. 1325
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

o_0^{RI} , o_1^{RI} , o_2^{RI}	RI
0, 0, 0	1
0, 0, 1	2
0, 1, 0	3
0, 1, 1	4
1, 0, 0	5
1, 0, 1	6
1, 1, 0	7
1, 1, 1	8

- If RI feedback for a given DL cell consists of 3-bits of information, i.e., $[o_0^{RI}\ o_1^{RI}\ o_2^{RI}]$ with o_0^{RI} corresponding to MSB of 3-bit input and o_2^{RI} corresponding to LSB. The $[o_0^{RI}\ o_1^{RI}\ o_2^{RI}]$ to RI mapping is given by Table 5.2.2.6-7.

- If RI feedback consists of $3 \le O^{RI} \le 11$ bits of information, i.e., $[o_0^{RI}\ o_1^{RI},...,o_{O^{RI}-1}^{RI}]$, then a coded bit sequence $[\tilde{q}_0^{RI}\ \tilde{q}_1^{RI},...,\tilde{q}_{31}^{RI}]$ is obtained by using the bit sequence $[o_0^{RI}\ o_1^{RI},...,o_{O^{RI}-1}^{RI}]$ as the input to the channel coding block described in section 5.2.2.6.4.

- If RI feedback consists of $11 < O^{RI} \le 22$ bits of information as a result of the aggregation of RI bits corresponding to multiple DL cells or multiple CSI processes, i.e., $[o_0^{RI}\ o_1^{RI},...,o_{O^{RI}-1}^{RI}]$, then the coded bit sequence $q_0^{RI}, q_1^{RI}, q_2^{RI},..., q_{Q_{RI}-1}^{RI}$ is obtained by using the bit sequence $[o_0^{RI}\ o_1^{RI},...,o_{O^{RI}-1}^{RI}]$ as the input to the channel coding block described in section 5.2.2.6.5.

- If RI feedback consists of $O^{RI} > 22$ bits of information as a result of the aggregation of RI bits corresponding to multiple DL cells or multiple CSI processes, i.e., $[o_0^{RI}\ o_1^{RI},...,o_{O^{RI}-1}^{RI}]$, then the coded bit sequence is denoted by $q_0^{RI}, q_1^{RI}, q_2^{RI},..., q_{Q_{RI}-1}^{RI}$. The CRC attachment, channel coding and rate matching of the HARQ-ACK bits are performed according to sections 5.1.1 setting L to 8 bits, 5.1.3.1 and 5.1.4.2, respectively. The input bit sequence to the CRC attachment operation is $[o_0^{RI}\ o_1^{RI},...,o_{O^{RI}-1}^{RI}]$. The output bit sequence of the CRC attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.

- A UE capable of supporting only up to 5 serving cells is not expected to support CRI/RI payload larger than 22 bits.

The 'x' and 'y' in Table 5.2.2.6-3 and 5.2.2.6-4 are placeholders for [2] to scramble the RI bits in a way that maximizes the Euclidean distance of the modulation symbols carrying rank information.

For the case where RI feedback for more than one DL cell is to be reported, the RI report for each DL cell is concatenated prior to coding in increasing order of cell index.

For the case where RI feedback for more than one CSI process is to be reported, the RI reports are concatenated prior to coding first in increasing order of CSI process index for each DL cell and then in increasing order of cell index.

For the case where RI feedback consists of one or two bits of information the bit sequence $q_0^{RI}, q_1^{RI}, q_2^{RI},..., q_{Q_{RI}-1}^{RI}$ is obtained by concatenation of multiple encoded RI blocks where Q_{RI} is the total number of coded bits for all the encoded RI blocks. The last concatenation of the encoded RI block may be partial so that the total bit sequence length is equal to Q_{RI} .

For the case where RI feedback consists of $3 \le O^{RI} \le 11$ bits of information, the bit sequence $q_0^{RI}, q_1^{RI}, q_2^{RI},..., q_{Q_{RI}-1}^{RI}$ is obtained by the circular repetition of the bit sequence $\tilde{q}_0^{RI}\ \tilde{q}_1^{RI},...,\tilde{q}_{31}^{RI}$ so that the total bit sequence length is equal to Q_{RI} .

For the case where CRI feedback is to be reported, the same procedures for RI are applied for CRI.When rank information is to be multiplexed with UL-SCH at a given PUSCH, the rank information is multiplexed in all layers of

Petitioners' Exhibit 1003, p. 1326
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

all transport blocks of that PUSCH. For a given transport block, the vector sequence output of the channel coding for rank information is denoted by $\underline{q}_0^{RI}, \underline{q}_1^{RI}, ..., \underline{q}_{Q'_{RI}-1}^{RI}$, where $\underline{q}_i^{RI}$, $i = 0,...,Q'_{RI}-1$ are column vectors of length $(Q_m \cdot N_L)$ and where $Q'_{RI} = Q_{RI} / Q_m$. The vector sequence is obtained as follows:

Set *i*, *j*, *k* to 0

while $i < Q_{RI}$

$\hat{\underline{q}}_k^{RI} = [q_i^{RI} \; ... q_{i+Q_m-1}^{RI}]$ -- temporary row vector

$\underline{q}_k^{RI} = [\overbrace{\hat{\underline{q}}_k^{RI} \cdots \hat{\underline{q}}_k^{RI}}^{N_L}]^T$ -- replicating the row vector $\hat{\underline{q}}_k^{RI}$ N_L times and transposing into a column vector

$i = i + Q_m$

$k = k + 1$

end while

where N_L is the number of layers onto which the UL-SCH transport block is mapped.

The same processing procedures for RI and RI multiplexing with UL-SCH at a given PUSCH are applied for CRI, using CRI instead of RI in the equations.

For channel quality control information (CQI and/or PMI denoted as CQI/PMI);

When the UE transmits channel quality control information bits, it shall determine the number of modulation coded symbols per layer Q' for channel quality information as

$$Q' = \min\left(\left\lceil \frac{(O+L) \cdot M_{sc}^{PUSCH-initial(x)} \cdot N_{symb}^{PUSCH-initial(x)} \cdot \beta_{offset}^{PUSCH}}{\sum_{r=0}^{C^{(x)}-1} K_r^{(x)}} \right\rceil, M_{sc}^{PUSCH} \cdot N_{symb}^{PUSCH} - \frac{Q_{RI}^{(x)}}{Q_m^{(x)}} \right)$$

where

- O is the number of CQI/PMI bits, and
- L is the number of CRC bits given by $L = \begin{cases} 0 & O \le 11 \\ 8 & \text{otherwise} \end{cases}$, and
- $Q_{CQI} = Q_m^{(x)} \cdot Q'$ and $\beta_{offset}^{PUSCH} = \beta_{offset}^{CQI}$, where β_{offset}^{CQI} shall be determined according to [3] depending on the number of transmission codewords for the corresponding PUSCH, and on the uplink power control subframe set for the corresponding PUSCH when two uplink power control subframe sets are configured by higher layers for the cell.
- If neither RI nor CRI is not transmitted then $Q_{RI}^{(x)} = 0$.

The variable '*x*' in $K_r^{(x)}$ represents the transport block index corresponding to the highest I_{MCS} value indicated by the initial UL grant. In case the two transport blocks have the same I_{MCS} value in the corresponding initial UL grant, '*x* =1', which corresponds to the first transport block. $M_{sc}^{PUSCH-initial(x)}$, $C^{(x)}$, and $K_r^{(x)}$ are obtained from the initial PDCCH or EPDCCH or MPDCCH for the same transport block. If there is no initial PDCCH or EPDCCH with DCI format 0 or MPDCCH with DCI format 6-0A/6-0B for the same transport block, $M_{sc}^{PUSCH-initial(x)}$, $C^{(x)}$, and $K_r^{(x)}$ shall be determined from:

Petitioners' Exhibit 1003, p. 1327
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- the most recent semi-persistent scheduling assignment PDCCH or EPDCCH or MPDCCH, when the initial PUSCH for the same transport block is semi-persistently scheduled, or,
- the random access response grant for the same transport block, when the PUSCH is initiated by the random access response grant.

$N_{symb}^{PUSCH-initial(x)}$ is the number of SC-FDMA symbols per subframe for initial PUSCH transmission for the same transport block.

For UL-SCH data information $G = N_L^{(x)} \cdot \left(N_{\text{symb}}^{\text{PUSCH}} \cdot M_{\text{sc}}^{\text{PUSCH}} \cdot Q_m^{(x)} - Q_{CQI} - Q_{RI}^{(x)} \right)$, where

- $N_L^{(x)}$ is the number of layers the corresponding UL-SCH transport block is mapped onto, and
- $M_{\text{sc}}^{\text{PUSCH}}$ is the scheduled bandwidth for PUSCH transmission in the current sub-frame for the transport block, and
- $N_{\text{symb}}^{\text{PUSCH}}$ is the number of SC-FDMA symbols in the current PUSCH transmission sub-frame given by $N_{\text{symb}}^{\text{PUSCH}} = \left(2 \cdot \left(N_{\text{symb}}^{\text{UL}} - 1\right) - N_{SRS}\right)$, where
  - N_{SRS} is equal to 1
    - if UE configured with one UL cell is configured to send PUSCH and SRS in the same subframe for initial transmission, or
    - if UE transmits PUSCH and SRS in the same subframe for the current subframe in the same serving cell, or
    - if the PUSCH resource allocation for the current subframe even partially overlaps with the cell-specific SRS subframe and bandwidth configuration defined in section 5.5.3 of [2], or
    - if the current subframe in the same serving cell is a UE-specific type-1 SRS subframe as defined in Section 8.2 of [3], or
    - if the current subframe in the same serving cell is a UE-specific type-0 SRS subframe as defined in section 8.2 of [3] and the UE is configured with multiple TAGs.
  - Otherwise N_{SRS} is equal to 0.

In case of CQI/PMI report for more than one DL cell, $o_0, o_1, o_2, ..., o_{O-1}$ is the result of concatenating the CQI/PMI report for each DL cell in increasing order of cell index. For the case where CQI/PMI feedback for more than one CSI process is to be reported, $o_0, o_1, o_2, ..., o_{O-1}$ is the result of concatenating the CQI/PMI reports in increasing order of CSI process index for each DL cell and then in increasing order of cell index.

– If the payload size is less than or equal to 11 bits, the channel coding of the channel quality information is performed according to section 5.2.2.6.4 with input sequence $o_0, o_1, o_2, ..., o_{O-1}$.

– For payload sizes greater than 11 bits, the CRC attachment, channel coding and rate matching of the channel quality information is performed according to sections 5.1.1, 5.1.3.1 and 5.1.4.2, respectively. The input bit sequence to the CRC attachment operation is $o_0, o_1, o_2, ..., o_{O-1}$. The output bit sequence of the CRC attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.

The output sequence for the channel coding of channel quality information is denoted by $q_0, q_1, q_2, q_3, ..., q_{N_L \cdot Q_{CQI} - 1}$, where N_L is the number of layers the corresponding UL-SCH transport block is mapped onto.

Petitioners' Exhibit 1003, p. 1328
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.2.2.6.1 Channel quality information formats for wideband CQI reports

If the parameter *CQI-ReportModeAperiodic* is configured to the value of *rm10-v13xy* by higher layers [6], Table 5.2.3.3.1-1 shows the fields and the corresponding bit widths for the channel quality information feedback, Table 5.2.3.3.1-3 shows the fields and the corresponding bit widths for the rank indication feedback.

If the parameter *CQI-ReportModeAperiodic* is configured to the value of *rm11-v13xx* by higher layers [6], Table 5.2.3.3.1-2, Table 5.2.3.3.1-2A, Table 5.2.3.3.1-2B, Table 5.2.3.3.1-2C and Table 5.2.3.3.1-2D show the fields and the corresponding bit widths for the channel quality and precoding matrix information feedback, Table 5.2.3.3.1-3 shows the fields and the corresponding bit widths for the rank indication feedback, and Table 5.2.3.3.1-3A and Table 5.2.3.3.1-3B show the fields and the corresponding bit widths for the joint transmission of rank indication and i1.

If the parameter *CQI-ReportModeAperiodic* is configured to the value of *rm12* by higher layers [6], the fields and the corresponding bit widths for channel quality information and rank indication feedback are described as below.

Table 5.2.2.6.1-1, Table 5.2.2.6.1-1A and Table 5.2.2.6.1-1B show the fields and the corresponding bit widths for the channel quality information feedback for wideband reports for PDSCH transmissions associated with transmission mode 4, transmission mode 6, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" for a CSI process with K>1, and K=1 except with *alternativeCodebookEnabledCLASSB_K1=TRUE*. The number of configured CSI-RS resources in a CSI process K is defined in [3] and *alternativeCodebookEnabledCLASSB_K1* is configured by higher layers [6].

Table 5.2.2.6.1-1C and Table 5.2.2.6.1-1D show the fields and the corresponding bit widths for the channel quality information feedback for wideband reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A".

Table 5.2.2.6.2-1E shows the fields and corresponding bit widths for the channel quality information feedback for wideband reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and higher layer parameter *alternativeCodebookEnabledCLASSB_K1=TRUE* configured.

For Table 5.2.2.6.1-1, Table 5.2.2.6.1-1A, Table 5.2.2.6.1-1B, Table 5.2.2.6.1-1C, Table 5.2.2.6.1-D and Table 5.2.2.6.1-1E, N is defined in section 7.2 of [3]. For Table 5.2.2.6.1-1C and Table 5.2.2.6.1-D, the codebook configuration (N_1, N_2, O_1, O_2) is defined in [3], and *CodebookConfig* is configured by higher layers [6]. The parameters (S_1, S_2) in rank 3 and 4 are defined as $(S_1, S_2) = (1,1)$ for *CodebookConfig*=1, $(S_1, S_2) = \left(\frac{O_1}{2}, \frac{O_2}{2}\right)$ for *CodebookConfig*=2, $(S_1, S_2) = \left(O_1, \frac{O_2}{2}\right)$ for *CodebookConfig*=3, $(S_1, S_2) = \left(O_1, \frac{O_2}{4}\right)$ for *CodebookConfig*=4. The parameters (S_1, S_2) in rank 5 to 8 are defined as $(S_1, S_2) = (1,1)$ for *CodebookConfig*=1, $(S_1, S_2) = \left(\frac{O_1}{4}, \frac{O_2}{4}\right)$ for *CodebookConfig*=2/3/4.

Table 5.2.2.6.1-1: Fields for channel quality information feedback for wideband CQI reports (transmission mode 4, transmission mode 6, transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 9 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 10 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter eMIMO-Type, and eMIMO-Type is set to "CLASS B" with 2/4 antenna ports with K>1, and K=1 except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*).

Petitioners' Exhibit 1003, p. 1329
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Field	Bit width			
	2 antenna ports		4 antenna ports	
	Rank = 1	Rank = 2	Rank = 1	Rank > 1
Wideband CQI codeword 0	4	4	4	4
Wideband CQI codeword 1	0	4	0	4
Precoding matrix indicator	$2N$	N	$4N$	$4N$

Table 5.2.2.6.1-1A: Fields for channel quality information feedback for wideband CQI reports (transmission mode 9 configured with PMI/RI reporting with 8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with 8 antenna ports with K>1, and K=1 except with *alternativeCodebookEnabledCLASSB_K1=TRUE*).

Field	Bit width			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wideband CQI codeword 0	4	4	4	4
Wideband CQI codeword 1	0	4	4	4
Wideband first PMI i1	4	4	2	2
Subband second PMI i2	$4N$	$4N$	$4N$	$3N$
Field	**Bit width**			
	Rank = 5	Rank = 6	Rank = 7	Rank = 8
Wideband CQI codeword 0	4	4	4	4
Wideband CQI codeword 1	4	4	4	4
Wideband first PMI i1	2	2	2	0
Subband second PMI i2	0	0	0	0

Table 5.2.2.6.1-1B: Fields for channel quality information feedback for wideband CQI reports with 4 antenna ports (transmission mode 8, transmission mode 9 and transmission mode 10 configured with PMI/RI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with 4 antenna ports with K>1, and K=1 except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wideband CQI codeword 0	4	4	4	4
Wideband CQI codeword 1	0	4	4	4
Wideband first PMI i1	4	4	0	0
Subband second PMI i2	$4N$	$4N$	$4N$	$4N$

Petitioners' Exhibit 1003, p. 1330
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.2.2.6.1-1C: Fields for channel quality information feedback for wideband CQI reports (transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A" with codebook configuration (N_1, N_2, O_1, O_2) and *CodebookConfig*=1)

Field	Bit width			
	Rank = 1	Rank = 2	Rank =3	Rank =4
Wideband CQI codeword 0	4	4	4	4
Wideband CQI codeword 1	0	4	4	4
Wideband first PMI i1,1	$\lceil \log_2(N_1 O_1) \rceil$	$\lceil \log_2(N_1 O_1) \rceil$	$\left\lceil \log_2\left(\frac{N_1 O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$	$\left\lceil \log_2\left(\frac{N_1 O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$
Wideband first PMI i1,2	$\lceil \log_2(N_2 O_2) \rceil$	$\lceil \log_2(N_2 O_2) \rceil$	$\lceil \log_2(N_2 O_2) \rceil$	$\lceil \log_2(N_2 O_2) \rceil$
Subband second PMI i2	$2N$	$2N$	N	N
Field	Bit width			
	Rank = 5	Rank = 6	Rank =7	Rank =8
Wideband CQI codeword 0	4	4	4	4
Wideband CQI codeword 1	4	4	4	4
Wideband first PMI i1,1	$\lceil \log_2(N_1 O_1 / S_1) \rceil$	$\lceil \log_2(N_1 O_1 / S_1) \rceil$	$\lceil \log_2(N_1 O_1 / S_1) \rceil$	$\lceil \log_2(N_1 O_1 / S_1) \rceil$
Wideband first PMI i1,2	$\lceil \log_2(N_2 O_2 / S_2) \rceil$	$\lceil \log_2(N_2 O_2 / S_2) \rceil$	$\lceil \log_2(N_2 O_2 / S_2) \rceil$	$\lceil \log_2(N_2 O_2 / S_2) \rceil$
Subband second PMI i2	0	0	0	0

Table 5.2.2.6.1-1D: Fields for channel quality information feedback for wideband CQI reports (transmission mode 9/10 configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A" with codebook configuration (N_1, N_2, O_1, O_2) and *CodebookConfig*=2/3/4)

Field	Bit width			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4

Petitioners' Exhibit 1003, p. 1331
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Wideband CQI codeword 0	4	4	4	4
Wideband CQI codeword 1	0	4	4	4
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/2) \rceil$	$\lceil \log_2(N_1O_1/2) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/2) \rceil$	$\lceil \log_2(N_2O_2/2) \rceil$	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right) \right\rceil$	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right) \right\rceil$
Subband second PMI i2	$4N$	$4N$	$4N$	$3N$

Field	Bit width			
	Rank = 5	Rank = 6	Rank = 7	Rank= 8
Wideband CQI codeword 0	4	4	4	4
Wideband CQI codeword 1	4	4	4	4
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Subband second PMI i2	0	0	0	0

Table 5.2.2.6.1-1E: Fields for channel quality information feedback for wideband CQI reports (transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with 2/4/8 antenna ports with K=1 with *alternativeCodebookEnabledCLASSB_K1=TRUE*)

Field	**Bit width**					
	2 antenna ports		**4 antenna ports**			
	Rank = 1	**Rank = 2**	**Rank = 1**	**Rank =2**	**Rank =3**	**Rank =4**
Wideband CQI codeword 0	4	4	4	4	4	4
Wideband CQI codeword 1	0	4	0	4	4	4
Precoding matrix indicator	$2N$	N	$3N$	$3N$	$2N$	N

Field	**Bit width**				
	8 antenna ports				
	Rank = 1	**Rank = 2**	**Rank = 3**	**Rank =4**	**Rank =5~8**
Wideband CQI codeword 0	4	4	4	4	4
Wideband CQI codeword 1	0	4	0	4	4
Precoding matrix indicator	$4N$	$4N$	$4N$	$3N$	0

Petitioners' Exhibit 1003, p. 1332
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.2.2.6.1-2 shows the fields and the corresponding bit width for the rank indication feedback for wideband CQI reports for PDSCH transmissions associated with transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B", and transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A".

Table 5.2.2.6.1-2A shows the fields and the corresponding bit width for the joint CRI and RI feedback for wideband CQI reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1.

Table 5.2.2.6.1-2: Fields for rank indication feedback for wideband CQI reports
(transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B", and transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A").

Field	Bit width					
	2 antenna ports	4 antenna ports		8/12/16 antenna ports		
		Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers	Max 8 layers
Rank indication	1	1	2	1	2	3

Table 5.2.2.6.1-2A: Fields for joint CRI and RI feedback for wideband CQI reports
(transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1).

Field	Bit width					
	2 antenna ports	4 antenna ports		8 antenna ports		
		Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers	Max 8 layers
CRI	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$
Rank indication	1	1	2	1	2	3

The channel quality bits in Table 5.2.2.6.1-1, Table 5.2.2.6.1-1A, Table 5.2.2.6.1-1B, Table 5.2.2.6.1-1C, Table 5.2.2.6.1-1D, Table 5.2.2.6.1-1E, and 5.2.2.6.1-2A form the bit sequence $o_0, o_1, o_2, ..., o_{O-1}$ with o_0 corresponding to the first bit of the first field in the table, o_1 corresponding to the second bit of the first field in the table, and o_{O-1} corresponding to the last bit in the last field in the table. The field of PMI shall be in the increasing order of the subband index [3]. The first bit of each field corresponds to MSB and the last bit LSB. The RI bits sequence in Table 5.2.2.6.1-2 and Table 5.2.2.6.1-2A are encoded according to section 5.2.2.6.

For transmission mode 9/10 configured with Class B CSI reporting and K>1, the number of antenna port in Table 5.2.2.6.1-2A refers to the maximum number of antenna ports of K CSI-RS resources configured for the CSI-process for the UE.

5.2.2.6.2 Channel quality information formats for higher layer configured subband CQI reports

Table 5.2.2.6.2-1 shows the fields and the corresponding bit width for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 1, transmission mode 2, transmission mode 3, transmission mode 7, transmission mode 8 configured without PMI/RI reporting, transmission mode 9 configured without PMI/RI reporting or configured with 1 antenna port, and transmission mode 10 configured without PMI/RI reporting or configured with 1 antenna port. N in Table 5.2.2.6.2-1 is defined in section 7.2 of [3].

Petitioners' Exhibit 1003, p. 1333
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.2.2.6.2-1A shows the fields and the corresponding bit width for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 9/10 configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with 2/4/8 antenna ports.

Table 5.2.2.6.2-1: Fields for channel quality information feedback for higher layer configured subband CQI reports (transmission mode 1, transmission mode 2, transmission mode 3, transmission mode 7, transmission mode 8 configured without PMI/RI reporting, transmission mode 9 configured without PMI/RI reporting or configured with 1 antenna port, and transmission mode 10 configured without PMI/RI reporting or configured with 1 antenna port)

Field	Bit width
Wide-band CQI codeword	4
Subband differential CQI	$2N$

Table 5.2.2.6.2-1A Fields for channel quality information feedback for higher layer configured subband CQI reports (transmission mode 9/10 configured without PMI reporting **and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B"** with 2/4/8 antenna ports)

Field	Bit width	
	Rank = 1	Rank > 1
Wide-band CQI codeword 0	4	4
Subband differential CQI codeword 0	$2N$	$2N$
Wide-band CQI codeword 1	0	4
Subband differential CQI codeword 1	0	$2N$

Table 5.2.2.6.2-2, Table 5.2.2.6.2-2A and Table 5.2.2.6.2-2B show the fields and the corresponding bit widths for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 4, transmission mode 5, transmission mode 6, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and K=1 except with *alternativeCodebookEnabledCLASSB_K1=TRUE*. The number of configured CSI-RS resources in a CSI process K is defined in [3] and *alternativeCodebookEnabledCLASSB_K1* is configured by higher layers [6].

Table 5.2.2.6.2-2B-1 and Table 5.2.2.6.2-2B-2 show the fields and the corresponding bit widths for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A".

Table5.2.2.6.2-2B-3 shows the fields and the corresponding bit widths for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and *alternativeCodebookEnabledCLASSB_K1=TRUE*.

For Table 5.2.2.6.2-2, Table 5.2.2.6.2-2A, Table 5.2.2.6.2-2B, Table 5.2.2.6.2-2B-1, Table 5.2.2.6.2-2B-2 and Table 5.2.2.6.2-2B-3, N is defined in section 7.2 of [3]. For Table 5.2.2.6.2-2B-1 and Table 5.2.2.6.2-2B-2, the codebook configuration $\left(N_1, N_2, O_1, O_2\right)$ is defined in [3], and *CodebookConfig* is configured by higher layers [6]. The parameters $\left(S_1, S_2\right)$ in rank 3 and 4 are defined as $\left(S_1, S_2\right) = \left(1,1\right)$ for *CodebookConfig*=1, $\left(S_1, S_2\right) = \left(\frac{O_1}{2}, \frac{O_2}{2}\right)$ for *CodebookConfig*=2, $\left(S_1, S_2\right) = \left(O_1, \frac{O_2}{2}\right)$ for *CodebookConfig*=3, $\left(S_1, S_2\right) = \left(O_1, \frac{O_2}{4}\right)$ for

Petitioners' Exhibit 1003, p. 1334
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CodebookConfig=4. The parameters (S_1, S_2) in rank 5 to 8 are defined as $(S_1, S_2) = (1, 1)$ for *CodebookConfig*=1, $(S_1, S_2) = \left(\frac{O_1}{4}, \frac{O_2}{4}\right)$ for *CodebookConfig*=2/3/4.

Table 5.2.2.6.2-2: Fields for channel quality information feedback for higher layer configured subband CQI reports (transmission mode 4, transmission mode 5, transmission mode 6, transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 9 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 10 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 2/4 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and K=1 except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	2 antenna ports		4 antenna ports	
	Rank = 1	Rank = 2	Rank = 1	Rank > 1
Wide-band CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wide-band CQI codeword 1	0	4	0	4
Subband differential CQI codeword 1	0	$2N$	0	$2N$
Precoding matrix indicator	2	1	4	4

Table 5.2.2.6.2-2A: Fields for channel quality information feedback for higher layer configured subband CQI reports (transmission mode 9 configured with PMI/RI reporting with 8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and K=1 except with *alternativeCodebookEnabledCLASSB_K1=TRUE*).

Field	Bitwidth			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1	4	4	2	2
Wideband second PMI i2	4	4	4	3
Field	**Bitwidth**			
	Rank = 5	Rank = 6	Rank = 7	Rank = 8
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	4	4	4	4
Subband differential CQI codeword 1	$2N$	$2N$	$2N$	$2N$
Wideband first PMI i1	2	2	2	0

Petitioners' Exhibit 1003, p. 1335
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Wideband second PMI i2	0	0	0	0

Table 5.2.2.6.2-2B: Fields for channel quality information feedback for higher layer configured subband CQI reports with 4 antenna ports (transmission modes 8, 9 and 10 configured with PMI/RI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE,* and transmission mode 9/10 configured with PMI/RI reporting with 4 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and K=1 except with *alternativeCodebookEnabledCLASSB_K1=TRUE,* with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bitwidth			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1	4	4	0	0
Wideband second PMI i2	4	4	4	4

Table 5.2.2.6.2-2B-1: Fields for channel quality information feedback for higher layer configured subband CQI reports (transmission mode 9/10 configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A" with codebook configuration (N_1, N_2, O_1, O_2) and *CodebookConfig*=1)

Field	Bit width			
	Rank = 1	Rank = 2	Rank =3	Rank =4
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1,1	$\lceil \log_2(N_1 O_1) \rceil$	$\lceil \log_2(N_1 O_1) \rceil$	$\left\lceil \log_2\left(\frac{N_1 O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$	$\left\lceil \log_2\left(\frac{N_1 O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$

Petitioners' Exhibit 1003, p. 1336
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Wideband first PMI i1,2	$\lceil \log_2(N_2O_2) \rceil$	$\lceil \log_2(N_2O_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Wideband second PMI i2	2	2	1	1
Field	Bit width			
	Rank = 5	Rank = 6	Rank =7	Rank =8
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	4	4	4	4
Subband differential CQI codeword 1	$2N$	$2N$	$2N$	$2N$
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Wideband second PMI i2	0	0	0	0

Table 5.2.2.6.2-2B-2: Fields for channel quality information feedback for higher layer configured subband CQI reports (transmission mode 9/10 configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A" with codebook configuration (N_1, N_2, O_1, O_2) and *CodebookConfig*=2/3/4)

Field	Bit width			
	Rank = 1	Rank = 2	Rank =3	Rank =4
Wideband CQI codeword 0	4	4	4	4

Petitioners' Exhibit 1003, p. 1337
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1) \rceil$	$\lceil \log_2(N_1O_1) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2) \rceil$	$\lceil \log_2(N_2O_2) \rceil$	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right) \right\rceil$	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right) \right\rceil$
Wideband second PMI i2	2	2	4	3

Field	Bit width			
	Rank = 5	Rank = 6	Rank =7	Rank =8
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	4	4	4	4
Subband differential CQI codeword 1	$2N$	$2N$	$2N$	$2N$
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Wideband second PMI i2	0	0	0	0

Table 5.2.2.6.2-2B-3: Fields for channel quality information feedback for higher layer configured subband CQI reports (transmission mode 9/10 configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with 2/4/8 antenna ports with K=1 and *alternativeCodebookEnabledCLASSB_K1=TRUE*)

Petitioners' Exhibit 1003, p. 1338
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Field	Bit width					
	2 antenna ports		4 antenna ports			
	Rank = 1	Rank = 2	Rank = 1	Rank =2	Rank =3	Rank =4
Wideband CQI codeword 0	4	4	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	0	$2N$	$2N$	$2N$
Precoding matrix indicator	2	1	3	3	2	1

Field	Bit width				
	8 antenna ports				
	Rank = 1	Rank = 2	Rank = 3	Rank =4	Rank =5 to Rank = 8
Wideband CQI codeword 0	4	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$	$2N$
Precoding matrix indicator	4	4	4	3	0

Table 5.2.2.6.2-2C, Table 5.2.2.6.2-2D and Table 5.2.2.6.2-2E show the fields and the corresponding bit widths for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 4, transmission mode 6, transmission mode 8 configured with subband PMI/RI reporting, transmission mode 9 configured with subband PMI/RI reporting with 2/4/8 antenna ports, transmission mode 10 configured with subband PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 9/10 configured with subband PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1 and K=1 except with *alternativeCodebookEnabledCLASSB_K1=TRUE*. The number of configured CSI-RS resources in a CSI process K is defined in [3] and *alternativeCodebookEnabledCLASSB_K1* is configured by higher layers [6].

Table 5.2.2.6.2-2E-1 and Table 5.2.2.6.2-2E-2 show the fields and the corresponding bit widths for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 9/10 configured with subband PMI/RI reporting with 8/12/16 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A".

Table5.2.2.6.2-2E-3 shows the fields and the corresponding bit widths for the channel quality information feedback for higher layer configured report for PDSCH transmissions associated with transmission mode 9/10 configured with subband PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and *alternativeCodebookEnabledCLASSB_K1=TRUE*.

For Table 5.2.2.6.2-2C, Table 5.2.2.6.2-2D, Table 5.2.2.6.2-2E, Table 5.2.2.6.2-2E-1, Table 5.2.2.6.2-2E-2 and Table 5.2.2.6.2-2E-3, N is defined in section 7.2 of [3]. For 5.2.2.6.2-2E-1 and Table 5.2.2.6.2-2E-2, the codebook configuration (N_1, N_2, O_1, O_2) is defined in [3], and *CodebookConfig* is configured by higher layers [6]. The parameters (S_1, S_2) in rank 3 and 4 are defined as $(S_1, S_2) = (1,1)$ for *CodebookConfig*=1, $(S_1, S_2) = \left(\frac{O_1}{2}, \frac{O_2}{2}\right)$ for *CodebookConfig*=2, $(S_1, S_2) = \left(O_1, \frac{O_2}{2}\right)$ for *CodebookConfig*=3, $(S_1, S_2) = \left(O_1, \frac{O_2}{4}\right)$ for *CodebookConfig*=4. The parameters (S_1, S_2) in rank 5 to 8 are defined as $(S_1, S_2) = (1,1)$ for *CodebookConfig*=1, $(S_1, S_2) = \left(\frac{O_1}{4}, \frac{O_2}{4}\right)$ for *CodebookConfig*=2/3/4.

Table 5.2.2.6.2-2C: Fields for channel quality information feedback for higher layer configured subband CQI and subband PMI reports
(transmission mode 4 and transmission mode 6 configured with subband PMI reporting, transmission mode 8 configured with subband PMI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 9 and transmission 10 configured with subband PMI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with subband PMI/RI reporting with 2/4 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with

Petitioners' Exhibit 1003, p. 1339
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

K>1, and K=1 except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*).

Field	Bit width					
	2 antenna ports		4 antenna ports			
	Rank = 1	Rank = 2	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wide-band CQI codeword 0	4	4	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$	$2N$	$2N$
Wide-band CQI codeword 1	0	4	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	0	$2N$	$2N$	$2N$
Subband precoding matrix indicator	$2N$	N	$4N$	$4N$	$4N$	$4N$

Table 5.2.2.6.2-2D: Fields for channel quality information feedback for higher layer configured subband CQI and subband PMI reports with 8 antenna ports (transmission mode 9 configured with subband PMI reporting, transmission mode 10 configured with subband PMI reporting, and transmission mode 9/10 configured with subband PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and K=1 except with *alternativeCodebookEnabledCLASSB_K1=TRUE*)

Field	Bitwidth			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1	4	4	2	2
Subband second PMI i2	$4N$	$4N$	$4N$	$3N$
Field	**Bitwidth**			
	Rank = 5	Rank = 6	Rank = 7	Rank = 8
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	4	4	4	4
Subband differential CQI codeword 1	$2N$	$2N$	$2N$	$2N$
Wideband first PMI i1	2	2	2	0
Subband second PMI i2	0	0	0	0

Table 5.2.2.6.2-2E: Fields for channel quality information feedback for higher layer configured subband CQI and subband PMI reports with 4 antenna ports (transmission modes 8, 9 and 10 configured with subband PMI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 9/10 configured with subband PMI/RI reporting with 2/4 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and K=1 with except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bitwidth			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4

Petitioners' Exhibit 1003, p. 1340
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1	4	4	0	0
Subband second PMI i2	$4N$	$4N$	$4N$	$4N$

Table 5.2.2.6.2-2E-1: Fields for channel quality information feedback for higher layer configured subband CQI reports and subband PMI reports (transmission mode 9/10 configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A" with codebook configuration (N_1, N_2, O_1, O_2) and *CodebookConfig*=1)

Field	Bitwidth			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1,1	$\lceil \log_2(N_1 O_1) \rceil$	$\lceil \log_2(N_1 O_1) \rceil$	$\left\lceil \log_2\left(\frac{N_1 O_1}{S_1}\right)\right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$	$\left\lceil \log_2\left(\frac{N_1 O_1}{S_1}\right)\right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$
Wideband first PMI i1,2	$\lceil \log_2(N_2 O_2) \rceil$	$\lceil \log_2(N_2 O_2) \rceil$	$\lceil \log_2(N_2 O_2) \rceil$	$\lceil \log_2(N_2 O_2) \rceil$
Subband second PMI i2	$2N$	$2N$	N	N
Field	**Bitwidth**			
	Rank = 5	**Rank = 6**	**Rank = 7**	**Rank = 8**
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	4	4	4	4
Subband differential CQI codeword 1	$2N$	$2N$	$2N$	$2N$

Petitioners' Exhibit 1003, p. 1341
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Subband second PMI i2	0	0	0	0

Table 5.2.2.6.2-2E-2: Fields for channel quality information feedback for higher layer configured subband CQI reports and subband PMI reports (transmission mode 9/10 configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A" with codebook configuration (N_1, N_2, O_1, O_2) and *CodebookConfig*=2/3/4)

Field	Bitwidth			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wideband CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/2) \rceil$	$\lceil \log_2(N_1O_1/2) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/2) \rceil$	$\lceil \log_2(N_2O_2/2) \rceil$	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right) \right\rceil$	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right) \right\rceil$
Subband second PMI i2	$4N$	$4N$	$4N$	$3N$
Field	**Bitwidth**			
	Rank = 5	**Rank = 6**	**Rank = 7**	**Rank = 8**
Wideband CQI codeword 0	4	4	4	4
Subband differential	$2N$	$2N$	$2N$	$2N$

Petitioners' Exhibit 1003, p. 1342
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

CQI codeword 0				
Wideband CQI codeword 1	4	4	4	4
Subband differential CQI codeword 1	$2N$	$2N$	$2N$	$2N$
Wideband first PMI i1,1	$\lceil \log_2 (N_1 O_1 / S_1) \rceil$	$\lceil \log_2 (N_1 O_1 / S_1) \rceil$	$\lceil \log_2 (N_1 O_1 / S_1) \rceil$	$\lceil \log_2 (N_1 O_1 / S_1) \rceil$
Wideband first PMI i1,2	$\lceil \log_2 (N_2 O_2 / S_2) \rceil$	$\lceil \log_2 (N_2 O_2 / S_2) \rceil$	$\lceil \log_2 (N_2 O_2 / S_2) \rceil$	$\lceil \log_2 (N_2 O_2 / S_2) \rceil$
Subband second PMI i2	0	0	0	0

Table 5.2.2.6.2-2E-3: Fields for channel quality information feedback for higher layer configured subband CQI reports and subband PMI reports (transmission mode 9/10 configured and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with 2/4/8 antenna ports with K=1 and *alternativeCodebookEnabledCLASSB_K1=TRUE*)

Field	**Bit width**					
	2 antenna ports		**4 antenna ports**			
	Rank = 1	**Rank = 2**	**Rank = 1**	**Rank =2**	**Rank =3**	**Rank =4**
Wideband CQI codeword 0	4	4	4	4	4	4
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$	$2N$	$2N$
Wideband CQI codeword 1	0	4	0	4	4	4
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$	$2N$	$2N$
Precoding matrix indicator	$2N$	N	$3N$	$3N$	$2N$	N
Field	**Bit width**					
	8 antenna ports					
	Rank = 1	**Rank = 2**	**Rank = 3**	**Rank =4**	**Rank = 5 to Rank = 8**	
Wideband CQI codeword 0	4	4	4	4	4	
Subband differential CQI codeword 0	$2N$	$2N$	$2N$	$2N$	$2N$	
Wideband CQI codeword 1	0	4	4	4	4	
Subband differential CQI codeword 1	0	$2N$	$2N$	$2N$	$2N$	
Precoding matrix indicator	$4N$	$4N$	$4N$	$3N$	0	

Table 5.2.2.6.2-3 shows the fields and the corresponding bit width for the rank indication feedback for higher layer configured subband CQI reports for PDSCH transmissions associated with transmission mode 3, transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1, transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A", and transmission mode 9/10 configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 with 2/4/8 antenna ports.

Petitioners' Exhibit 1003, p. 1343
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.2.2.6.2-3A shows the fields and the corresponding bit width for the CSI-RS resource indication feedback for higher layer configured subband CQI reports for PDSCH transmissions associated with transmission mode 9/10 configured with 1 antenna port for each CSI-RS resource and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1.

Table 5.2.2.6.2-3B shows the fields and the corresponding bit width for the joint CRI and RI feedback for higher layer configured subband CQI reports for PDSCH transmissions associated with transmission mode 9/10 configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1 and 2/4/8 antenna ports.

Table 5.2.2.6.2-3: Fields for rank indication feedback for higher layer configured subband CQI reports (transmission mode 3, transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1, transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A", and transmission mode 9/10 configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 with 2/4/8 antenna ports).

Field	Bit width					
	2 antenna ports	4 antenna ports		8/12/16 antenna ports		
		Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers	Max 8 layers
Rank indication	1	1	2	1	2	3

Table 5.2.2.6.2-3A: Fields for CRI feedback for higher layer configured subband CQI reports (transmission mode 9/10 configured with 1 antenna port for each CSI-RS resource and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1).

Field	Bit width		
	K = 2	K = 3 and K = 4	K = 5 to K = 8
CRI	1	2	3

Table 5.2.2.6.2-3B: Fields for joint CRI and RI feedback for higher layer configured subband CQI reports (transmission mode 9/10 configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1 and 2/4/8 antenna ports).

Field	Bit width					
	2 antenna ports	4 antenna ports		8 antenna ports		
		Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers	Max 8 layers
CRI	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$
Rank indication	1	1	2	1	2	3

The channel quality bits in Table 5.2.2.6.2-1, Table 5.2.2.6.2-2, Table 5.2.2.6.2-2A, Table 5.2.2.6.2-2B, Table 5.2.2.6.2-2C, Table 5.2.2.6.2-2D, Table 5.2.2.6.2-2E, Table 5.2.2.6.2-2B-1, Table 5.2.2.6.2-2B-2, Table 5.2.2.6.2-2B-3, Table 5.2.2.6.2-2E-1, Table 5.2.2.6.2-2E-2, Table 5.2.2.6.2-2E-3, and Table 5.2.2.6.2-3B form the bit sequence $o_0, o_1, o_2, ..., o_{O-1}$ with o_0 corresponding to the first bit of the first field in each of the tables, o_1 corresponding to the second bit of the first field in each of the tables, and o_{O-1} corresponding to the last bit in the last field in each of the tables. The field of the PMI and subband differential CQI shall be in the increasing order of the subband index [3]. The first bit of each field corresponds to MSB and the last bit LSB. The RI bits sequence in Table 5.2.2.6.2-3, 5.2.2.6.2-3B and the CRI sequence in Table 5.2.2.6.2-3A are encoded according to section 5.2.2.6.

Petitioners' Exhibit 1003, p. 1344
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

For transmission mode 9/10 configured with Class B CSI reporting and K>1, the number of antenna port in Table 5.2.2.6.2-3B refers to the maximum number of antenna ports of K CSI-RS resources configured for the CSI-process for the UE.

5.2.2.6.3 Channel quality information formats for UE selected subband CQI reports

Table 5.2.2.6.3-1 shows the fields and the corresponding bit widths for the channel quality information feedback for UE selected subband CQI for PDSCH transmissions associated with transmission mode 1, transmission mode 2, transmission mode 3, transmission mode 7, transmission mode 8 configured without PMI/RI reporting, transmission mode 9 configured without PMI/RI reporting or configured with 1 antenna port, and transmission mode 10 configured without PMI/RI reporting or configured with 1 antenna port. L in Table 5.2.2.6.3-1 is defined in section 7.2 of [3].

Table 5.2.2.6.3-1A shows the fields and the corresponding bit widths for the channel quality information feedback for UE selected subband CQI for PDSCH transmissions associated with transmission mode 9/10 configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with 2/4/8 antenna ports.

Table 5.2.2.6.3-1: Fields for channel quality information feedback for UE selected subband CQI reports (transmission mode 1, transmission mode 2, transmission mode 3, transmission mode 7, transmission mode 8 configured without PMI/RI reporting, transmission mode 9 configured without PMI/RI reporting or configured with 1 antenna port, and transmission mode 10 configured without PMI/RI reporting or configured with 1 antenna port)

Field	Bit width
Wide-band CQI codeword	4
Subband differential CQI	2
Position of the M selected subbands	L

Table 5.2.2.6.3-1A Fields for channel quality information feedback for UE selected subband CQI reports (transmission mode 9/10 configured without PMI reporting **and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B"** with 2/4/8 antenna ports)

Field	Bit width	
	Rank = 1	Rank >1
Wide-band CQI codeword 0	4	4
Subband differential CQI codeword 0	2	2
Wide-band CQI codeword 1	0	4
Subband differential CQI codeword 1	0	2
Position of the M selected subbands	L	L

Table 5.2.2.6.3-2, Table 5.2.2.6.3-2A and Table 5.2.2.6.3-2B show the fields and the corresponding bit widths for the channel quality information feedback for UE selected subband CQI for PDSCH transmissions associated with transmission mode 4, transmission mode 6, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna port, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1 and K=1 except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, where the number of configured CSI-RS resources in a CSI process K is defined in [3] and *alternativeCodebookEnabledCLASSB_K1* is configured by higher layers [6].

Table 5.2.2.6.3-2C and Table 5.2.2.6.3-2D show the fields and the corresponding bit widths for the channel quality information feedback for UE selected subband CQI for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A".

Table 5.2.2.6.3-2E shows the fields and the corresponding bit widths for the channel quality information feedback for UE selected subband CQI for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and *alternativeCodebookEnabledCLASSB_K1=TRUE*.

For Table 5.2.2.6.3-2, Table 5.2.2.6.3-2A, Table 5.2.2.6.3-2B, Table 5.2.2.6.3-2C, Table 5.2.2.6.3-2D and Table 5.2.2.6.3-2E, L is defined in section 7.2 of [3]. For Table 5.2.2.6.3-2C and Table 5.2.2.6.3-2D, the codebook

Petitioners' Exhibit 1003, p. 1345
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

configuration (N_1, N_2, O_1, O_2) is defined in [3], and *CodebookConfig* is configured by higher layers [6]. The parameters (S_1, S_2) in rank 3 and 4 are defined as $(S_1, S_2) = (1,1)$ for *CodebookConfig*=1, $(S_1, S_2) = \left(\frac{O_1}{2}, \frac{O_2}{2}\right)$ for *CodebookConfig*=2, $(S_1, S_2) = \left(O_1, \frac{O_2}{2}\right)$ for *CodebookConfig*=3, $(S_1, S_2) = \left(O_1, \frac{O_2}{4}\right)$ for *CodebookConfig*=4. The parameters (S_1, S_2) in rank 5 to 8 are defined as $(S_1, S_2) = (1,1)$ for *CodebookConfig*=1, $(S_1, S_2) = \left(\frac{O_1}{4}, \frac{O_2}{4}\right)$ for *CodebookConfig*=2/3/4.

Table 5.2.2.6.3-2: Fields for channel quality information feedback for UE selected subband CQI reports (transmission mode 4, transmission mode 6, transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 9 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 10 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 2/4 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and K=1 except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	2 antenna ports		4 antenna ports	
	Rank = 1	Rank = 2	Rank = 1	Rank > 1
Wide-band CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	2	2	2	2
Wide-band CQI codeword 1	0	4	0	4
Subband differential CQI codeword 1	0	2	0	2
Position of the M selected subbands	*L*	*L*	*L*	*L*
Precoding matrix indicator	4	2	8	8

Table 5.2.2.6.3-2A: Fields for channel quality information feedback for UE selected subband CQI reports (transmission mode 9 configured with PMI/RI reporting with 8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and K=1 except with *alternativeCodebookEnabledCLASSB_K1=TRUE*).

Field	Bit width							
	Rank = 1	Rank = 2	Rank = 3	Rank = 4	Rank = 5	Rank = 6	Rank = 7	Rank = 8
Wide-band CQI codeword 0	4	4	4	4	4	4	4	4
Subband differential CQI codeword 0	2	2	2	2	2	2	2	2
Wide-band CQI codeword 1	0	4	4	4	4	4	4	4
Subband differential CQI codeword 1	0	2	2	2	2	2	2	2
Position of the M selected subbands	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*L*
Wideband first PMI i1	4	4	2	2	2	2	2	0
Wideband second PMI i2	4	4	4	3	0	0	0	0

Petitioners' Exhibit 1003, p. 1346
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Subband second PMI i2	4	4	4	3	0	0	0	0

Table 5.2.2.6.3-2B: Fields for channel quality information feedback for UE selected subband CQI reports with 4 antenna ports (transmission modes 8, 9 and 10 configured with PMI/RI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE,* and transmission mode 9/10 configured with PMI/RI reporting with 4 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and K=1 except with *alternativeCodebookEnabledCLASSB_K1=TRUE,* with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wide-band CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	2	2	2	2
Wide-band CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	2	2	2
Position of the M selected subbands	L	L	L	L
Wideband first PMI i1	4	4	0	0
Wideband second PMI i2	4	4	4	4
Subband second PMI i2	4	4	4	4

Table 5.2.2.6.3-2C: Fields for channel quality information feedback for UE selected subband CQI reports (transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A" with codebook configuration (N_1, N_2, O_1, O_2) and *CodebookConfig*=1)

Field	Bit width			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wide-band CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	2	2	2	2
Wide-band CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	2	2	2
Position of the M selected subbands	L	L	L	L

Petitioners' Exhibit 1003, p. 1347
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Wideband first PMI i1,1	$\lceil \log_2(N_1O_1) \rceil$	$\lceil \log_2(N_1O_1) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2) \rceil$	$\lceil \log_2(N_2O_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Wideband second PMI i2	2	2	1	1
Subband second PMI i2	2	2	1	1
Field	Bit width			
	Rank = 5	Rank = 6	Rank = 7	Rank = 8
Wide-band CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	2	2	2	2
Wide-band CQI codeword 1	4	4	4	4
Subband differential CQI codeword 1	2	2	2	2
Position of the M selected subbands	L	L	L	L
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$	$\lceil \log_2(N_1O_1/S_1) \rceil$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Wideband second PMI i2	0	0	0	0
Subband second PMI i2	0	0	0	0

Table 5.2.2.6.3-2D: Fields for channel quality information feedback for UE selected subband CQI reports (transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A" with codebook configuration (N_1, N_2, O_1, O_2) and *CodebookConfig*=2/3/4)

Field	Bit width			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wide-band CQI codeword	4	4	4	4

Petitioners' Exhibit 1003, p. 1348
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

0				
Subband differential CQI codeword 0	2	2	2	2
Wide-band CQI codeword 1	0	4	4	4
Subband differential CQI codeword 1	0	2	2	2
Position of the M selected subbands	L	L	L	L
Wideband first PMI i1,1	$\lceil \log_2(N_1O_1/2) \rceil$	$\lceil \log_2(N_1O_1/2) \rceil$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right)\right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right)\right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$
Wideband first PMI i1,2	$\lceil \log_2(N_2O_2/2) \rceil$	$\lceil \log_2(N_2O_2/2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$	$\lceil \log_2(N_2O_2/S_2) \rceil$
Wideband second PMI i2	4	4	4	3
Subband second PMI i2	4	4	4	3
Field	Bit width			
	Rank = 5	Rank = 6	Rank = 7	Rank = 8
Wide-band CQI codeword 0	4	4	4	4
Subband differential CQI codeword 0	2	2	2	2
Wide-band CQI codeword 1	4	4	4	4
Subband differential CQI	2	2	2	2

Petitioners' Exhibit 1003, p. 1349
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

codeword 1				
Position of the M selected subbands	L	L	L	L
Wideband first PMI i1,1	$\lceil \log_2 (N_1 O_1 / S_1) \rceil$	$\lceil \log_2 (N_1 O_1 / S_1) \rceil$	$\lceil \log_2 (N_1 O_1 / S_1) \rceil$	$\lceil \log_2 (N_1 O_1 / S_1) \rceil$
Wideband first PMI i1,2	$\lceil \log_2 (N_2 O_2 / S_2) \rceil$	$\lceil \log_2 (N_2 O_2 / S_2) \rceil$	$\lceil \log_2 (N_2 O_2 / S_2) \rceil$	$\lceil \log_2 (N_2 O_2 / S_2) \rceil$
Wideband second PMI i2	0	0	0	0
Subband second PMI i2	0	0	0	0

Table 5.2.2.6.3-2E: Fields for channel quality information feedback for UE selected subband CQI reports (transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and *alternativeCodebookEnabledCLASSB_K1=TRUE*)

Field	**Bit width**					
	2 antenna ports		**4 antenna ports**			
	Rank = 1	**Rank = 2**	**Rank = 1**	**Rank =2**	**Rank =3**	**Rank =4**
Wideband CQI codeword 0	4	4	4	4	4	4
Subband differential CQI codeword 0	2	2	2	2	2	2
Wideband CQI codeword 1	0	4	0	4	4	4
Subband differential CQI codeword 1	0	2	2	2	2	2
Position of the M selected subbands	L	L	L	L	L	L
Wideband Precoding matrix indicator	2	1	3	3	2	1
Subband Precoding matrix indicator	2	1	3	3	2	1
Field	**Bit width**					
	8 antenna ports					
	Rank = 1	**Rank = 2**	**Rank = 3**	**Rank =4**	**Rank =5~8**	
Wideband CQI codeword 0	4	4	4	4	4	
Subband differential CQI codeword 0	2	2	2	2	2	
Wideband CQI codeword 1	0	4	4	4	4	
Subband differential CQI codeword 1	0	2	2	2	2	
Position of the M selected subbands	L	L	L	L	L	
Wideband Precoding matrix indicator	4	4	4	3	0	
Subband Precoding matrix indicator	4	4	4	3	0	

Table 5.2.2.6.3-3 shows the fields and the corresponding bit widths for the rank indication feedback for UE selected subband CQI reports for PDSCH transmissions associated with transmission mode 3, transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1, transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A", and transmission mode 9/10 configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 with with 2/4/8 antenna ports.

Table 5.2.2.6.3-3A shows the fields and the corresponding bit widths for the CSI-RS resource indication feedback for UE selected subband CQI reports for PDSCH transmissions associated with transmission mode 9/10 configured with 1

Petitioners' Exhibit 1003, p. 1350
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

antenna port for each CSI-RS resource and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1.

Table 5.2.2.6.3-3B shows the fields and the corresponding bit widths for the joint CRI and RI feedback for UE selected subband CQI report for PDSCH transmissions associated with transmission mode 9/10 configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1 and 2/4/8 antenna ports.

Table 5.2.2.6.3-3: Fields for rank indication feedback for UE selected subband CQI reports (transmission mode 3, transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports and transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1, transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A", and transmission mode 9/10 configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 with with 2/4/8 antenna ports).

Field	Bit width					
	2 antenna ports	4 antenna ports		8/12/16 antenna ports		
		Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers	Max 8 layers
Rank indication	1	1	2	1	2	3

Table 5.2.2.6.3-3A: Fields for CSI-RS resource indication feedback for UE selected subband CQI reports (transmission mode 9/10 configured with 1 antenna port for each CSI-RS resource and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1).

Field	Bit width		
	K = 2	K = 3 and K= 4	K = 5 to K = 8
CRI	1	2	3

Table 5.2.2.6.3-3B: Fields for joint CRI and RI feedback for UE selected subband CQI report (transmission mode 9/10 configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1 and 2/4/8 antenna ports).

Field	Bit width					
	2 antenna ports	4 antenna ports		8 antenna ports		
		Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers	Max 8 layers
CRI	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$
Rank indication	1	1	2	1	2	3

The channel quality bits in Table 5.2.2.6.3-1, Table 5.2.2.6.3-2, Table 5.2.2.6.3-2A, Table 5.2.2.6.3-2B, Table 5.2.2.6.3-2C, Table 5.2.2.6.3-2D, Table 5.2.2.6.3-2E, and Table 5.2.2.6.3-3B form the bit sequence $o_0, o_1, o_2, ..., o_{O-1}$ with o_0 corresponding to the first bit of the first field in each of the tables, o_1 corresponding to the second bit of the first field in each of the tables, and o_{O-1} corresponding to the last bit in the last field in each of the tables. The field of PMI shall start with the wideband PMI followed by the PMI for the M selected subbands. The first bit of each field corresponds to MSB and the last bit LSB. The RI bits sequence in Table 5.2.2.6.3-3, Table 5.2.2.6.3-3B, and the CRI sequence in Table 5.2.2.6.3-3A are encoded according to section 5.2.2.6.

For transmission mode 9/10 configured with Class B CSI reporting and K>1, the number of antenna port in Table 5.2.2.6.3-3B refers to the maximum number of antenna ports of K CSI-RS resources configured for the CSI-process for the UE.

Petitioners' Exhibit 1003, p. 1351
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.2.2.6.4 Channel coding for CQI/PMI information in PUSCH

The channel quality bits input to the channel coding block are denoted by $o_0, o_1, o_2, o_3, ..., o_{O-1}$ where O is the number of bits. The number of channel quality bits depends on the transmission format. When PUCCH-based reporting format is used, the number of CQI/PMI bits is defined in section 5.2.3.3.1 for wideband reports and in section 5.2.3.3.2 for UE selected subbands reports. When PUSCH-based reporting format is used, the number of CQI/PMI bits is defined in section 5.2.2.6.1 for wideband reports, in section 5.2.2.6.2 for higher layer configured subbands reports and in section 5.2.2.6.3 for UE selected subbands reports.

The channel quality information is first coded using a (32, O) block code. The code words of the (32, O) block code are a linear combination of the 11 basis sequences denoted $M_{i,n}$ and defined in Table 5.2.2.6.4-1.

Table 5.2.2.6.4-1: Basis sequences for (32, O) code.

i	$M_{i,0}$	$M_{i,1}$	$M_{i,2}$	$M_{i,3}$	$M_{i,4}$	$M_{i,5}$	$M_{i,6}$	$M_{i,7}$	$M_{i,8}$	$M_{i,9}$	$M_{i,10}$
0	1	1	0	0	0	0	0	0	0	0	1
1	1	1	1	0	0	0	0	0	0	1	1
2	1	0	0	1	0	0	1	0	1	1	1
3	1	0	1	1	0	0	0	0	1	0	1
4	1	1	1	1	0	0	0	1	0	0	1
5	1	1	0	0	1	0	1	1	1	0	1
6	1	0	1	0	1	0	1	0	1	1	1
7	1	0	0	1	1	0	0	1	1	0	1
8	1	1	0	1	1	0	0	1	0	1	1
9	1	0	1	1	1	0	1	0	0	1	1
10	1	0	1	0	0	1	1	1	0	1	1
11	1	1	1	0	0	1	1	0	1	0	1
12	1	0	0	1	0	1	0	1	1	1	1
13	1	1	0	1	0	1	0	1	0	1	1
14	1	0	0	0	1	1	0	1	0	0	1
15	1	1	0	0	1	1	1	1	0	1	1
16	1	1	1	0	1	1	1	0	0	1	0
17	1	0	0	1	1	1	0	0	1	0	0
18	1	1	0	1	1	1	1	1	0	0	0
19	1	0	0	0	0	1	1	0	0	0	0
20	1	0	1	0	0	0	1	0	0	0	1
21	1	1	0	1	0	0	0	0	0	1	1
22	1	0	0	0	1	0	0	1	1	0	1
23	1	1	1	0	1	0	0	0	1	1	1
24	1	1	1	1	1	0	1	1	1	1	0
25	1	1	0	0	0	1	1	1	0	0	1
26	1	0	1	1	0	1	0	0	1	1	0
27	1	1	1	1	0	1	0	1	1	1	0
28	1	0	1	0	1	1	1	0	1	0	0
29	1	0	1	1	1	1	1	1	1	0	0
30	1	1	1	1	1	1	1	1	1	1	1
31	1	0	0	0	0	0	0	0	0	0	0

The encoded CQI/PMI block is denoted by $b_0, b_1, b_2, b_3, ..., b_{B-1}$ where $B = 32$ and

$$b_i = \sum_{n=0}^{O-1} \left(o_n \cdot M_{i,n} \right) \bmod 2 \text{ where } i = 0, 1, 2, \ldots, B\text{-}1.$$

The output bit sequence $q_0, q_1, q_2, q_3, ..., q_{N_L \cdot Q_{CQI}-1}$ is obtained by circular repetition of the encoded CQI/PMI block as follows

$q_i = b_{(i \bmod B)}$ where $i = 0, 1, 2, \ldots, N_L \cdot Q_{CQI}\text{-}1$, where N_L is the number of layers the corresponding UL-SCH transport block is mapped onto .

Petitioners' Exhibit 1003, p. 1352
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.2.2.6.5 Channel coding for more than 11 bits of HARQ-ACK information

The HARQ-ACK bits input to the channel coding block are denoted by $o_0^{ACK}\ o_1^{ACK},...,o_{O^{ACK}-1}^{ACK}$ where $11 < O^{ACK} \le 22$ is the number of bits.

The sequences of bits $o_0^{ACK}, o_1^{ACK}, o_2^{ACK},..., o_{\lceil O^{ACK}/2 \rceil - 1}^{ACK}$ and $o_{\lceil O^{ACK}/2 \rceil}^{ACK}, o_{\lceil O^{ACK}/2 \rceil + 1}^{ACK}, o_{\lceil O^{ACK}/2 \rceil + 2}^{ACK},..., o_{O^{ACK}-1}^{ACK}$ are encoded as follows

$$\tilde{q}_i = \left(\sum_{n=0}^{\lceil O^{ACK}/2 \rceil - 1} o_n^{ACK} \cdot M_{i,n} \right) \bmod 2$$

and

$$\tilde{\tilde{q}}_i = \left(\sum_{n=0}^{O^{ACK} - \lceil O^{ACK}/2 \rceil - 1} o_{\lceil O^{ACK}/2 \rceil + n}^{ACK} \cdot M_{i,n} \right) \bmod 2$$

where i = 0, 1, 2, …, 31 and the basis sequences $M_{i,n}$ are defined in Table 5.2.2.6.4-1.

The output bit sequence $q_0^{ACK}, q_1^{ACK}, q_2^{ACK},..., q_{Q_{ACK}-1}^{ACK}$ is obtained by the concatenation and circular repetition of the bit sequences $\tilde{q}_0, \tilde{q}_1, \tilde{q}_2,..., \tilde{q}_{31}$ and $\tilde{\tilde{q}}_0, \tilde{\tilde{q}}_1, \tilde{\tilde{q}}_2,..., \tilde{\tilde{q}}_{31}$ as follows:

Set i = 0

while $i < \lceil Q'/2 \rceil \cdot Q_m$

$q_i^{ACK} = \tilde{q}_{i \bmod 32}$

$i = i + 1$

end while

Set i = 0

while $i < (Q' - \lceil Q'/2 \rceil) \cdot Q_m$

$q_{\lceil Q'/2 \rceil \cdot Q_m + i}^{ACK} = \tilde{\tilde{q}}_{i \bmod 32}$

$i = i + 1$

end while

5.2.2.7 Data and control multiplexing

The control and data multiplexing is performed such that HARQ-ACK information is present on both slots and is mapped to resources around the demodulation reference signals. In addition, the multiplexing ensures that control and data information are mapped to different modulation symbols.

The inputs to the data and control multiplexing are the coded bits of the control information denoted by $q_0, q_1, q_2, q_3,..., q_{N_L \cdot Q_{CQI} - 1}$ and the coded bits of the UL-SCH denoted by $f_0, f_1, f_2, f_3,..., f_{G-1}$. The output of the data and control multiplexing operation is denoted by $\underline{g}_0, \underline{g}_1, \underline{g}_2, \underline{g}_3,..., \underline{g}_{H'-1}$, where $H = (G + N_L \cdot Q_{CQI})$ and $H' = H / (N_L \cdot Q_m)$, and where $\underline{g}_i$, $i = 0,..., H'-1$ are column vectors of length $(Q_m \cdot N_L)$. H is the total number of coded bits allocated for UL-SCH data and CQI/PMI information across the N_L transmission layers of the transport block.

Petitioners' Exhibit 1003, p. 1353
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

In case where more than one UL-SCH transport block are transmitted in a subframe of an UL cell, the CQI/PMI information is multiplexed with data only on the UL-SCH transport block with highest I_{MCS} value on the initial grant. In case the two transport blocks have the same I_{MCS} value in the corresponding initial UL grant, the CQI/PMI information is multiplexed with data only on the first transport block. For that UL-SCH transport block or in the case of single transport block transmission, and assuming that N_L is the number of layers onto which the UL-SCH transport block is mapped, the control information and the data shall be multiplexed as follows:

Set *i*, *j*, *k* to 0

while $j < N_L.Q_{CQI}$ -- first place the control information

$\underline{g}_k = [q_j \ldots q_{j+N_L \cdot Q_m - 1}]^T$

$j = j + N_L \cdot Q_m$

$k = k + 1$

end while

while $i < G$ -- then place the data

$\underline{g}_k = [f_i \ldots f_{i+Q_m \cdot N_L - 1}]^T$

$i = i + Q_m \cdot N_L$

$k = k + 1$

end while

5.2.2.8 Channel interleaver

The channel interleaver described in this section in conjunction with the resource element mapping for PUSCH in [2] implements a time-first mapping of modulation symbols onto the transmit waveform while ensuring that the HARQ-ACK and RI information are present on both slots in the subframe. HARQ-ACK information is mapped to resources around the uplink demodulation reference signals while RI information is mapped to resources around those used by HARQ-ACK.

The input to the channel interleaver are denoted by $\underline{g}_0, \underline{g}_1, \underline{g}_2, \ldots, \underline{g}_{H'-1}$, $\underline{q}_0^{RI}, \underline{q}_1^{RI}, \underline{q}_2^{RI}, \ldots, \underline{q}_{Q'_{RI}-1}^{RI}$ and $\underline{q}_0^{ACK}, \underline{q}_1^{ACK}, \underline{q}_2^{ACK}, \ldots, \underline{q}_{Q'_{ACK}-1}^{ACK}$. In case where more than one UL-SCH transport block are transmitted in a subframe of an UL cell, the HARQ-ACK and RI information are multiplexed with data on both UL-SCH transport blocks.

The number of modulation symbols per layer in the subframe is given by $H'_{total} = H' + Q'_{RI}$. The output bit sequence from the channel interleaver is derived as follows:

(1) Assign $C_{mux} = N_{\text{symb}}^{\text{PUSCH}}$ to be the number of columns of the matrix. The columns of the matrix are numbered 0, 1, 2,…, $C_{mux} - 1$ from left to right. $N_{\text{symb}}^{\text{PUSCH}}$ is determined according to section 5.2.2.6.

(2) The number of rows of the matrix is $R_{mux} = \left(H'_{total} \cdot Q_m \cdot N_L\right) / C_{mux}$ and we define $R'_{mux} = R_{mux} / \left(Q_m \cdot N_L\right)$.

The rows of the rectangular matrix are numbered 0, 1, 2,…, $R_{mux} - 1$ from top to bottom.

(3) If rank information is transmitted in this subframe, the vector sequence $\underline{q}_0^{RI}, \underline{q}_1^{RI}, \underline{q}_2^{RI}, \ldots, \underline{q}_{Q'_{RI}-1}^{RI}$ is written onto the columns indicated by Table 5.2.2.8-1, and by sets of $\left(Q_m \cdot N_L\right)$ rows starting from the last row and moving upwards according to the following pseudo-code.

Set *i*, *j* to 0.

Petitioners' Exhibit 1003, p. 1354
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Set r to $R'_{mux} - 1$

while $i < Q'_{RI}$

$c_{RI} = \text{Column Set}(j)$

$\underline{y}_{r \times C_{mux} + c_{RI}} = \underline{q}_i^{RI}$

$i = i + 1$

$r = R'_{mux} - 1 - \lfloor i/4 \rfloor$

$j = (j + 3) \bmod 4$

end while

Where ColumnSet is given in Table 5.2.2.8-1 and indexed left to right from 0 to 3.

(4) Write the input vector sequence, for k = 0, 1,…, $H' - 1$, into the $(R_{mux} \times C_{mux})$ matrix by sets of $(Q_m \cdot N_L)$ rows starting with the vector $\underline{y}_0$ in column 0 and rows 0 to $(Q_m \cdot N_L - 1)$ and skipping the matrix entries that are already occupied:

$$\begin{bmatrix} \underline{y}_0 & \underline{y}_1 & \underline{y}_2 & \cdots & \underline{y}_{C_{mux}-1} \\ \underline{y}_{C_{mux}} & \underline{y}_{C_{mux}+1} & \underline{y}_{C_{mux}+2} & \cdots & \underline{y}_{2C_{mux}-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \underline{y}_{(R'_{mux}-1)\times C_{mux}} & \underline{y}_{(R'_{mux}-1)\times C_{mux}+1} & \underline{y}_{(R'_{mux}-1)\times C_{mux}+2} & \cdots & \underline{y}_{(R'_{mux}\times C_{mux}-1)} \end{bmatrix}$$

The pseudocode is as follows:

Set i, k to 0.

while k < H',

if $\underline{y}_i$ is not assigned to RI symbols

$\underline{y}_i = \underline{g}_k$

k = k + 1

end if

i = i+1

end while

(5) If HARQ-ACK information is transmitted in this subframe, the vector sequence $\underline{q}_0^{ACK}, \underline{q}_1^{ACK}, \underline{q}_2^{ACK}, ..., \underline{q}_{Q'_{ACK}-1}^{ACK}$ is written onto the columns indicated by Table 5.2.2.8-2, and by sets of $(Q_m \cdot N_L)$ rows starting from the last row and moving upwards according to the following pseudo-code. Note that this operation overwrites some of the channel interleaver entries obtained in step (4).

Set i, j to 0.

Set r to $R'_{mux} - 1$

while $i < Q'_{ACK}$

$c_{ACK} = \text{ColumnSet}(j)$

Petitioners' Exhibit 1003, p. 1355
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$\underline{y}_{r\times C_{mux}+c_{ACK}} = \underline{q}_i^{ACK}$

$i = i+1$

$r = R'_{mux} - 1 - \lfloor i/4 \rfloor$

$j = (j+3) \bmod 4$

end while

Where ColumnSet is given in Table 5.2.2.8-2 and indexed left to right from 0 to 3.

(6) The output of the block interleaver is the bit sequence read out column by column from the $(R_{mux} \times C_{mux})$ matrix. The bits after channel interleaving are denoted by $h_0, h_1, h_2, ..., h_{H+N_L \cdot Q_{RI}-1}$, where N_L is the number of layers the corresponding UL-SCH transport block is mapped onto.

Table 5.2.2.8-1: Column set for Insertion of rank information.

CP configuration	Column Set
Normal	{1, 4, 7, 10}
Extended	{0, 3, 5, 8}

Table 5.2.2.8-2: Column set for Insertion of HARQ-ACK information.

CP configuration	Column Set
Normal	{2, 3, 8, 9}
Extended	{1, 2, 6, 7}

The same channel interleaver procedures for RI are applied for CRI, using CRI instead of RI in the equations.

5.2.3 Uplink control information on PUCCH

Data arrives to the coding unit in the form of indicators for measurement indication, scheduling request and HARQ acknowledgement.

Three forms of channel coding are used as shown in Figure 5.2.3-1,

- one for HARQ-ACK and for combination of HARQ-ACK and periodic CSI transmitted on PUCCH format 3, including the cases with scheduling request,
- another for the channel quality information CQI/PMI transmitted on PUCCH format 2,
- and another for combination of CQI/PMI and HARQ-ACK transmitted on PUCCH format 2/2a/2b.

A fourth form of channel coding is used as shown in Figure 5.2.3-2, for HARQ-ACK and for combination of HARQ-ACK and periodic CSI transmitted on PUCCH format 4 or PUCCH format 5 including the cases with scheduling request, or for periodic CSI transmitted on PUCCH format 4 or PUCCH format 5 including the cases with scheduling request.

Petitioners' Exhibit 1003, p. 1356
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

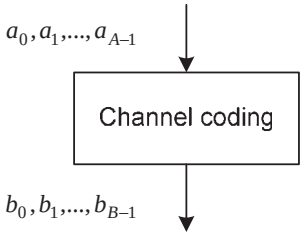


Figure 5.2.3-1: Processing for UCI.

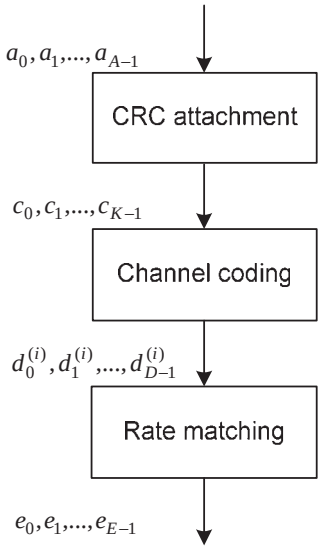


Figure 5.2.3-2: Processing for UCI.

5.2.3.1 Channel coding for UCI HARQ-ACK

The HARQ-ACK bits are received from higher layers for each subframe of each cell. Each positive acknowledgement (ACK) is encoded as a binary "1" and each negative acknowledgement (NACK) is encoded as a binary "0". For UEs configured with no more than five DL cells, or for UEs configured by higher layers with *codebooksizeDetermination-r13 = 1*, and for the case where PUCCH format 3, PUCCH format 4 or PUCCH format 5 [2] is configured by higher layers and is used for transmission of the HARQ-ACK feedback information, the HARQ-ACK feedback consists of the concatenation of HARQ-ACK bits for each of the serving cells. For UEs configured by higher layers with *codebooksizeDetermination-r13 = 0*, the HARQ-ACK feedback consists of the HARQ-ACK bits for the serving cells depending on the Downlink Assignment Index (DAI) as in Table 5.3.3.1.1-2 and as defined in [3]. For cells configured with transmission modes 1, 2, 5, 6 or 7 [3], i.e., single codeword transmission modes, 1 bit of HARQ-ACK information, a_k, is used for that cell. For cells configured with other transmission modes, 2 bits of HARQ-ACK information are used for those cells, i.e., a_k, a_{k+1} with a_k corresponding to HARQ-ACK bit for codeword 0 and a_{k+1} corresponding to that for codeword 1.

Define O^{ACK} as the number of HARQ-ACK feedback bits and $N_{A/N}^{\text{PUCCH format 3}}$ as the number of HARQ-ACK feedback bits including the possible concurrent transmission of scheduling request and/or periodic CSI when PUCCH format 3 is used for transmission of HARQ-ACK feedback (section 10.1 in [3]), and $N_{A/N}^{\text{PUCCH format 4}}$ as the number of HARQ-ACK feedback bits including the possible concurrent transmission of scheduling request and/or periodic CSI when PUCCH format 4 is used for transmission of HARQ-ACK feedback (section 10.1 in [3]), and $N_{A/N}^{\text{PUCCH format 5}}$ as the number of HARQ-ACK feedback bits including the possible concurrent transmission of scheduling request and/or periodic CSI when PUCCH format 5 is used for transmission of HARQ-ACK feedback (section 10.1 in [3]).

Petitioners' Exhibit 1003, p. 1357
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

For UEs configured by higher layers with *codebooksizeDetermination-r13 = 0*, the bit sequence $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ is determined according to the Downlink Assignment Index (DAI) as in Table 5.3.3.1.1-2 and as defined in [3]. Otherwise, the bit sequence $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ is determined as below.

For FDD, the sequence of bits $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ is the result of the concatenation of HARQ-ACK bits for different cells according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

Set N_{cells}^{DL} to the number of cells configured by higher layers for the UE

while $c <$ N_{cells}^{DL}

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ -- 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK} =$ HARQ-ACK bit of this cell

$j = j + 1$

else

if the UE is not configured with spatial bundling on PUCCH by higher layers $\tilde{o}_j^{ACK} =$ HARQ-ACK bit corresponding to the first codeword of this cell

$j = j + 1$

$\tilde{o}_j^{ACK} =$ HARQ-ACK bit corresponding to the second codeword of this cell

$j = j + 1$

else

$\tilde{o}_j^{ACK} =$ binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell

$j = j + 1$

end if

end if

$c = c + 1$

end while

For the aggregation of more than one DL cell including a primary cell using FDD and at least one secondary cell using TDD, the sequence of bits $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, ..., \tilde{o}_{O^{ACK}-1}^{ACK}$ is the result of the concatenation of HARQ-ACK bits for different cells. Define N_{cells}^{DL} as the number of cells configured by higher layers for the UE and B_c^{DL} as the number of subframes for which the UE needs to feed back HARQ-ACK bits in UL subframe n for the *c*-th serving cell. For a cell using TDD, the subframes are determined by the DL-reference UL/DL configuration if the UE is configured with higher layer parameter *eimta-HARQ-ReferenceConfig*, and determined by the UL/DL configuration otherwise. For a cell using TDD, $B_c^{DL} = 1$ if subframe n-4 in the cell is a DL subframe or a special subframe with special subframe configurations 1/2/3/4/6/7/8/9 and normal downlink CP or a special subframe with special subframe configurations 1/2/3/5/6/7 and extended downlink CP, and $B_c^{DL} = 0$ otherwise. For a cell using FDD, $B_c^{DL} = 1$.

Petitioners' Exhibit 1003, p. 1358
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The sequence of bits $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \ldots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is performed according to the following pseudo-code:

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

while $c < N_{cells}^{DL}$

if $B_c^{DL} = 1$

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ – 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK}$ = HARQ-ACK bit of this cell

$j = j + 1$

else

if the UE is not configured with spatial bundling on PUCCH by higher layers $\tilde{o}_j^{ACK}$ = HARQ-ACK bit corresponding to the first codeword of this cell

$j = j + 1$

$\tilde{o}_j^{ACK}$ = HARQ-ACK bit corresponding to the second codeword of this cell

$j = j + 1$

else

$\tilde{o}_j^{ACK}$ = binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell

$j = j + 1$

end if

end if

end if

$c = c + 1$

end while

For the cases with TDD primary cell, the sequence of bits $\tilde{o}_0^{ACK}, \tilde{o}_1^{ACK}, \ldots, \tilde{o}_{O^{ACK}-1}^{ACK}$ is obtained from the HARQ-ACK bits for different cells and different subframes.

Define N_{cells}^{DL} as the number of cells configured by higher layers for the UE and B_c^{DL} as the number of subframes for which the UE needs to feed back HARQ-ACK bits in cell c as defined in Section 7.3 of [3].

The number of HARQ-ACK bits k and the number of HARQ-ACK bits after spatial bundling k_b are computed as follows:

Set $k = 0$ – counter of HARQ-ACK bits

Set $k_b = 0$ – counter of HARQ-ACK bits after spatial bundling

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

while c < N_{cells}^{DL}

Petitioners' Exhibit 1003, p. 1359
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

set l = 0;

while $l <$ B_c^{DL}

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ -- 1 bit HARQ-ACK feedback for this cell

$k = k + 1$

$k_b = k_b + 1$

else

$k = k + 2$

$k_b = k_b + 1$

end if

$l = l+1$

end while

$c = c + 1$

end while

In case the transmission of HARQ-ACK feedback using PUCCH format 3, PUCCH format 4 or PUCCH format 5 coincides with a sub-frame configured to the UE by higher layers for transmission of scheduling request, the number of scheduling request bit O^{SR} is 1; otherwise O^{SR}=0.

In case the transmission of HARQ-ACK feedback using PUCCH format 3, PUCCH format 4 or PUCCH format 5 coincides with a sub-frame configured to the UE by higher layers for transmission of periodic CSI, O^{CSI} is the number of periodic CSI bit(s) for the CSI report as defined in section 7.2.2 [3]; otherwise O^{CSI}=0.

For PUCCH format 3, the number of HARQ-ACK feedback bits O^{ACK} is computed as follows:
Set $k_{\max} = 20$ when TDD is used in all the configured serving cell(s) of the UE and $k_{\max} = 21$ when FDD is used in at least one of the configured serving cells with TDD primary cell.

If $k \le k_{\max}$ and $O^{\text{CSI}} = 0$, or if $k + O^{\text{CSI}} + O^{SR} \le 22$ and $O^{\text{CSI}} > 0$, or if $k_b + O^{\text{CSI}} + O^{SR} > 22$ and $k \le k_{\max}$, then

- $O^{ACK} = k$

else,

- $O^{ACK} = k_b$.

For PUCCH format 4 or PUCCH format 5, $O^{ACK} = k$ if the UE is not configured with spatial bundling on PUCCH by higher layers; otherwise $O^{ACK} = k_b$.

If $O^{ACK} = k$, the multiplexing of HARQ-ACK bits is performed according to the following pseudo-code:

Set c = 0 – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set j = 0 – HARQ-ACK bit index

while c < N_{cells}^{DL}

set l = 0;

while $l <$ B_c^{DL}

Petitioners' Exhibit 1003, p. 1360
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ -- 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ HARQ-ACK bit of this cell as defined in Section 7.3 of [3]

$j = j + 1$

else

$[\tilde{o}_j^{ACK}, \tilde{o}_{j+1}^{ACK}] = [o_{c,2l}^{ACK}, o_{c,2l+1}^{ACK}]$ HARQ-ACK bit of this cell as defined in Section 7.3 of [3]

$j = j + 2$

end if

$l = l+1$

end while

$c = c + 1$

end while

If $O^{ACK} = k_b$, spatial bundling is applied to all subframes in all cells and the multiplexing of HARQ-ACK bits is performed according to the following pseudo-code

Set $c = 0$ – cell index: lower indices correspond to lower RRC indices of corresponding cell

Set $j = 0$ – HARQ-ACK bit index

while c < N_{cells}^{DL}

set $l = 0$;

while $l <$ B_c^{DL}

if transmission mode configured in cell $c \in \{1,2,5,6,7\}$ – 1 bit HARQ-ACK feedback for this cell

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ HARQ-ACK bit of this cell as defined in Section 7.3 of [3]

$j = j + 1$

else

$\tilde{o}_j^{ACK} = o_{c,l}^{ACK}$ binary AND operation of the HARQ-ACK bits corresponding to the first and second codewords of this cell as defined in Section 7.3 of [3]

$j = j + 1$

end if

$l = l+1$

end while

$c = c + 1$

end while

In case the transmission of HARQ-ACK feedback using PUCCH format 3, PUCCH format 4 or PUCCH format 5 [2] coincides with a sub-frame configured to the UE by higher layers for transmission of scheduling request, the scheduling request bit (1 = positive SR; 0 = negative SR) is appended at the end of the sequence of concatenated HARQ-ACK bits.

Petitioners' Exhibit 1003, p. 1361
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

In case the transmission of HARQ-ACK feedback using PUCCH format 3, PUCCH format 4 or PUCCH format 5 [2] coincides with a sub-frame configured to the UE by higher layers for transmission of periodic CSI, and periodic CSI is not dropped as defined in section 7.3.2 and section 10.1.1 of [3], the periodic CSI bits for the CSI report as defined in section 7.2.2 [3] are appended at the end of the sequence of concatenated HARQ-ACK bits and scheduling request bit (if any), where in case of CSI report for more than one DL cell, the CSI report for each DL cell is appended in increasing order of cell index. As with the transmission of the scheduling request, the procedure above is used with $N_{A/N}^{\text{PUCCH format 3}}$, $N_{A/N}^{\text{PUCCH format 4}}$ or $N_{A/N}^{\text{PUCCH format 5}}$ including the number of periodic CSI bits and scheduling request bit (if any).

For $N_{A/N}^{\text{PUCCH format 3}} \le 11$, the bit sequence $a_0, a_1, a_2, \ldots, a_{N_{A/N}^{\text{PUCCH format 3}}-1}$ is obtained by setting $a_i = \tilde{o}_i^{ACK}$.

For $11 < N_{A/N}^{\text{PUCCH format 3}} \le 22$, the bit sequence $a_0, a_1, a_2, \ldots, a_{N_{A/N}^{\text{PUCCH format 3}}-1}$ is obtained by setting $a_{i/2} = \tilde{o}_i^{ACK}$ if i is even and $a_{\lceil N_{A/N}^{PUCCH format 3}/2 \rceil + (i-1)/2} = \tilde{o}_i^{ACK}$ if i is odd.

For $N_{A/N}^{\text{PUCCH format 3}} \le 11$, the sequence of bits $a_0, a_1, a_2, \ldots, a_{N_{A/N}^{\text{PUCCH format 3}}-1}$ is encoded as follows

$$\tilde{b}_i = \sum_{n=0}^{N_{A/N}^{\text{PUCCH format 3}}-1} \left(a_n \cdot M_{i,n}\right) \bmod 2$$

where i = 0, 1, 2, …, 31 and the basis sequences $M_{i,n}$ are defined in Table 5.2.2.6.4-1.

The output bit sequence $b_0, b_1, b_2, \ldots, b_{B-1}$ is obtained by circular repetition of the sequence $\tilde{b}_0, \tilde{b}_1, \tilde{b}_2, \ldots, \tilde{b}_{31}$

$$b_i = \tilde{b}_{(i \bmod 32)}$$

where i = 0, 1, 2, …, B-1 and where $B = 4 \cdot N_{\text{sc}}^{\text{RB}}$.

For $11 < N_{A/N}^{\text{PUCCH format 3}} \le 22$, the sequences of bits $a_0, a_1, a_2, \ldots, a_{\lceil N_{A/N}^{\text{PUCCH format 3}}/2 \rceil - 1}$ and $a_{\lceil N_{A/N}^{\text{PUCCH format 3}}/2 \rceil}, a_{\lceil N_{A/N}^{\text{PUCCH format 3}}/2 \rceil + 1}, a_{\lceil N_{A/N}^{\text{PUCCH format 3}}/2 \rceil + 2}, \ldots, a_{N_{A/N}^{\text{PUCCH format 3}}-1}$ are encoded as follows

$$\tilde{b}_i = \sum_{n=0}^{\lceil N_{A/N}^{\text{PUCCH format 3}}/2 \rceil - 1} \left(a_n \cdot M_{i,n}\right) \bmod 2$$

and

$$\tilde{\tilde{b}}_i = \sum_{n=0}^{N_{A/N}^{\text{PUCCH format 3}} - \lceil N_{A/N}^{\text{PUCCH format 3}}/2 \rceil - 1} \left(a_{\lceil N_{A/N}^{\text{PUCCH format 3}}/2 \rceil + n} \cdot M_{i,n}\right) \bmod 2$$

where i = 0, 1, 2, …, 23 and the basis sequences $M_{i,n}$ are defined in Table 5.2.2.6.4-1.

The output bit sequence $b_0, b_1, b_2, \ldots, b_{B-1}$ where $B = 4 \cdot N_{\text{sc}}^{\text{RB}}$ is obtained by the alternate concatenation of the bit sequences $\tilde{b}_0, \tilde{b}_1, \tilde{b}_2, \ldots, \tilde{b}_{23}$ and $\tilde{\tilde{b}}_0, \tilde{\tilde{b}}_1, \tilde{\tilde{b}}_2, \ldots, \tilde{\tilde{b}}_{23}$ as follows

Set i, j = 0

while $i < 4 \cdot N_{\text{sc}}^{\text{RB}}$

$b_i = \tilde{b}_j$, $b_{i+1} = \tilde{b}_{j+1}$

Petitioners' Exhibit 1003, p. 1362
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$b_{i+2} = \tilde{\tilde{b}}_j$, $b_{i+3} = \tilde{\tilde{b}}_{j+1}$

$i = i + 4$

$j = j + 2$

end while

For $N_{A/N}^{\text{PUCCH format 4}} > 22$, the bit sequence $a_0, a_1, a_2, ..., a_{N_{A/N}^{\text{PUCCH format 4}}-1}$ is obtained by setting $a_i = \tilde{o}_i^{ACK}$, and the output bit sequence after the rate matching is denoted by $e_0, e_1, e_2, ..., e_{E-1}$, where $E = Q_m \cdot M_{RB}^{PUCCH\,4} \cdot N_{symb}^{PUSCH} \cdot N_{sc}^{RB}$, Q_m is the modulation order of the PUCCH format 4, N_{symb}^{PUSCH} is determined according to section 5.2.4.1, and $M_{RB}^{PUCCH\,4}$ represents the bandwidth of the PUCCH format 4 in terms of resource blocks [2]. The CRC attachment, channel coding and rate matching are performed according to sections 5.1.1 by setting L to 8 bits, 5.1.3.1 and 5.1.4.2, respectively. The input bit sequence to the CRC attachment operation is $a_0, a_1, a_2, ..., a_{N_{A/N}^{\text{PUCCH format 4}}-1}$. The output bit sequence of the CRC attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.

For $N_{A/N}^{\text{PUCCH format 5}} > 22$, the bit sequence $a_0, a_1, a_2, ..., a_{N_{A/N}^{\text{PUCCH format 5}}-1}$ is obtained by setting $a_i = \tilde{o}_i^{ACK}$, and the output bit sequence after the rate matching is denoted by $e_0, e_1, e_2, ..., e_{E-1}$, where $E = Q_m \cdot N_{symb}^{PUSCH} \cdot N_{sc}^{RB} / 2$, Q_m is the modulation order of the PUCCH format 5 and N_{symb}^{PUSCH} is determined according to section 5.2.4.1. The CRC attachment, channel coding and rate matching are performed according to sections 5.1.1 by setting L to 8 bits, 5.1.3.1 and 5.1.4.2, respectively. The input bit sequence to the CRC attachment operation is $a_0, a_1, a_2, ..., a_{N_{A/N}^{\text{PUCCH format 5}}-1}$. The output bit sequence of the CRC attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.

When PUCCH format 3, PUCCH format 4 or PUCCH format 5 is not used for transmission of HARQ-ACK feedback, the HARQ-ACK bits are processed for transmission according to section 10.1 in [3].

5.2.3.2 Channel coding for UCI scheduling request

The scheduling request indication is received from higher layers and is processed according to [2].

5.2.3.3 Channel coding for UCI channel quality information

The channel quality and possible concurrent scheduling request bits input to the channel coding block are denoted by $a_0, a_1, a_2, a_3, ..., a_{A-1}$ where A is the number of bits. The number of channel quality bits depends on the transmission format as indicated in section 5.2.3.3.1 for wideband reports and in section 5.2.3.3.2 for UE-selected subbands reports.

For PUCCH format 2, the channel quality information is coded using a (20, A) code. The code words of the (20, A) code are a linear combination of the 13 basis sequences denoted $M_{i,n}$ and defined in Table 5.2.3.3-1.

Table 5.2.3.3-1: Basis sequences for (20, A) code.

Petitioners' Exhibit 1003, p. 1363
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

i	$M_{i,0}$	$M_{i,1}$	$M_{i,2}$	$M_{i,3}$	$M_{i,4}$	$M_{i,5}$	$M_{i,6}$	$M_{i,7}$	$M_{i,8}$	$M_{i,9}$	$M_{i,10}$	$M_{i,11}$	$M_{i,12}$
0	1	1	0	0	0	0	0	0	0	0	1	1	0
1	1	1	1	0	0	0	0	0	0	1	1	1	0
2	1	0	0	1	0	0	1	0	1	1	1	1	1
3	1	0	1	1	0	0	0	0	1	0	1	1	1
4	1	1	1	1	0	0	0	1	0	0	1	1	1
5	1	1	0	0	1	0	1	1	1	0	1	1	1
6	1	0	1	0	1	0	1	0	1	1	1	1	1
7	1	0	0	1	1	0	0	1	1	0	1	1	1
8	1	1	0	1	1	0	0	1	0	1	1	1	1
9	1	0	1	1	1	0	1	0	0	1	1	1	1
10	1	0	1	0	0	1	1	1	0	1	1	1	1
11	1	1	1	0	0	1	1	0	1	0	1	1	1
12	1	0	0	1	0	1	0	1	1	1	1	1	1
13	1	1	0	1	0	1	0	1	0	1	1	1	1
14	1	0	0	0	1	1	0	1	0	0	1	0	1
15	1	1	0	0	1	1	1	1	0	1	1	0	1
16	1	1	1	0	1	1	1	0	0	1	0	1	1
17	1	0	0	1	1	1	0	0	1	0	0	1	1
18	1	1	0	1	1	1	1	1	0	0	0	0	0
19	1	0	0	0	0	1	1	0	0	0	0	0	0

After encoding the bits are denoted by $b_0, b_1, b_2, b_3, ..., b_{B-1}$ where $B = 20$ and with

$$b_i = \sum_{n=0}^{A-1} \left(a_n \cdot M_{i,n} \right) \bmod 2 \text{ where } i = 0, 1, 2, \ldots, B\text{-}1.$$

For PUCCH format 4, the output bit sequence after the rate matching is denoted by $e_0, e_1, e_2, ..., e_{E-1}$, where $E = Q_m \cdot M_{RB}^{PUCCH\,4} \cdot N_{symb}^{PUSCH} \cdot N_{sc}^{RB}$, Q_m is the modulation order of the PUCCH format 4, N_{symb}^{PUSCH} is determined according to section 5.2.4.1, and $M_{RB}^{PUCCH\,4}$ represents the bandwidth of the PUCCH format 4 in terms of resource blocks [2]. The CRC attachment, channel coding and rate matching are performed according to sections 5.1.1 by setting L to 8 bits, 5.1.3.1 and 5.1.4.2, respectively. The input bit sequence to the CRC attachment operation is $a_0, a_1, a_2, ..., a_{A-1}$. The output bit sequence of the CRC attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.

For PUCCH format 5, the output bit sequence after the rate matching is denoted by $e_0, e_1, e_2, ..., e_{E-1}$, where $E = Q_m \cdot N_{symb}^{PUSCH} \cdot N_{sc}^{RB} / 2$, Q_m is the modulation order of the PUCCH format 5 and N_{symb}^{PUSCH} is determined according to section 5.2.4.1. The CRC attachment, channel coding and rate matching are performed according to sections 5.1.1 by setting L to 8 bits, 5.1.3.1 and 5.1.4.2, respectively. The input bit sequence to the CRC attachment operation is $a_0, a_1, a_2, ..., a_{A-1}$. The output bit sequence of the CRC attachment operation is the input bit sequence to the channel coding operation. The output bit sequence of the channel coding operation is the input bit sequence to the rate matching operation.

5.2.3.3.1 Channel quality information formats for wideband reports

Table 5.2.3.3.1-1 shows the fields and the corresponding bit widths for the channel quality information feedback for wideband reports for PDSCH transmissions associated with a transmission mode 1, transmission mode 2, transmission mode 3, transmission mode 7, transmission mode 8 configured without PMI/RI reporting, transmission mode 9 configured without PMI/RI reporting or configured with 1 antenna port, transmission mode 10 configured without PMI/RI reporting or configured with 1 antenna port, and transmission mode 9/10 configured without PMI with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B".

Petitioners' Exhibit 1003, p. 1364
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.2.3.3.1-1A shows the fields and the corresponding bit widths for the channel quality information feedback for wideband reports for PDSCH transmissions associated with transmission mode 9/10 configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with 2/4/8 antenna ports.

Table 5.2.3.3.1-1: UCI fields for channel quality information feedback for wideband CQI reports (transmission mode 1, transmission mode 2, transmission mode 3, transmission mode 7, transmission mode 8 configured without PMI/RI reporting, transmission mode 9 configured without PMI/RI reporting or configured with 1 antenna port, transmission mode 10 configured without PMI/RI reporting or configured with 1 antenna port, and transmission mode 9/10 configured without PMI with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B").

Field	Bit width
Wide-band CQI	4

Table 5.2.3.3.1-1A: UCI fields for channel quality information feedback for wideband CQI reports (transmission mode 9/10 configured without PMI reporting **and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B"** with 2/4/8 antenna ports)

Field	Bit width	
	Rank = 1	Rank > 1
Wide-band CQI	4	4
Spatial differential CQI	0	3

Table 5.2.3.3.1-2 shows the fields and the corresponding bit widths for the channel quality and precoding matrix information feedback for wideband reports for PDSCH transmissions associated with transmission mode 4, transmission mode 5, transmission mode 6, and transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*.

Table 5.2.3.3.1-2: UCI fields for channel quality information feedback for wideband CQI reports (transmission mode 4, transmission mode 5, transmission mode 6, and transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	2 antenna ports		4 antenna ports	
	Rank = 1	Rank = 2	Rank = 1	Rank > 1
Wide-band CQI	4	4	4	4
Spatial differential CQI	0	3	0	3
Precoding matrix indicator	2	1	4	4

Table 5.2.3.3.1-2A and Table 5.2.3.3.1-2B show the fields and the corresponding bit widths for the channel quality and precoding matrix information feedback for wideband reports for PDSCH transmissions associated with transmission mode 9 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 10 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, K>1, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*. The number of configured CSI-RS resources in a CSI process K is defined in [3] and *alternativeCodebookEnabledCLASSB_K1* is configured by higher layers [6].

Table 5.2.3.3.1-2A-1and Table 5.2.3.3.1-2A-2 show the fields and the corresponding bit widths for the channel quality and precoding matrix information feedback for wideband reports for PDSCH transmissions associated with transmission mode 9 /10 configured with PMI/RI reporting with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A".

Table 5.2.3.3.1-2A: UCI fields for transmission of wideband CQI and precoding information (i2) (transmission mode 9 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 10 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer

Petitioners' Exhibit 1003, p. 1365
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, K>1, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width							
	2 antenna ports		4 antenna ports		8 antenna ports			
	Rank = 1	Rank = 2	Rank = 1	Rank > 1	Rank = 1	Rank = 2,3	Rank = 4	Rank > 4
Wide-band CQI	4	4	4	4	4	4	4	4
Spatial differential CQI	0	3	0	3	0	3	3	3
Wide-band PMI (2 or 4 antenna ports) or i2 (8 antenna ports)	2	1	4	4	4	4	3	0

Table 5.2.3.3.1-2A-1: UCI fields for transmission of wideband CQI and precoding information (i2) (transmission mode 9/10 configured PMI/RI with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A" and with codebook configuration (N_1, N_2, O_1, O_2), and *CodebookConfig*=1)

Field	Bit width							
	8/12/16 antenna ports							
	Rank = 1	Rank = 2	Rank = 3	Rank = 4	Rank = 5	Rank = 6	Rank = 7	Rank = 8
Wide-band CQI	4	4	4	4	4	4	4	4
Spatial differential CQI	0	3	3	3	3	3	3	3
Wide-band i2	2	2	1	1	0	0	0	0

Table 5.2.3.3.1-2A-2: UCI fields for transmission of wideband CQI and precoding information (i2) (transmission mode 9/10 configured PMI/RI with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A" and with codebook configuration (N_1, N_2, O_1, O_2), and *CodebookConfig*=2/3/4)

Field	Bit width							
	8/12/16 antenna ports							
	Rank = 1	Rank = 2	Rank = 3	Rank = 4	Rank = 5	Rank = 6	Rank = 7	Rank = 8
Wide-band CQI	4	4	4	4	4	4	4	4
Spatial differential CQI	0	3	3	3	3	3	3	3
Wide-band i2	4	4	4	3	0	0	0	0

Table 5.2.3.3.1-2B: UCI fields for transmission of wideband CQI and precoding information (i1, i2) for transmission mode 9 configured with PMI/RI reporting with 8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, K>1

Field	Bit width							
	8 antenna ports							
	Rank = 1	Rank = 2	Rank = 3	Rank =4	Rank = 5	Rank = 6	Rank = 7	Rank = 8
Wide-band CQI	4	4	4	4	4	4	4	4
Spatial differential CQI	0	3	3	3	3	3	3	3
i1	3	3	1	1	2	2	2	0
Wide-band i2	1	1	3	3	0	0	0	0

Table 5.2.3.3.1-2C and Table 5.2.3.3.1-2D show the fields and the corresponding bit widths for the channel quality and precoding matrix information feedback for wideband reports for PDSCH transmissions for 4 antenna ports associated with transmission modes 8, 9 and 10 configured with PMI/RI reporting and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with 4 antenna ports with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, K>1, and *alternativeCodeBookEnabledFor4TX-r12=TRUE*.

Table 5.2.3.3.1-2E shows the fields and the corresponding bit widths for the channel quality and precoding matrix information feedback for wideband reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and *alternativeCodebookEnabledCLASSB_K1=TRUE*.

Petitioners' Exhibit 1003, p. 1366
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.2.3.3.1-2C: UCI fields for transmission of wideband CQI and precoding information (i2) with 4 antenna ports (transmission modes 8, 9 and 10 configured with PMI/RI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE,* and transmission mode 9/10 configured with 4 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, K>1, and *alternativeCodeBookEnabledFor4TX-r12=TRUE*))

Field	Bit width			
	4 antenna ports			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wide-band CQI	4	4	4	4
Spatial differential CQI	0	3	3	3
Wideband i2	4	4	4	4

Table 5.2.3.3.1-2D: UCI fields for transmission of wideband CQI and precoding information (i1, i2) with 4 antenna ports (transmission modes 8, 9 and 10 configured with PMI/RI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE,* and transmission mode 9/10 configured with 4 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, K>1, and *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	4 antenna ports			
	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wide-band CQI	4	4	4	4
Spatial differential CQI	0	3	3	3
i1	2	2	0	0
Wideband i2	2	2	4	4

Table 5.2.3.3.1-2E: UCI fields for transmission of wideband CQI and precoding information (transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and *alternativeCodebookEnabledCLASSB_K1=TRUE*)

Field	Bit width					
	2 antenna ports		4 antenna ports			
	Rank = 1	Rank = 2	Rank = 1	Rank = 2	Rank = 3	Rank = 4
Wide-band CQI	4	4	4	4	4	4
Spatial differential CQI	0	3	0	3	3	3
Wide-band PMI	2	1	3	3	2	1

Field	Bit width				
	8 antenna ports				
	Rank = 1	Rank = 2	Rank = 3	Rank = 4	Rank = 5 to Rank = 8
Wide-band CQI	4	4	4	4	4
Spatial differential CQI	0	3	3	3	3
Wide-band PMI	4	4	4	3	0

Table 5.2.3.3.1-3 shows the fields and the corresponding bit widths for the rank indication feedback for wideband reports for PDSCH transmissions associated with transmission mode 3, transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B", transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A", and transmission mode 9/10 configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with 2/4/8 antenna ports.

Table 5.2.3.3.1-3: UCI fields for rank indication feedback for wideband reports (transmission mode 3, transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports,

Petitioners' Exhibit 1003, p. 1367
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B", transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A", and transmission mode 9/10 configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with 2/4/8 antenna ports).

Field	Bit width					
	2 antenna ports	4 antenna ports		8/12/16 antenna ports		
		Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers	Max 8 layers
Rank indication	1	1	2	1	2	3

Table 5.2.3.3.1-3A shows the fields and the corresponding bit widths for the joint transmission of rank indication and i1 for wideband reports for PDSCH transmissions associated with transmission mode 9 and transmission mode 10, and transmission mode 9/10 configured with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, and K>1, except with *alternativeCodeBookEnabledFor4TX-r12 =TRUE*.

Table 5.2.3.3.1-3A: UCI fields for joint report of RI and i1 (transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12 =TRUE* and transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12 =TRUE*, and transmission mode 9/10 configured with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, and K>1, except with *alternativeCodeBookEnabledFor4TX-r12 =TRUE*)

Field	Bit width					
	2 antenna ports	4 antenna ports		8 antenna ports		
		Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers	Max 8 layers
Rank indication	1	1	2	4	5	5
i1	-	-	-			

Table 5.2.3.3.1-3B shows the fields and the corresponding bit widths for the joint transmission of rank indication and i1 for wideband reports for PDSCH transmissions associated with transmission modes 8, 9 and 10 configured with PMI/RI reporting with 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12 =TRUE*, and transmission mode 9/10 configured with 4 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, and K>1, with *alternativeCodeBookEnabledFor4TX-r12 =TRUE*..

Table 5.2.3.3.1-3B: UCI fields for joint report of RI and i1 with 4 antenna ports (transmission modes 8, 9 and 10 configured with PMI/RI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with 4 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, and K>1, with *alternativeCodeBookEnabledFor4TX-r12 =TRUE*)

Field	Bit width	
	4 antenna ports	
	Max 1 or 2 layers	Max 4 layers
Rank indication and i1	4	5

Table 5.2.3.3.1-3C shows the fields and the corresponding bit widths for the joint report of CRI and rank indication feedback for wideband reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and transmission mode 9/10 configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1.

Petitioners' Exhibit 1003, p. 1368
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.2.3.3.1-3C: UCI fields for joint report of CRI and rank indication feedback for wideband reports (transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and transmission mode 9/10 configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1).

Field	Bit width					
	2 antenna ports	4 antenna ports		8 antenna ports		
		Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers	Max 8 layers
CRI	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$
Rank indication	1	1	2	1	2	3

Table 5.2.3.3.1-3D shows the fields and the corresponding bit widths for the joint report of CRI , rank indication and i1 feedback for wideband reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 4/8 ports, and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, with alternativeCodeBookEnabledFor4TX-r12=TRUE.

Table 5.2.3.3.1-3D: UCI fields for joint report of CRI, rank indication and i1 feedback for wideband reports (transmission mode 9/10 configured with PMI/RI reporting with 8 ports, and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, transmission mode 9/10 configured with PMI/RI reporting with 4 ports Class B CSI reporting with K>1 *with alternativeCodeBookEnabledFor4TX-r12=TRUE*).

Field	Bit width				
	4 antenna ports		8 antenna ports		
	Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers	Max 8 layers
CRI	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$
Rank indication and i1	4	5	4	5	5

Table 5.2.3.3.1-3E shows the fields and the corresponding bit widths for the CRI feedback for wideband reports for PDSCH transmissions associated with transmission mode 9/10 configured with 1 antenna port for each CSI-RS resource, Class B CSI reporting with K>1.

Table 5.2.3.3.1-3E: Fields for CRI feedback for wideband CQI reports (transmission mode 9/10 configured with 1 antenna port for each CSI-RS resource for Class B CSI reporting with K>1).

Field	Bit width		
	K = 2	K = 3 and K = 4	K = 5 to K = 8
CRI	1	2	3

Table 5.2.3.3.1-4 show the fields and the corresponding bit widths for the precoding matrix information feedback for wideband reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A". The parameters (S_1, S_2) in rank 3 and 4 are defined as $(S_1, S_2) = (1,1)$ for *CodebookConfig*=1, $(S_1, S_2) = \left(\frac{O_1}{2}, \frac{O_2}{2}\right)$ for *CodebookConfig*=2, $(S_1, S_2) = \left(O_1, \frac{O_2}{2}\right)$ for *CodebookConfig*=3, $(S_1, S_2) = \left(O_1, \frac{O_2}{4}\right)$ for *CodebookConfig*=4. The parameters (S_1, S_2) in rank 5 to 8 are defined as $(S_1, S_2) = (1,1)$ for *CodebookConfig*=1, $(S_1, S_2) = \left(\frac{O_1}{4}, \frac{O_2}{4}\right)$ for *CodebookConfig*=2/3/4.

Petitioners' Exhibit 1003, p. 1369
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.2.3.3.1-4: UCI fields for channel quality information feedback for precoding information (i1) (transmission mode 9/10 configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A" with codebook configuration (N_1, N_2, O_1, O_2))

Field	Bit width			
	Rank = 1	Rank = 2	Rank =3	Rank =4
Wideband first PMI i1,1	$\lceil \log_2(N_1 O_1 / S_1) \rceil$	$\lceil \log_2(N_1 O_1 / S_1) \rceil$	$\left\lceil \log_2\left(\frac{N_1 O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$	$\left\lceil \log_2\left(\frac{N_1 O_1}{S_1}\right) \right\rceil + \left\lfloor \frac{7-N_2}{3} \right\rfloor$
Wideband first PMI i1,2	$\lceil \log_2(N_2 O_2 / S_2) \rceil$	$\lceil \log_2(N_2 O_2 / S_2) \rceil$	$\lceil \log_2(N_2 O_2 / S_2) \rceil$	$\lceil \log_2(N_2 O_2 / S_2) \rceil$
Field	Bit width			
	Rank = 5	Rank = 6	Rank =7	Rank =8
Wideband first PMI i1,1	$\lceil \log_2(N_1 O_1 / S_1) \rceil$	$\lceil \log_2(N_1 O_1 / S_1) \rceil$	$\lceil \log_2(N_1 O_1 / S_1) \rceil$	$\lceil \log_2(N_1 O_1 / S_1) \rceil$
Wideband first PMI i1,2	$\lceil \log_2(N_2 O_2 / S_2) \rceil$	$\lceil \log_2(N_2 O_2 / S_2) \rceil$	$\lceil \log_2(N_2 O_2 / S_2) \rceil$	$\lceil \log_2(N_2 O_2 / S_2) \rceil$

The channel quality bits in Table 5.2.3.3.1-1 through Table 5.2.3.3.1-4 form the bit sequence $a_0, a_1, a_2, a_3, ..., a_{A-1}$ with a_0 corresponding to the first bit of the first field in each of the tables, a_1 corresponding to the second bit of the first field in each of the tables, and a_{A-1} corresponding to the last bit in the last field in each of the tables. The first bit of each field corresponds to MSB and the last bit LSB. The RI feedback for one bit is mapped according to Table 5.2.2.6-5 with o_0^{RI} replaced by a_0. The RI feedback for two bits is mapped according to Table 5.2.2.6-6 with o_0^{RI}, o_1^{RI} replaced by a_0, a_1. The RI feedback for three bits is mapped according to Table 5.2.2.6-7 with o_0^{RI}, o_1^{RI}, o_2^{RI} replaced by a_0, a_1, a_2. The same procedures for RI mapping are applied to CRI, replacing RI with CRI. The mapping for the jointly coded RI and i1 is provided in Table 7.2.2-1E of [3].

When multiplexed with UL-SCH, the channel coding and multiplexing for the transmission configurations in Table 5.2.3.3.1-3, Table 5.2.3.3.1-3A, Table 5.2.3.3.1-3B, Table 5.2.3.3.1-3C, Table 5.2.3.3.1-3D, and Table 5.2.3.3.1-3E is performed assuming RI transmission in section 5.2.2.6. All other transmission configurations in this section are coded and multiplexed assuming CQI/PMI transmission in section 5.2.2.6.

For transmission mode 9/10 configured with Class B CSI reporting and K>1, the number of antenna port in Table 5.2.3.3.1-3C, 5.2.3.3.1-3D refers to the maximum number of antenna ports of K CSI-RS resources configured for the CSI-process for the UE.

5.2.3.3.2 Channel quality information formats for UE-selected sub-band reports

Table 5.2.3.3.2-1 shows the fields and the corresponding bit widths for the sub-band channel quality information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 1, transmission mode 2, transmission mode 3, transmission mode 7, transmission mode 8 configured without PMI/RI reporting, transmission mode 9 configured without PMI/RI reporting or configured with 1 antenna port, and transmission mode 10 configured without PMI/RI reporting or configured with 1 antenna port.

Table 5.2.3.3.2-1A shows the fields and the corresponding bit widths for the sub-band channel quality information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9/10

Petitioners' Exhibit 1003, p. 1370
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with 2/4/8 antenna ports.

Table 5.2.3.3.2-1: UCI fields for channel quality information feedback for UE-selected sub-band CQI reports (transmission mode 1, transmission mode 2, transmission mode 3, transmission mode 7, transmission mode 8 configured without PMI/RI reporting, transmission mode 9 configured without PMI/RI reporting or configured with 1 antenna port, transmission mode 10 configured without PMI/RI reporting or configured with 1 antenna port, and transmission mode 9/10 configured without PMI/RI with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B")

Field	Bit width
Sub-band CQI	4
Sub-band label	1 or 2

Table 5.2.3.3.2-1A: UCI fields for channel quality information feedback for UE-selected subband CQI reports (transmission mode 9/10 configured without PMI reporting **and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B"** with 2/4/8 antenna ports)

Field	Bit width	
	Rank = 1	Rank > 1
Wide-band CQI	4	4
Spatial differential CQI	0	3
Sub-band label	1 or 2	1 or 2

Table 5.2.3.3.2-2 shows the fields and the corresponding bit widths for the sub-band channel quality information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 4, transmission mode 5, transmission mode 6, and transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*.

Table 5.2.3.3.2-2: UCI fields for channel quality information feedback for UE-selected sub-band reports (transmission mode 4, transmission mode 5, transmission mode 6 and transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	2 antenna ports		4 antenna ports	
	Rank = 1	Rank = 2	Rank = 1	Rank > 1
Sub-band CQI	4	4	4	4
Spatial differential CQI	0	3	0	3
Sub-band label	1 or 2	1 or 2	1 or 2	1 or 2

Table 5.2.3.3.2-2A and Table 5.2.3.3.2-2B show the fields and the corresponding bit widths for the sub-band channel quality information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE,* and transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE,* and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE,* or K>1, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*. The number of configured CSI-RS resources in a CSI process K is defined in [3] and *alternativeCodebookEnabledCLASSB_K1* is configured by higher layers [6].

Table 5.2.3.3.2-2A-1 shows UCI fields for channel quality information feedback for UE-selected sub-band reports (transmission mode 9/10 configured with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and *alternativeCodebookEnabledCLASSB_K1=TRUE,* and transmission mode 9/10 configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with 2/4/8 antenna ports.

Table 5.2.3.3.2-2C shows the fields and the corresponding bit widths for the sub-band channel quality information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission modes 8, 9 and 10 configured with PMI/RI reporting and *alternativeCodeBookEnabledFor4TX-r12 =TRUE*, and transmission mode 9/10

Petitioners' Exhibit 1003, p. 1371
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

configured with PMI/RI reporting with 4 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, and with *alternativeCodeBookEnabledFor4TX-r12=TRUE*..

Table 5.2.3.3.2-2A: UCI fields for channel quality information feedback for UE-selected sub-band reports (transmission mode 9 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 10 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with 2/4 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, K>1 except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	2 antenna ports		4 antenna ports	
	Rank = 1	Rank = 2	Rank = 1	Rank > 1
Wide-band CQI	0	0	0	0
Sub-band CQI	4	4	4	4
Spatial differential CQI	0	3	0	3
Wide-band i2	0	0	0	0
Sub-band i2	0	0	0	0
Sub-band label	1 or 2	1 or 2	1 or 2	1 or 2

Table 5.2.3.3.2-2A-1: UCI fields for channel quality information feedback for UE-selected sub-band reports (transmission mode 9/10 configured with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and *alternativeCodebookEnabledCLASSB_K1=TRUE, transmission mode 9/10 configured without PMI reporting* and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" *with 2/4/8 antenna ports*)

Field	Bit width	
	2/4/8 antenna ports	
	Rank = 1	Rank > 1
Wide-band CQI	0	0
Sub-band CQI	4	4
Spatial differential CQI	0	3
Wide-band i2	0	0
Sub-band i2	0	0
Sub-band label	1 or 2	1 or 2

Table 5.2.3.3.2-2B: UCI fields for channel quality feedback for UE-selected sub-band reports (transmission mode 9 configured with PMI/RI reporting with 8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 8 antenna ports, and transmission mode 9/10 configured with 8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, and K>1)

Field	Bit width									
	8 antenna ports									
	Rank = 1		Rank = 2, 3		Rank = 4		Rank = 5, 6, 7		Rank = 8	
	PTI=0	PTI=1	PTI=0	PTI=1	PTI=0	PTI=1	PTI=0	PTI=1	PTI=0	PTI=1
Wide-band CQI	4	0	4	0	4	0	4	0	4	0
Sub-band CQI	0	4	0	4	0	4	0	4	0	4
Spatial differential CQI	0	0	3	3	3	3	3	3	3	3
Wide-band i2	4	0	4	0	3	0	0	0	0	0
Sub-band i2	0	4	0	2	0	2	0	0	0	0
Sub-band label	0	1 or 2	0	1 or 2	0	1 or 2	0	1 or 2	0	1 or 2

Table 5.2.3.3.2-2C: UCI fields for channel quality feedback for UE-selected sub-band reports with 4 antenna ports (transmission modes 8, 9 and 10 configured with PMI/RI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE,* and transmission mode 9/10 configured with 4 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, and K>1, with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Petitioners' Exhibit 1003, p. 1372
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Field	Bit width					
	4 antenna ports					
	Rank = 1		Rank = 2		Rank = 3	Rank=4
	PTI=0	PTI=1	PTI=0	PTI=1	PTI=1	PTI=1
Wide-band CQI	4	0	4	0	0	0
Sub-band CQI	0	4	0	4	4	4
Spatial differential CQI	0	0	3	3	3	3
Wide-band i2	4	0	4	0	0	0
Sub-band i2	0	4	0	2	2	2
Sub-band label	0	1 or 2	0	1 or 2	1 or 2	1 or 2

Table 5.2.3.3.2-3 shows the fields and the corresponding bit widths for the wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 4, transmission mode 5, transmission mode 6 and transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*.

Table 5.2.3.3.2-3: UCI fields for channel quality information feedback for UE-selected sub-band CQI reports (transmission mode 4, transmission mode 5, transmission mode 6 and transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width			
	2 antenna ports		4 antenna ports	
	Rank = 1	Rank = 2	Rank = 1	Rank > 1
Wide-band CQI	4	4	4	4
Spatial differential CQI	0	3	0	3
Precoding matrix indicator	2	1	4	4

Table 5.2.3.3.2-3A and Table 5.2.3.3.2-3B show the fields and the corresponding bit widths for the wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, and K>1, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*

Table 5.2.3.3.2-3A-1 shows the fields and the corresponding bit widths for the wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and *alternativeCodebookEnabledCLASSB_K1=TRUE*.

Table 5.2.3.3.2-3C shows the fields and the corresponding bit widths for the wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission modes 8, 9 and 10 configured with PMI/RI reporting, 4 antenna ports and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 4 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, K>1 with *alternativeCodeBookEnabledFor4TX-r12=TRUE*.

Table 5.2.3.3.2-3A: UCI fields for wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports (transmission mode 9 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 10 configured with PMI/RI reporting with 2/4 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 2/4 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, K>1, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Petitioners' Exhibit 1003, p. 1373
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Field	Bit width			
	2 antenna ports		4 antenna ports	
	Rank = 1	Rank = 2	Rank = 1	Rank > 1
Wide-band CQI	4	4	4	4
Spatial differential CQI	0	3	0	3
i1	0	0	0	0
Wide-band i2	2	1	4	4

Table 5.2.3.3.2-3A-1: UCI fields for wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports (transmission mode 9/10 configured with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and *alternativeCodebookEnabledCLASSB_K1=TRUE*)

Field	Bit width					
	2 antenna ports		4 antenna ports			
	Rank = 1	Rank = 2	Rank = 1	Rank =2	Rank =3	Rank =4
Wideband CQI	4	4	4	4	4	4
Spatial differential CQI	0	3	0	3	3	3
i1	0	0	0	0	0	0
Wide-band i2	2	1	3	3	2	1
Field	**Bit width**					
	8 antenna ports					
	Rank = 1	**Rank = 2**	**Rank = 3**	**Rank =4**	**Rank =5~8**	
Wideband CQI	4	4	4	4	4	
Spatial differential CQI	0	3	3	3	3	
i1	0	0	0	0	0	
Wide-band i2	4	4	4	3	0	

Table 5.2.3.3.2-3B: UCI fields for wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports (transmission mode 9 configured with PMI/RI reporting with 8 antenna ports and transmission mode 10 configured with PMI/RI reporting with 8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, K>1)

Field	Bit width					
	8 antenna ports					
	Rank = 1		Rank = 2		Rank = 3	
	PTI=0	PTI=1	PTI=0	PTI=1	PTI=0	PTI=1
Wide-band CQI	0	4	0	4	0	4
Spatial differential CQI	0	0	0	3	0	3
i1	4	0	4	0	2	0
Wide-band i2	0	4	0	4	0	4
Field	**Bit width**					
	8 antenna ports					
	Rank = 4		**Rank = 5, 6, 7**		**Rank = 8**	
	PTI=0	**PTI=1**	**PTI=0**	**PTI=1**	**PTI=0**	**PTI=1**
Wide-band CQI	0	4	0	4	0	4
Spatial differential CQI	0	3	0	3	0	3
i1	2	0	2	0	0	0
Wide-band i2	0	3	0	0	0	0

Table 5.2.3.3.2-3B-1 shows the fields and the corresponding bit widths for the wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A" with *CodebookConfig*=1.

Table 5.2.3.3.2-3B-2 shows the fields and the corresponding bit widths for the wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A" with *CodebookConfig*=2/3/4.

Petitioners' Exhibit 1003, p. 1374
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.2.3.3.2-3B-1: UCI fields for wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports (transmission mode 9/10 configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A" with codebook configuration (N_1, N_2, O_1, O_2), and *CodebookConfig*=1)

Field	Bit width					
	8/12/16 antenna ports					
	Rank = 1		Rank = 2		Rank = 3	
	PTI=0	PTI=1	PTI=0	PTI=1	PTI=0	PTI=1
Wide-band CQI	0	4	0	4	0	4
Spatial differential CQI	0	0	0	3	0	3
Wideband first PMI i1,1	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right)\right\rceil$	0	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right)\right\rceil$	0	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right)\right\rceil + \left\lfloor \frac{7-N_2}{3}\right\rfloor$	0
Wideband first PMI i1,2	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right)\right\rceil$	0	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right)\right\rceil$	0	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right)\right\rceil$	0
Wide-band i2	0	2	0	2	0	1

Field	Bit width			
	8/12/16 antenna ports			
	Rank = 4		Rank = 5 to Rank = 8	
	PTI=0	PTI=1	PTI=0	PTI=1
Wide-band CQI	0	4	0	4
Spatial differential CQI	0	3	0	3
Wideband first PMI i1,1	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right)\right\rceil + \left\lfloor \frac{7-N_2}{3}\right\rfloor$	0	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right)\right\rceil$	0
Wideband first PMI i1,2	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right)\right\rceil$	0	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right)\right\rceil$	0
Wide-band i2	0	1	0	0

Table 5.2.3.3.2-3B-2: UCI fields for wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports (transmission mode 9/10 configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A" with codebook configuration (N_1, N_2, O_1, O_2), and *CodebookConfig*=2/3/4)

Field	Bit width					
	8/12/16 antenna ports					
	Rank = 1		Rank = 2		Rank = 3	
	PTI=0	PTI=1	PTI=0	PTI=1	PTI=0	PTI=1

Petitioners' Exhibit 1003, p. 1375
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Wide-band CQI	0	4	0	4	0	4
Spatial differential CQI	0	0	0	3	0	3
Wideband first PMI i1,1	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right)\right\rceil$	0	$\left\lceil \log\left(\frac{N_1O_1}{S_1}\right)\right\rceil$	0	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right)\right\rceil+\left\lfloor \frac{7-N_2}{3}\right\rfloor$	0
Wideband first PMI i1,2	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right)\right\rceil$	0	$\left\lceil \log\left(\frac{N_2O_2}{S_2}\right)\right\rceil$	0	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right)\right\rceil$	0
Wide-band i2	0	4	0	4	0	4

Field	Bit width 8/12/16 antenna ports			
	Rank = 4		Rank = 5 to Rank = 8	
	PTI=0	PTI=1	PTI=0	PTI=1
Wide-band CQI	0	4	0	4
Spatial differential CQI	0	3	0	3
Wideband first PMI i1,1	$\left\lceil \log_2\left(\frac{N_1O_1}{S_1}\right)\right\rceil+\left\lfloor \frac{7-N_2}{3}\right\rfloor$	0	$\left\lceil \log\left(\frac{N_1O_1}{S_1}\right)\right\rceil$	0
Wideband first PMI i1,2	$\left\lceil \log_2\left(\frac{N_2O_2}{S_2}\right)\right\rceil$	0	$\left\lceil \log\left(\frac{N_2O_2}{S_2}\right)\right\rceil$	0
Wide-band i2	0	3	0	0

Table 5.2.3.3.2-3C: UCI fields for wide-band channel quality and precoding matrix information feedback for UE-selected sub-band reports with 4 antenna ports (transmission modes 8, 9 and 10 configured with PMI/RI reporting and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, and K>1, with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width 4 antenna ports					
	Rank = 1		Rank = 2		Rank = 3	Rank=4
	PTI=0	PTI=1	PTI=0	PTI=1	PTI=1	PTI=1
Wide-band CQI	0	4	0	4	4	4
Spatial differential CQI	0	0	0	3	3	3
i1	4	0	4	0	0	0
Wide-band i2	0	4	0	4	4	4

Table 5.2.3.3.2-4 shows the fields and the corresponding bit width for the rank indication feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 3, transmission mode 4, transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and *alternativeCodebookEnabledCLASSB_K1=TRUE*, and transmission mode 9/10 configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and *alternativeCodebookEnabledCLASSB_K1=TRUE* for 2/4/8 antenna ports.

Table 5.2.3.3.2-4: UCI fields for rank indication feedback for UE-selected sub-band reports (transmission mode 3, transmission mode 4, and transmission mode 8 configured with PMI/RI reporting except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and *alternativeCodebookEnabledCLASSB_K1=TRUE*, and transmission mode 9/10 configured without PMI reporting and

Petitioners' Exhibit 1003, p. 1376
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and *alternativeCodebookEnabledCLASSB_K1=TRUE* for 2/4/8 antenna ports).

Field	Bit width					
	2 antenna ports	4 antenna ports		8 antenna ports		
		Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers	Max 8 layers
Rank indication	1	1	2	1	2	3

Table 5.2.3.3.2-4A shows the fields and the corresponding bit width for the rank indication and precoder type indication (PTI) feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports and transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, or K>1, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE* for 4Tx, and transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A".

Table 5.2.3.3.2-4B shows the fields and the corresponding bit width for the rank indication and precoder type indication (PTI) feedback with 4 antenna ports for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 8, transmission mode 9 and transmission mode 10 configured with PMI/RI reporting and *alternativeCodeBookEnabledFor4TX-r12 =TRUE*, and transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, K>1, with *alternativeCodeBookEnabledFor4TX-r12=TRUE*.

Table 5.2.3.3.2-4A: UCI fields for joint report of RI and PTI (transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports except with *alternativeCodeBookEnabledFor4TX-r12=TRUE*, transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, or K>1, except with *alternativeCodeBookEnabledFor4TX-r12=TRUE* for 4Tx, and transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS A")

Field	Bit width					
	2 antenna ports	4 antenna ports		8/12/16 antenna ports		
		Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers	Max 8 layers
Rank indication	1	1	2	1	2	3
Precoder type indication	-	-	-	1	1	1

Table 5.2.3.3.2-4B: UCI fields for joint report of RI and PTI with 4 antenna ports (transmission mode 8, transmission mode 9 and transmission mode 10 configured with PMI/RI reporting and *alternativeCodeBookEnabledFor4TX-r12=TRUE*, and transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K=1 and except with *alternativeCodebookEnabledCLASSB_K1=TRUE*, K>1, with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width	
	4 antenna ports	
	Max 1 or 2 layers	Max 4 layers
Rank indication	1	2
Precoder type indication	1	1

Table 5.2.3.3.2-4C shows the fields and the corresponding bit widths for the joint report of CRI and rank indication feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1,and transmission mode 9/10 configured without PMI reporting with 2/4 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1.

Petitioners' Exhibit 1003, p. 1377
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.2.3.3.2-4D shows the fields and the corresponding bit widths for the joint report of CRI , rank indication and PTI feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9/10 configured with PMI/RI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1.

Table 5.2.3.3.2-4C: UCI fields for joint report of CRI and rank indication feedback for UE-selected subband reports (transmission mode 9/10 configured with PMI/RI reporting with 2/4 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, and transmission mode 9/10 configured without PMI reporting with 2/4 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1).

Field	Bit width		Bit width	
	2 antenna ports		4 antenna ports	
	Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers
CRI	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$
Rank indication	1	1	2	2

Table 5.2.3.3.2-4D: UCI fields for joint report of CRI, RI and PTI (transmission mode 9/10 configured with PMI/RI reporting with 8 antenna ports with higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to "CLASS B" with K>1, transmission mode 9/10 configured with PMI/RI reporting with 4 antenna ports with Class B CSI reporting with K>1with *alternativeCodeBookEnabledFor4TX-r12=TRUE*)

Field	Bit width				
	4 antenna ports		8 antenna ports		
	Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers	Max 8 layers
CRI	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$	$\lceil \log_2(K) \rceil$
Rank indication	1	2	1	2	3
Precoder type indication	1	1	1	1	1

Table 5.2.3.3.2-4E shows the fields and the corresponding bit width for CRI feedback for UE-selected sub-band reports for PDSCH transmissions associated with transmission mode 9/10 configured with 1 antenna port for each CSI-RS resource reporting for Class B CSI reporting with K>1.

Table 5.2.3.3.2-4E: Fields for CRI feedback for transmission mode 9/10 configured with 1 antenna port for each CSI-RS resource for Class B CSI reporting with K>1).

Field	Bit width		
	K = 2	K = 3 and K = 4	K = 5 to K = 8
CRI	1	2	3

The channel quality bits in Table 5.2.3.3.2-1 through Table 5.2.3.3.2-4E form the bit sequence $a_0, a_1, a_2, a_3, ..., a_{A-1}$ with a_0 corresponding to the first bit of the first field in each of the tables, a_1 corresponding to the second bit of the first field in each of the tables, and a_{A-1} corresponding to the last bit in the last field in each of the tables. The first bit of each field corresponds to MSB and the last bit LSB. The RI feedback for one bit is mapped according to Table 5.2.2.6-5 with o_0^{RI} replaced by a_0 . The RI feedback for two bits is mapped according to Table 5.2.2.6-6 with o_0^{RI} , o_1^{RI} replaced by a_0, a_1 . The RI feedback for three bits is mapped according to Table 5.2.2.6-7 with o_0^{RI} , o_1^{RI} , o_2^{RI} replaced by a_0, a_1, a_2 . The same procedures for RI mapping are applied to CRI, replacing RI with CRI.

When multiplexed with UL-SCH, the channel coding and multiplexing for the transmission configurations in Table 5.2.3.3.2-4, Table 5.2.3.3.2-4A, Table 5.2.3.3.2-4B, Table 5.2.3.3.2-4C and Table 5.2.3.3.2-4D is performed assuming RI transmission in section 5.2.2.6. All other transmission configurations in this section are coded and multiplexed assuming CQI/PMI transmission in section 5.2.2.6.

Petitioners' Exhibit 1003, p. 1378
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

For transmission mode 9/10 configured with Class B CSI reporting and K>1, the number of antenna port in Table 5.2.3.3.2-4C, 5.2.3.3.2-4D refers to the maximum number of antenna ports of K CSI-RS resources configured for the CSI-process for the UE.

5.2.3.4 Channel coding for UCI channel quality information and HARQ-ACK

This section defines the channel coding scheme for the simultaneous transmission of channel quality information and HARQ-ACK information in a subframe.

When normal CP is used for uplink transmission, the channel quality information is coded according to section 5.2.3.3 with input bit sequence $a'_0, a'_1, a'_2, a'_3, ..., a'_{A'-1}$ and output bit sequence $b'_0, b'_1, b'_2, b'_3, ..., b'_{B'-1}$, where $B' = 20$. The HARQ-ACK bits are denoted by a''_0 in case one HARQ-ACK bit or a''_0, a''_1 in case two HARQ-ACK bits are reported per subframe. Each positive acknowledgement (ACK) is encoded as a binary "1" and each negative acknowledgement (NACK) is encoded as a binary "0".

The output of this channel coding block for normal CP is denoted by $b_0, b_1, b_2, b_3, ..., b_{B-1}$, where

$$b_i = b'_i, i = 0, ..., B' - 1$$

In case one HARQ-ACK bit is reported per subframe:

$$b_{B'} = a''_0 \text{ and } B = (B' + 1)$$

In case two HARQ-ACK bits are reported per subframe:

$$b_{B'} = a''_0, b_{B'+1} = a''_1 \text{ and } B = (B' + 2)$$

When extended CP is used for uplink transmission, the channel quality information and the HARQ-ACK bits are jointly coded. The HARQ-ACK bits are denoted by a''_0 in case one HARQ-ACK bit or $[a''_0, a''_1]$ in case two HARQ-ACK bits are reported per subframe.

The channel quality information denoted by $a'_0, a'_1, a'_2, a'_3, ..., a'_{A'-1}$ is multiplexed with the HARQ-ACK bits to yield the sequence $a_0, a_1, a_2, a_3, ..., a_{A-1}$ as follows

$$a_i = a'_i, i = 0, ..., A' - 1$$

and

$a_{A'} = a''_0$ and $A = (A' + 1)$ in case one HARQ-ACK bit is reported per subframe, or

$a_{A'} = a''_0$, $a_{(A'+1)} = a''_1$ and $A = (A' + 2)$ in case two HARQ-ACK bits are reported per subframe.

The sequence $a_0, a_1, a_2, a_3, ..., a_{A-1}$ is encoded according to section 5.2.3.3 to yield the output bit sequence $b_0, b_1, b_2, b_3, ..., b_{B-1}$ where $B = 20$.

5.2.4 Uplink control information on PUSCH without UL-SCH data

When control data are sent via PUSCH without UL-SCH data, the following coding steps can be identified:

- Channel coding of control information
- Control information mapping
- Channel interleaver

Petitioners' Exhibit 1003, p. 1379
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.2.4.1 Channel coding of control information

Control data arrives at the coding unit in the form of channel quality information (CQI and/or PMI), HARQ-ACK and rank indication. Different coding rates for the control information are achieved by allocating different number of coded symbols for its transmission. When the UE transmits HARQ-ACK bits or rank indicator bits, it shall determine the number of coded symbols Q' for HARQ-ACK or rank indicator as

$$Q' = \min\left(\left\lceil \frac{O \cdot M_{sc}^{PUSCH} \cdot N_{symb}^{PUSCH} \cdot \beta_{offset}^{PUSCH}}{O_{CQI-MIN}} \right\rceil, 4 \cdot M_{sc}^{PUSCH}\right)$$

where O is the number of HARQ-ACK bits as defined in section 5.2.2.6, or rank indicator bits, $O_{CQI-MIN}$ is the number of CQI bits including CRC bits assuming rank equals to 1 for all serving cells for which an aperiodic CSI report is triggered [3], M_{sc}^{PUSCH} is the scheduled bandwidth for PUSCH transmission in the current subframe expressed as a number of subcarriers in [2], and N_{symb}^{PUSCH} is the number of SC-FDMA symbols in the current PUSCH transmission sub-frame given by $N_{symb}^{PUSCH} = \left(2 \cdot \left(N_{symb}^{UL} - 1\right) - N_{SRS}\right)$, where N_{SRS} is equal to 1 if UE is configured to send PUSCH and SRS in the same subframe for the current subframe, or if the PUSCH resource allocation for the current subframe even partially overlaps with the cell-specific SRS subframe and bandwidth configuration defined in section 5.5.3 of [2], or if the current subframe is a UE-specific type-1 SRS subframe as defined in Section 8.2 of [3], or if the current subframe is a UE-specific type-0 SRS subframe as defined in section 8.2 of [3] and the UE is configured with multiple TAGs. Otherwise N_{SRS} is equal to 0.

For HARQ-ACK information $Q_{ACK} = Q_m \cdot Q'$ and [$\beta_{offset}^{PUSCH} = \beta_{offset}^{HARQ-ACK} / \beta_{offset}^{CQI}$]. For UEs configured with no more than five DL cells, $\beta_{offset}^{HARQ-ACK}$ shall be determined according to [3]. For UEs configured with more than five DL cells, $\beta_{offset}^{HARQ-ACK}$ shall be determined according to [3] depending on the number of HARQ-ACK feedback bits.

For rank indication or CRI, $Q_{RI} = Q_m \cdot Q'$, $Q_{CRI} = Q_m \cdot Q'$ and [$\beta_{offset}^{PUSCH} = \beta_{offset}^{RI} / \beta_{offset}^{CQI}$], where β_{offset}^{RI} shall be determined according to [3].

For CQI and/or PMI information $Q_{CQI} = N_{symb}^{PUSCH} \cdot M_{sc}^{PUSCH} \cdot Q_m - Q_{RI}$.

The channel coding and rate matching of the control data is performed according to section 5.2.2.6. The coded output sequence for channel quality information is denoted by $q_0, q_1, q_2, q_3, ..., q_{Q_{CQI}-1}$, the coded vector sequence output for HARQ-ACK is denoted by $\underline{q}_0^{ACK}, \underline{q}_1^{ACK}, \underline{q}_2^{ACK}, ..., \underline{q}_{Q'_{ACK}-1}^{ACK}$ and the coded vector sequence output for rank indication or CRI, is denoted by $\underline{q}_0^{RI}, \underline{q}_1^{RI}, \underline{q}_2^{RI}, ..., \underline{q}_{Q'_{RI}-1}^{RI}$.

5.2.4.2 Control information mapping

The input are the coded bits of the channel quality information denoted by $q_0, q_1, q_2, q_3, ..., q_{Q_{CQI}-1}$. The output is denoted by $\underline{g}_0, \underline{g}_1, \underline{g}_2, \underline{g}_3, ..., \underline{g}_{H'-1}$, where $H = Q_{CQI}$ and $H' = H / Q_m$, and where $\underline{g}_i$, $i = 0, ..., H'-1$ are column vectors of length Q_m. H is the total number of coded bits allocated for CQI/PMI information.

The control information shall be mapped as follows:

Set j, k to 0

while $j < Q_{CQI}$

$\underline{g}_k = [q_j \ ... \ q_{j+Q_m-1}]^T$

Petitioners' Exhibit 1003, p. 1380
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$j = j + Q_m$

$k = k + 1$

end while

5.2.4.3 Channel interleaver

The vector sequences $\underline{g}_0, \underline{g}_1, \underline{g}_2, ..., \underline{g}_{H'-1}$, $\underline{q}_0^{RI}, \underline{q}_1^{RI}, \underline{q}_2^{RI}, ..., \underline{q}_{Q'_{RI}-1}^{RI}$ and $\underline{q}_0^{ACK}, \underline{q}_1^{ACK}, \underline{q}_2^{ACK}, ..., \underline{q}_{Q'_{ACK}-1}^{ACK}$ are channel interleaved according section 5.2.2.8. The bits after channel interleaving are denoted by $h_0, h_1, h_2, ..., h_{H+Q_{RI}-1}$.

5.3 Downlink transport channels and control information

If the UE is configured with a Master Cell Group (MCG) and Secondary Cell Group (SCG) [6], the procedures described in this clause are applied to the MCG and SCG, respectively. When the procedures are applied to a SCG, the term primary cell refers to the primary SCell (PSCell) of the SCG.

If the UE is configured with a PUCCH SCell [6], the procedures described in this clause are applied to the group of DL cells associated with the primary cell and the group of DL cells associated with the PUCCH SCell, respectively. When the procedures are applied to the group of DL cells associated with the PUCCH SCell, the term primary cell refers to the PUCCH SCell.

5.3.1 Broadcast channel

Figure 5.3.1-1 shows the processing structure for the BCH transport channel. Data arrives to the coding unit in the form of a maximum of one transport block every transmission time interval (TTI) of 40ms. The following coding steps can be identified:

- Add CRC to the transport block
- Channel coding
- Rate matching

The coding steps for BCH transport channel are shown in the figure below.

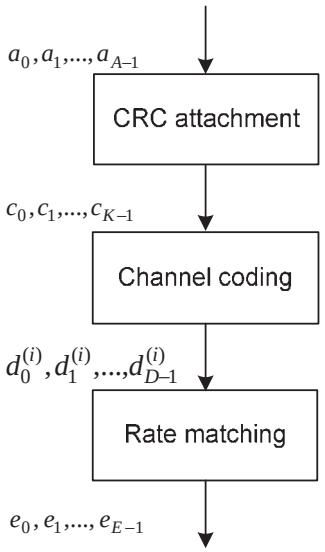


Figure 5.3.1-1: Transport channel processing for BCH.

Petitioners' Exhibit 1003, p. 1381
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.3.1.1 Transport block CRC attachment

Error detection is provided on BCH transport blocks through a Cyclic Redundancy Check (CRC).

The entire transport block is used to calculate the CRC parity bits. Denote the bits in a transport block delivered to layer 1 by $a_0, a_1, a_2, a_3, ..., a_{A-1}$, and the parity bits by $p_0, p_1, p_2, p_3, ..., p_{L-1}$. A is the size of the transport block and set to 24 bits and L is the number of parity bits. The lowest order information bit a_0 is mapped to the most significant bit of the transport block as defined in section 6.1.1 of [5].

The parity bits are computed and attached to the BCH transport block according to section 5.1.1 setting L to 16 bits. After the attachment, the CRC bits are scrambled according to the eNodeB transmit antenna configuration with the sequence $x_{ant,0}, x_{ant,1}, ..., x_{ant,15}$ as indicated in Table 5.3.1.1-1 to form the sequence of bits $c_0, c_1, c_2, c_3, ..., c_{K-1}$ where

$c_k = a_k$ for k = 0, 1, 2, …, A-1

$c_k = (p_{k-A} + x_{ant,k-A}) \bmod 2$ for $k = A, A+1, A+2, ..., A+15$.

Table 5.3.1.1-1: CRC mask for PBCH.

Number of transmit antenna ports at eNodeB	PBCH CRC mask $< x_{ant,0}, x_{ant,1}, ..., x_{ant,15} >$
1	<0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0>
2	<1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1>
4	<0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1>

5.3.1.2 Channel coding

Information bits are delivered to the channel coding block. They are denoted by $c_0, c_1, c_2, c_3, ..., c_{K-1}$, where K is the number of bits, and they are tail biting convolutionally encoded according to section 5.1.3.1.

After encoding the bits are denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, d_3^{(i)}, ..., d_{D-1}^{(i)}$, with i = 0,1, and 2, and where D is the number of bits on the i-th coded stream, i.e., $D = K$.

5.3.1.3 Rate matching

A tail biting convolutionally coded block is delivered to the rate matching block. This block of coded bits is denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, d_3^{(i)}, ..., d_{D-1}^{(i)}$, with i = 0,1, and 2, and where i is the coded stream index and D is the number of bits in each coded stream. This coded block is rate matched according to section 5.1.4.2.

After rate matching, the bits are denoted by $e_0, e_1, e_2, e_3, ..., e_{E-1}$, where E is the number of rate matched bits as defined in section 6.6.1 of [2].

5.3.2 Downlink shared channel, Paging channel and Multicast channel

Figure 5.3.2-1 shows the processing structure for each transport block for the DL-SCH, PCH and MCH transport channels. Data arrives to the coding unit in the form of a maximum of two transport blocks every transmission time interval (TTI) per DL cell. The following coding steps can be identified for each transport block of a DL cell:

- Add CRC to the transport block
- Code block segmentation and code block CRC attachment
- Channel coding
- Rate matching
- Code block concatenation

Petitioners' Exhibit 1003, p. 1382
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

The coding steps for PCH and MCH transport channels, and for one transport block of DL-SCH are shown in the figure below. The same processing applies for each transport block on each DL cell.

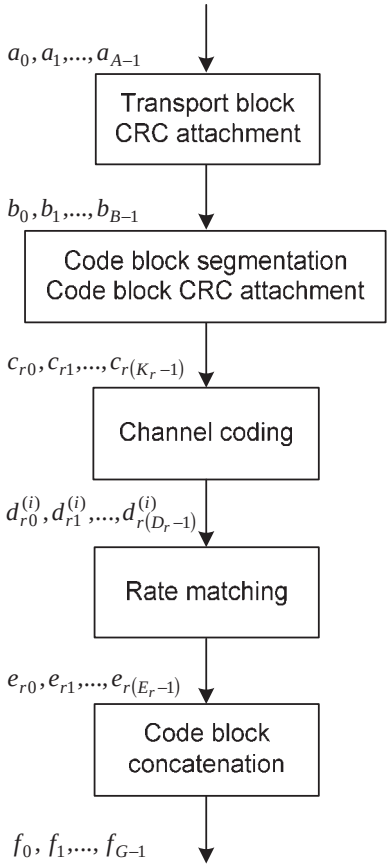


Figure 5.3.2-1: Transport block processing for DL-SCH, PCH and MCH.

5.3.2.1 Transport block CRC attachment

Error detection is provided on transport blocks through a Cyclic Redundancy Check (CRC).

The entire transport block is used to calculate the CRC parity bits. Denote the bits in a transport block delivered to layer 1 by $a_0, a_1, a_2, a_3, ..., a_{A-1}$, and the parity bits by $p_0, p_1, p_2, p_3, ..., p_{L-1}$. A is the size of the transport block and L is the number of parity bits. The lowest order information bit a_0 is mapped to the most significant bit of the transport block as defined in section 6.1.1 of [5].

The parity bits are computed and attached to the transport block according to section 5.1.1 setting L to 24 bits and using the generator polynomial $g_{CRC24A}(D)$.

5.3.2.2 Code block segmentation and code block CRC attachment

The bits input to the code block segmentation are denoted by $b_0, b_1, b_2, b_3, ..., b_{B-1}$ where B is the number of bits in the transport block (including CRC).

Code block segmentation and code block CRC attachment are performed according to section 5.1.2.

The bits after code block segmentation are denoted by $c_{r0}, c_{r1}, c_{r2}, c_{r3}, ..., c_{r(K_r-1)}$, where r is the code block number and K_r is the number of bits for code block number r.

Petitioners' Exhibit 1003, p. 1383
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.3.2.3 Channel coding

Code blocks are delivered to the channel coding block. They are denoted by $c_{r0}, c_{r1}, c_{r2}, c_{r3}, ..., c_{r(K_r-1)}$, where r is the code block number, and K_r is the number of bits in code block number r. The total number of code blocks is denoted by C and each code block is individually turbo encoded according to section 5.1.3.2.

After encoding the bits are denoted by $d_{r0}^{(i)}, d_{r1}^{(i)}, d_{r2}^{(i)}, d_{r3}^{(i)}, ..., d_{r(D_r-1)}^{(i)}$, with $i = 0,1,$ and 2 , and where D_r is the number of bits on the i-th coded stream for code block number r, i.e. $D_r = K_r + 4$.

5.3.2.4 Rate matching

Turbo coded blocks are delivered to the rate matching block. They are denoted by $d_{r0}^{(i)}, d_{r1}^{(i)}, d_{r2}^{(i)}, d_{r3}^{(i)}, ..., d_{r(D_r-1)}^{(i)}$, with $i = 0,1,$ and 2 , and where r is the code block number, i is the coded stream index, and D_r is the number of bits in each coded stream of code block number r. The total number of code blocks is denoted by C and each coded block is individually rate matched according to section 5.1.4.1.

After rate matching, the bits are denoted by $e_{r0}, e_{r1}, e_{r2}, e_{r3}, ..., e_{r(E_r-1)}$, where r is the coded block number, and where E_r is the number of rate matched bits for code block number r.

5.3.2.5 Code block concatenation

The bits input to the code block concatenation block are denoted by $e_{r0}, e_{r1}, e_{r2}, e_{r3}, ..., e_{r(E_r-1)}$ for $r = 0, ..., C-1$ and where E_r is the number of rate matched bits for the r-th code block.

Code block concatenation is performed according to section 5.1.5.

The bits after code block concatenation are denoted by $f_0, f_1, f_2, f_3, ..., f_{G-1}$, where G is the total number of coded bits for transmission. This sequence of coded bits corresponding to one transport block after code block concatenation is referred to as one codeword in section 6.3.1 of [2]. In case of multiple transport blocks per TTI, the transport block to codeword mapping is specified according to section 5.3.3.1.5, 5.3.3.1.5A or 5.3.3.1.5B, depending on the DCI Format.

5.3.3 Downlink control information

A DCI transports downlink, uplink or sidelink scheduling information, requests for aperiodic CQI reports, LAA common information, notifications of MCCH change [6] or uplink power control commands for one cell and one RNTI. The RNTI is implicitly encoded in the CRC.

Figure 5.3.3-1 shows the processing structure for one DCI. The following coding steps can be identified:

- Information element multiplexing
- CRC attachment
- Channel coding
- Rate matching

The coding steps for DCI are shown in the figure below.

Petitioners' Exhibit 1003, p. 1384
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

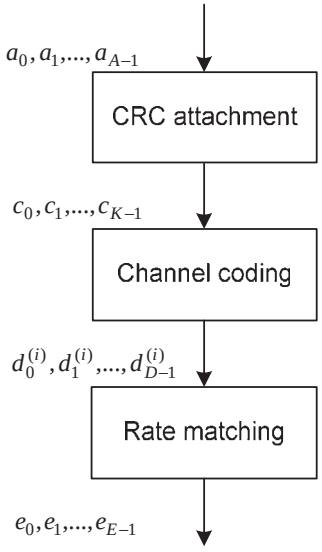


Figure 5.3.3-1: Processing for one DCI.

5.3.3.1 DCI formats

The fields defined in the DCI formats below are mapped to the information bits a_0 to a_{A-1} as follows.

Each field is mapped in the order in which it appears in the description, including the zero-padding bit(s), if any, with the first field mapped to the lowest order information bit a_0 and each successive field mapped to higher order information bits. The most significant bit of each field is mapped to the lowest order information bit for that field, e.g. the most significant bit of the first field is mapped to a_0.

5.3.3.1.1 Format 0

DCI format 0 is used for the scheduling of PUSCH in one UL cell.

The following information is transmitted by means of the DCI format 0:

- Carrier indicator – 0 or 3 bits. This field is present according to the definitions in [3].
- Flag for format0/format1A differentiation – 1 bit, where value 0 indicates format 0 and value 1 indicates format 1A
- Frequency hopping flag – 1 bit as defined in section 8.4 of [3]. This field is used as the MSB of the corresponding resource allocation field for resource allocation type 1.
- Resource block assignment and hopping resource allocation – $\left\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{UL}}(N_{\mathrm{RB}}^{\mathrm{UL}}+1)/2) \right\rceil$ bits
  - For PUSCH hopping (resource allocation type 0 only):
    - N_{UL_hop} MSB bits are used to obtain the value of $\tilde{n}_{PRB}(i)$ as indicated in section 8.4 of [3]
    - $\left(\left\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{UL}}(N_{\mathrm{RB}}^{\mathrm{UL}}+1)/2) \right\rceil - N_{\mathrm{UL\_hop}} \right)$ bits provide the resource allocation of the first slot in the UL subframe
  - For non-hopping PUSCH with resource allocation type 0:
    - $\left(\left\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{UL}}(N_{\mathrm{RB}}^{\mathrm{UL}}+1)/2) \right\rceil \right)$ bits provide the resource allocation in the UL subframe as defined in section 8.1.1 of [3]
  - For non-hopping PUSCH with resource allocation type 1:

Petitioners' Exhibit 1003, p. 1385
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- The concatenation of the frequency hopping flag field and the resource block assignment and hopping resource allocation field provides the resource allocation field in the UL subframe as defined in section 8.1.2 of [3]

- Modulation and coding scheme and redundancy version – 5 bits as defined in section 8.6 of [3]

- New data indicator – 1 bit

- TPC command for scheduled PUSCH – 2 bits as defined in section 5.1.1.1 of [3]

- Cyclic shift for DM RS and OCC index – 3 bits as defined in section 5.5.2.1.1 of [2]

- UL index – 2 bits as defined in sections 5.1.1.1, 7.2.1, 8 and 8.4 of [3] (this field is present only for TDD operation with uplink-downlink configuration 0)

- Downlink Assignment Index (DAI) – 2 bits as defined in section 7.3 of [3] (this field is present only for cases with TDD primary cell and either TDD operation with uplink-downlink configurations 1-6 or FDD operation)

- CSI request – 1, 2 or 3 bits as defined in section 7.2.1 of [3]. The 2-bit field applies to UEs configured with no more than five DL cells and to

  - UEs that are configured with more than one DL cell and when the corresponding DCI format is mapped onto the UE specific search space given by the C-RNTI as defined in [3];

  - UEs that are configured by higher layers with more than one CSI process and when the corresponding DCI format is mapped onto the UE specific search space given by the C-RNTI as defined in [3];

  - UEs that are configured with two CSI measurement sets by higher layers with the parameter *csi-MeasSubframeSet*, and when the corresponding DCI format is mapped onto the UE specific search space given by the C-RNTI as defined in [3];

  the 3-bit field applies to UEs that are configured with more than five DL cells and when the corresponding DCI format is mapped onto the UE specific search space given by the C-RNTI as defined in [3];

  otherwise the 1-bit field applies

- SRS request – 0 or 1 bit. This field can only be present in DCI formats scheduling PUSCH which are mapped onto the UE specific search space given by the C-RNTI as defined in [3]. The interpretation of this field is provided in section 8.2 of [3]

- Resource allocation type – 1 bit. This field is only present if $N_{\mathrm{RB}}^{\mathrm{UL}} \le N_{\mathrm{RB}}^{\mathrm{DL}}$. The interpretation of this field is provided in section 8.1 of [3]

If the number of information bits in format 0 mapped onto a given search space is less than the payload size of format 1A for scheduling the same serving cell and mapped onto the same search space (including any padding bits appended to format 1A), zeros shall be appended to format 0 until the payload size equals that of format 1A.

5.3.3.1.2 Format 1

DCI format 1 is used for the scheduling of one PDSCH codeword in one cell.

The following information is transmitted by means of the DCI format 1:

- Carrier indicator – 0 or 3 bits. This field is present according to the definitions in [3].

- Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3]

  If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed.

- Resource block assignment:

  - For resource allocation type 0 as defined in section 7.1.6.1 of [3]:

    - $\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil$ bits provide the resource allocation

Petitioners' Exhibit 1003, p. 1386
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- For resource allocation type 1 as defined in section 7.1.6.2 of [3]:

  - $\lceil \log_2(P) \rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset

  - 1 bit indicates a shift of the resource allocation span

  - $\left(\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil - \lceil \log_2(P) \rceil - 1 \right)$ bits provide the resource allocation

  where the value of P depends on the number of DL resource blocks as indicated in section 7.1.6.1 of [3]

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- HARQ process number – 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)

- New data indicator – 1 bit

- Redundancy version – 2 bits

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2.

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If the UE is not configured to decode PDCCH or EPDCCH with CRC scrambled by the C-RNTI and the number of information bits in format 1 is equal to that for format 0/1A, one bit of value zero shall be appended to format 1.

If the UE is configured to decode PDCCH or EPDCCH with CRC scrambled by the C-RNTI and the number of information bits in format 1 is equal to that for format 0/1A for scheduling the same serving cell and mapped onto the UE specific search space given by the C-RNTI as defined in [3], one bit of value zero shall be appended to format 1.

If the number of information bits in format 1 carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one or more zero bit(s) shall be appended to format 1 until the payload size of format 1 does not belong to one of the sizes in Table 5.3.3.1.2-1 and is not equal to that of format 0/1A mapped onto the same search space.

Table 5.3.3.1.2-1: Ambiguous Sizes of Information Bits.

{12, 14, 16 ,20, 24, 26, 32, 40, 44, 56}

Table 5.3.3.1.2-2: Number of bits for Downlink Assignment Index.

Petitioners' Exhibit 1003, p. 1387
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Number of bits	
4	For UEs configured by higher layers with *codebooksizeDetermination-r13* = *0*, the 4-bit DAI further consists of a 2-bit counter DAI and a 2-bit total DAI. - Counter DAI – 2 bits as defined in section 7.3 of [3] - Total DAI – 2 bits as defined in section 7.3 of [3]
2	For UEs configured with no more than five DL cells, or for UEs configured by higher layers with *codebooksizeDetermination-r13* = *1*, this field is present for FDD or TDD operation, for cases with TDD primary cell. If the UL/DL configuration of all TDD serving cells is same and the UE is not configured to decode PDCCH with CRC scrambled by *eimta-RNTI*, then this field only applies to serving cell with UL/DL configuration 1-6 If at least two TDD serving cells have different UL/DL configurations or the UE is configured to decode PDCCH with CRC scrambled by *eimta-RNTI*, then this field applies to a serving cell with DL-reference UL/DL configuration 1-6 as defined in section 10.2 of [3]
0	For UEs configured with no more than five DL cells, or for UEs configured by higher layers with *codebooksizeDetermination-r13* = *1*, this field is not present for FDD or TDD operation, for cases with FDD primary cell.

5.3.3.1.3 Format 1A

DCI format 1A is used for the compact scheduling of one PDSCH codeword in one cell and random access procedure initiated by a PDCCH order. The DCI corresponding to a PDCCH order can be carried by PDCCH or EPDCCH.

The following information is transmitted by means of the DCI format 1A:

- Carrier indicator – 0 or 3 bits. This field is present according to the definitions in [3].

- Flag for format0/format1A differentiation – 1 bit, where value 0 indicates format 0 and value 1 indicates format 1A

Format 1A is used for random access procedure initiated by a PDCCH order only if format 1A CRC is scrambled with C-RNTI and all the remaining fields are set as follows:

- Localized/Distributed VRB assignment flag – 1 bit is set to "0"

- Resource block assignment – $\left\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{DL}}(N_{\mathrm{RB}}^{\mathrm{DL}}+1)/2) \right\rceil$ bits, where all bits shall be set to 1

- Preamble Index – 6 bits

- PRACH Mask Index – 4 bits, [5]

- All the remaining bits in format 1A for compact scheduling assignment of one PDSCH codeword are set to zero

Otherwise,

- Localized/Distributed VRB assignment flag – 1 bit as defined in 7.1.6.3 of [3]

- Resource block assignment – $\left\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{DL}}(N_{\mathrm{RB}}^{\mathrm{DL}}+1)/2) \right\rceil$ bits as defined in section 7.1.6.3 of [3]:

  - For localized VRB:

    $\left\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{DL}}(N_{\mathrm{RB}}^{\mathrm{DL}}+1)/2) \right\rceil$ bits provide the resource allocation

  - For distributed VRB:

    - If $N_{\mathrm{RB}}^{\mathrm{DL}} < 50$ or if the format 1A CRC is scrambled by RA-RNTI, P-RNTI, SI-RNTI, SC-RNTI or G-RNTI:

Petitioners' Exhibit 1003, p. 1388
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- $\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{DL}}(N_{\mathrm{RB}}^{\mathrm{DL}}+1)/2) \rceil$ bits provide the resource allocation

- Else

- 1 bit, the MSB indicates the gap value, where value 0 indicates $N_{\mathrm{gap}} = N_{\mathrm{gap},1}$ and value 1 indicates $N_{\mathrm{gap}} = N_{\mathrm{gap},2}$

- $(\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{DL}}(N_{\mathrm{RB}}^{\mathrm{DL}}+1)/2) \rceil - 1)$ bits provide the resource allocation,

where N_{gap} is defined in [2].

- Modulation and coding scheme – 5bits as defined in section 7.1.7 of [3]

- HARQ process number – 3 bits (for cases with FDD primary cell) , 4 bits (for cases with TDD primary cell)

- New data indicator – 1 bit

- If the format 1A CRC is scrambled by RA-RNTI, P-RNTI, SI-RNTI, SC-RNTI or G-RNTI:

- If $N_{\mathrm{RB}}^{\mathrm{DL}} \geq 50$ and Localized/Distributed VRB assignment flag is set to 1

- the new data indicator bit indicates the gap value, where value 0 indicates $N_{\mathrm{gap}} = N_{\mathrm{gap},1}$ and value 1 indicates $N_{\mathrm{gap}} = N_{\mathrm{gap},2}$.

- Else the new data indicator bit is reserved.

- Else

- The new data indicator bit as defined in [5]

- Redundancy version – 2 bits

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- If the format 1A CRC is scrambled by RA-RNTI, P-RNTI, or SI-RNTI:

- The most significant bit of the TPC command is reserved.

- The least significant bit of the TPC command indicates column $N_{\mathrm{PRB}}^{1\mathrm{A}}$ of the TBS table defined of [3].

- If least significant bit is 0 then $N_{\mathrm{PRB}}^{1\mathrm{A}} = 2$ else $N_{\mathrm{PRB}}^{1\mathrm{A}} = 3$.

- Else

- The two bits including the most significant bit indicates the TPC command

- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2.

- SRS request – 0 or 1 bit. This field can only be present in DCI formats scheduling PDSCH which are mapped onto the UE specific search space given by the C-RNTI as defined in [3]. The interpretation of this field is provided in section 8.2 of [3]

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If the UE is not configured to decode PDCCH or EPDCCH with CRC scrambled by the C-RNTI, and the number of information bits in format 1A is less than that of format 0, zeros shall be appended to format 1A until the payload size equals that of format 0.

Petitioners' Exhibit 1003, p. 1389
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

If the UE is configured to decode PDCCH or EPDCCH with CRC scrambled by the C-RNTI and the number of information bits in format 1A mapped onto a given search space is less than that of format 0 for scheduling the same serving cell and mapped onto the same search space, zeros shall be appended to format 1A until the payload size equals that of format 0, except when format 1A assigns downlink resource on a secondary cell without an uplink configuration associated with the secondary cell.

If the number of information bits in format 1A carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one zero bit shall be appended to format 1A.

When the format 1A CRC is scrambled with a RA-RNTI, P-RNTI, SI-RNTI, SC-RNTI or G-RNTI then the following fields among the fields above are reserved:

- HARQ process number
- Downlink Assignment Index (used for cases with TDD primary cell and either FDD operation or TDD operation, and is not present for cases with FDD primary cell and either FDD operation or TDD operation)

5.3.3.1.3A Format 1B

DCI format 1B is used for the compact scheduling of one PDSCH codeword in one cell with precoding information.

The following information is transmitted by means of the DCI format 1B:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].
- Localized/Distributed VRB assignment flag – 1 bit as defined in section 7.1.6.3 of [3]
- Resource block assignment – $\left\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{DL}}(N_{\mathrm{RB}}^{\mathrm{DL}}+1)/2) \right\rceil$ bits as defined in section 7.1.6.3 of [3]
  - For localized VRB:

    $\left\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{DL}}(N_{\mathrm{RB}}^{\mathrm{DL}}+1)/2) \right\rceil$ bits provide the resource allocation
  - For distributed VRB:
    - For $N_{\mathrm{RB}}^{\mathrm{DL}} < 50$
      - $\left\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{DL}}(N_{\mathrm{RB}}^{\mathrm{DL}}+1)/2) \right\rceil$ bits provide the resource allocation
    - For $N_{\mathrm{RB}}^{\mathrm{DL}} \geq 50$
      - 1 bit, the MSB indicates the gap value, where value 0 indicates $N_{\mathrm{gap}} = N_{\mathrm{gap},1}$ and value 1 indicates $N_{\mathrm{gap}} = N_{\mathrm{gap},2}$
      - $\left(\left\lceil \log_2(N_{\mathrm{RB}}^{\mathrm{DL}}(N_{\mathrm{RB}}^{\mathrm{DL}}+1)/2) \right\rceil - 1\right)$ bits provide the resource allocation
- Modulation and coding scheme – 5bits as defined in section 7.1.7 of [3]
- HARQ process number – 3 bits (for cases with FDD primary cell) , 4 bits (for cases with TDD primary cell)
- New data indicator – 1 bit
- Redundancy version – 2 bits
- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]
- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2.
- TPMI information for precoding – number of bits as specified in Table 5.3.3.1.3A-1

  TPMI information indicates which codebook index is used in Table 6.3.4.2.3-1 or Table 6.3.4.2.3-2 of [2] corresponding to the single-layer transmission.

Petitioners' Exhibit 1003, p. 1390
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- PMI confirmation for precoding – 1 bit as specified in Table 5.3.3.1.3A-2

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If PMI confirmation indicates that the eNodeB has applied precoding according to PMI(s) reported by the UE, the precoding for the corresponding RB(s) in subframe *n* is according to the latest PMI(s) in an aperiodic CSI reported on or before subframe *n*-4.

Table 5.3.3.1.3A-1: Number of bits for TPMI information.

Number of antenna ports at eNodeB	Number of bits
2	2
4	4

Table 5.3.3.1.3A-2: Content of PMI confirmation.

Bit field mapped to index	Message
0	Precoding according to the indicated TPMI in the TPMI information field
1	Precoding using the precoder(s) according to PMI(s) indicated in the latest aperiodic CSI report. For aperiodic CSI mode 2-2: - Precoding of scheduled resource blocks belonging to the reported preferred M subband(s), use precoder(s) according to the preferred M subband PMI(s) indicated in the latest aperiodic CSI report; - Precoding of scheduled resource blocks not belonging to the reported preferred M subband(s), precoding using a precoder according to the wideband PMI indicated in the latest aperiodic CSI report.

If the number of information bits in format 1B is equal to that for format 0/1A for scheduling the same serving cell and mapped onto the UE specific search space given by the C-RNTI as defined in [3], one bit of value zero shall be appended to format 1B.

If the number of information bits in format 1B carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one or more zero bit(s) shall be appended to format 1B until the payload size of format 1B does not belong to one of the sizes in Table 5.3.3.1.2-1 and is not equal to that of format 0/1A mapped onto the same search space.

5.3.3.1.4 Format 1C

DCI format 1C is used for very compact scheduling of one PDSCH codeword, notifying MCCH change [6], notifying SC-MCCH change [6] , reconfiguring TDD, and LAA common information.

The following information is transmitted by means of the DCI format 1C:

If the format 1C is used for very compact scheduling of one PDSCH codeword

- 1 bit indicates the gap value, where value 0 indicates $N_{\text{gap}} = N_{\text{gap},1}$ and value 1 indicates $N_{\text{gap}} = N_{\text{gap},2}$

- For $N_{\text{RB}}^{\text{DL}} < 50$, there is no bit for gap indication

Petitioners' Exhibit 1003, p. 1391
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Resource block assignment – $\left\lceil \log_2 \left(\left\lfloor N_{\text{VRB,gap1}}^{\text{DL}} / N_{\text{RB}}^{\text{step}} \right\rfloor \cdot \left(\left\lfloor N_{\text{VRB,gap1}}^{\text{DL}} / N_{\text{RB}}^{\text{step}} \right\rfloor + 1 \right) / 2 \right) \right\rceil$ bits as defined in 7.1.6.3 of [3] where $N_{\text{VRB,gap1}}^{\text{DL}}$ is defined in [2] and $N_{\text{RB}}^{\text{step}}$ is defined in [3]

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

Else if the format 1C is used for notifying MCCH change

- Information for MCCH change notification – 8 bits as defined in section 5.8.1.3 of [6]

- Reserved information bits are added until the size is equal to that of format 1C used for very compact scheduling of one PDSCH codeword

Else if the format 1C is used for notifying SC-MCCH change

- Information for SC-MCCH change notification – 8 bits as defined in section 5.8a.1.3 of [6]

- Reserved information bits are added until the size is equal to that of format 1C used for very compact scheduling of one PDSCH codeword

Else if the format 1C is used for reconfiguring TDD

- UL/DL configuration indication:

  UL/DL configuration number 1, UL/DL configuration number 2,…, UL/DL configuration number *I*

  Where each UL/DL configuration is 3 bits, $I = \left\lfloor \frac{L_{\text{format 1c}}}{3} \right\rfloor$, $L_{\text{format 1c}}$ is equal to the payload size of format 1C used for very compact scheduling of one PDSCH codeword. The parameter *eimta-UL-DL-ConfigIndex* provided by higher layers determines the index to the UL/DL configuration indication for a serving cell.

- Zeros are added until the size is equal to that of format 1C used for very compact scheduling of one PDSCH codeword

Else

- Subframe configuration for LAA – 4 bits as defined in section x.y.z of [3]

- Reserved information bits are added until the size is equal to that of format 1C used for very compact scheduling of one PDSCH codeword

5.3.3.1.4A Format 1D

DCI format 1D is used for the compact scheduling of one PDSCH codeword in one cell with precoding and power offset information.

The following information is transmitted by means of the DCI format 1D:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].

- Localized/Distributed VRB assignment flag – 1 bit as defined in section 7.1.6.3 of [3]

- Resource block assignment – $\left\lceil \log_2 (N_{\text{RB}}^{\text{DL}} (N_{\text{RB}}^{\text{DL}} + 1) / 2) \right\rceil$ bits as defined in section 7.1.6.3 of [3]:

  - For localized VRB:

    $\left\lceil \log_2 (N_{\text{RB}}^{\text{DL}} (N_{\text{RB}}^{\text{DL}} + 1) / 2) \right\rceil$ bits provide the resource allocation

  - For distributed VRB:

    - For $N_{\text{RB}}^{\text{DL}} < 50$

Petitioners' Exhibit 1003, p. 1392
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- $\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL}+1)/2) \rceil$ bits provide the resource allocation

- For $N_{RB}^{DL} \geq 50$

  - 1 bit, the MSB indicates the gap value, where value 0 indicates $N_{gap} = N_{gap,1}$ and value 1 indicates $N_{gap} = N_{gap,2}$

  - $(\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL}+1)/2) \rceil - 1)$ bits provide the resource allocation

- Modulation and coding scheme – 5bits as defined in section 7.1.7 of [3]

- HARQ process number – 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)

- New data indicator – 1 bit

- Redundancy version – 2 bits

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2.

- TPMI information for precoding – number of bits as specified in Table 5.3.3.1.4A-1

  TPMI information indicates which codebook index is used in Table 6.3.4.2.3-1 or Table 6.3.4.2.3-2 of [2] corresponding to the single-layer transmission.

- Downlink power offset – 1 bit as defined in section 7.1.5 of [3]

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

Table 5.3.3.1.4A-1: Number of bits for TPMI information.

Number of antenna ports at eNodeB	Number of bits
2	2
4	4

If the number of information bits in format 1D is equal to that for format 0/1A for scheduling the same serving cell and mapped onto the UE specific search space given by the C-RNTI as defined in [3], one bit of value zero shall be appended to format 1D.

If the number of information bits in format 1D carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one or more zero bit(s) shall be appended to format 1D until the payload size of format 1D does not belong to one of the sizes in Table 5.3.3.1.2-1 and is not equal to that of format 0/1A mapped onto the same search space.

5.3.3.1.5 Format 2

The following information is transmitted by means of the DCI format 2:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].

- Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3]

  If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed.

- Resource block assignment:

Petitioners' Exhibit 1003, p. 1393
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- For resource allocation type 0 defined in section 7.1.6.1 of [3]:

  - $\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil$ bits provide the resource allocation

- For resource allocation type 1 as defined in section 7.1.6.2 of [3]:

  - $\lceil \log_2(P) \rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset

  - 1 bit indicates a shift of the resource allocation span

  - $\left(\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil - \lceil \log_2(P) \rceil - 1 \right)$ bits provide the resource allocation

where the value of P depends on the number of DL resource blocks as indicated in section 7.1.6.1 of [3]

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2.

- HARQ process number - 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)

- Transport block to codeword swap flag – 1 bit

In addition, for transport block 1:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

In addition, for transport block 2:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

- Precoding information – number of bits as specified in Table 5.3.3.1.5-3

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If both transport blocks are enabled, the transport block to codeword mapping is specified according to Table 5.3.3.1.5-1.

In case one of the transport blocks is disabled as specified in section 7.1.7.2 of [3], the transport block to codeword swap flag is reserved and the transport block to codeword mapping is specified according to Table 5.3.3.1.5-2.

Table 5.3.3.1.5-1: Transport block to codeword mapping
(two transport blocks enabled).

transport block to codeword swap flag value	codeword 0 (enabled)	codeword 1 (enabled)
0	transport block 1	transport block 2
1	transport block 2	transport block 1

Petitioners' Exhibit 1003, p. 1394
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.3.3.1.5-2: Transport block to codeword mapping
(one transport block enabled).

transport block 1	transport block 2	codeword 0 (enabled)	codeword 1 (disabled)
enabled	disabled	transport block 1	-
disabled	enabled	transport block 2	-

The interpretation of the precoding information field depends on the number of enabled codewords according to Table 5.3.3.1.5-4 and Table 5.3.3.1.5-5. Note that TPMI indicates which codebook index is used in Table 6.3.4.2.3-1 or Table 6.3.4.2.3-2 of [2]. For a single enabled codeword, indices 18 to 34 inclusive in Table 5.3.3.1.5-5 are only supported for retransmission of the corresponding transport block if that transport block has previously been transmitted using two layers with closed-loop spatial multiplexing.

If the number of information bits in format 2 carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one zero bit shall be appended to format 2.

Some entries in Table 5.3.3.1.5-4 and Table 5.3.3.1.5-5 are used for indicating that the eNodeB has applied precoding according to PMI(s) reported by the UE. In these cases the precoding for the corresponding RB(s) in subframe *n* is according to the latest PMI(s) in an aperiodic CSI reported on or before subframe *n*-4. For aperiodic CSI mode 2-2: Precoding of scheduled resource blocks belonging to the reported preferred M subband(s) use precoder(s) according to the preferred M subband PMI indicated by the latest aperiodic CSI report; Precoding of scheduled resource blocks not belonging to the reported preferred M subband(s) use a precoder according to the wideband PMI indicated by the latest aperiodic CSI report.

Table 5.3.3.1.5-3: Number of bits for precoding information.

Number of antenna ports at eNodeB	Number of bits for precoding information
2	3
4	6

Table 5.3.3.1.5-4: Content of precoding information field for 2 antenna ports.

Petitioners' Exhibit 1003, p. 1395
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

One codeword: Codeword 0 enabled, Codeword 1 disabled		Two codewords: Codeword 0 enabled, Codeword 1 enabled	
Bit field mapped to index	**Message**	**Bit field mapped to index**	**Message**
0	2 layers: Transmit diversity	0	2 layers: Precoding corresponding to precoder matrix $\frac{1}{2}\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix}$
1	1 layer: Precoding corresponding to precoding vector $\begin{bmatrix}1 & 1\end{bmatrix}^T/\sqrt{2}$	1	2 layers: Precoding corresponding to precoder matrix $\frac{1}{2}\begin{bmatrix}1 & 1\\ j & -j\end{bmatrix}$
2	1 layer: Precoding corresponding to precoder vector $\begin{bmatrix}1 & -1\end{bmatrix}^T/\sqrt{2}$	2	2 layers: Precoding according to the latest PMI report on PUSCH, using the precoder(s) indicated by the reported PMI(s)
3	1 layer: Precoding corresponding to precoder vector $\begin{bmatrix}1 & j\end{bmatrix}^T/\sqrt{2}$	3	reserved
4	1 layer: Precoding corresponding to precoder vector $\begin{bmatrix}1 & -j\end{bmatrix}^T/\sqrt{2}$	4	reserved
5	1 layer: Precoding according to the latest PMI report on PUSCH, using the precoder(s) indicated by the reported PMI(s), if RI=2 was reported, using 1st column multiplied by $\sqrt{2}$ of all precoders implied by the reported PMI(s)	5	reserved
6	1 layer: Precoding according to the latest PMI report on PUSCH, using the precoder(s) indicated by the reported PMI(s), if RI=2 was reported, using 2nd column multiplied by $\sqrt{2}$ of all precoders implied by the reported PMI(s)	6	reserved
7	reserved	7	reserved

Petitioners' Exhibit 1003, p. 1396
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Table 5.3.3.1.5-5: Content of precoding information field for 4 antenna ports.

One codeword: Codeword 0 enabled, Codeword 1 disabled		Two codewords: Codeword 0 enabled, Codeword 1 enabled	
Bit field mapped to index	**Message**	**Bit field mapped to index**	**Message**
0	4 layers: Transmit diversity	0	2 layers: TPMI=0
1	1 layer: TPMI=0	1	2 layers: TPMI=1
2	1 layer: TPMI=1	⋮	⋮
⋮	⋮	15	2 layers: TPMI=15
16	1 layer: TPMI=15	16	2 layers: Precoding according to the latest PMI report on PUSCH using the precoder(s) indicated by the reported PMI(s)
17	1 layer: Precoding according to the latest PMI report on PUSCH using the precoder(s) indicated by the reported PMI(s)	17	3 layers: TPMI=0
18	2 layers: TPMI=0	18	3 layers: TPMI=1
19	2 layers: TPMI=1	⋮	⋮
⋮	⋮	32	3 layers: TPMI=15
33	2 layers: TPMI=15	33	3 layers: Precoding according to the latest PMI report on PUSCH using the precoder(s) indicated by the reported PMI(s)
34	2 layers: Precoding according to the latest PMI report on PUSCH using the precoder(s) indicated by the reported PMI(s)	34	4 layers: TPMI=0
35 – 63	reserved	35	4 layers: TPMI=1
		⋮	⋮
		49	4 layers: TPMI=15
		50	4 layers: Precoding according to the latest PMI report on PUSCH using the precoder(s) indicated by the reported PMI(s)
		51 – 63	Reserved

5.3.3.1.5A Format 2A

The following information is transmitted by means of the DCI format 2A:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].

- Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3]

Petitioners' Exhibit 1003, p. 1397
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed.

- Resource block assignment:

  - For resource allocation type 0 as defined in section 7.1.6.1 of [3]

    - $\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil$ bits provide the resource allocation

  - For resource allocation type 1 as defined in section 7.1.6.2 of [3]

    - $\lceil \log_2(P) \rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset

    - 1 bit indicates a shift of the resource allocation span

    - $\left(\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil - \lceil \log_2(P) \rceil - 1 \right)$ bits provide the resource allocation

  where the value of P depends on the number of DL resource blocks as indicated in section 7.1.6.1 of [3]

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2.

- HARQ process number - 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)

- Transport block to codeword swap flag – 1 bit

In addition, for transport block 1:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

In addition, for transport block 2:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

- Precoding information – number of bits as specified in Table 5.3.3.1.5A-1

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If both transport blocks are enabled, the transport block to codeword mapping is specified according to Table 5.3.3.1.5-1.

In case one of the transport blocks is disabled, the transport block to codeword swap flag is reserved and the transport block to codeword mapping is specified according to Table 5.3.3.1.5-2.

The precoding information field is defined according to Table 5.3.3.1.5A-2. For a single enabled codeword, index 1 in Table 5.3.3.1.5A-2 is only supported for retransmission of the corresponding transport block if that transport block has previously been transmitted using two layers with large delay CDD.

For transmission with 2 antenna ports, the precoding information field is not present. The number of transmission layers is equal to 2 if both codewords are enabled; transmit diversity is used if codeword 0 is enabled while codeword 1 is disabled.

Petitioners' Exhibit 1003, p. 1398
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

If the number of information bits in format 2A carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one zero bit shall be appended to format 2A.

Table 5.3.3.1.5A-1: Number of bits for precoding information.

Number of antenna ports at eNodeB	Number of bits for precoding information
2	0
4	2

Table 5.3.3.1.5A-2: Content of precoding information field for 4 antenna ports.

One codeword: Codeword 0 enabled, Codeword 1 disabled		Two codewords: Codeword 0 enabled, Codeword 1 enabled	
Bit field mapped to index	**Message**	**Bit field mapped to index**	**Message**
0	4 layers: Transmit diversity	0	2 layers: precoder cycling with large delay CDD
1	2 layers: precoder cycling with large delay CDD	1	3 layers: precoder cycling with large delay CDD
2	reserved	2	4 layers: precoder cycling with large delay CDD
3	reserved	3	reserved

5.3.3.1.5B Format 2B

The following information is transmitted by means of the DCI format 2B:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].

- Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3]

  If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed.

- Resource block assignment:

  - For resource allocation type 0 as defined in section 7.1.6.1 of [3]

    - $\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil$ bits provide the resource allocation

  - For resource allocation type 1 as defined in section 7.1.6.2 of [3]

    - $\lceil \log_2(P) \rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset

    - 1 bit indicates a shift of the resource allocation span

    - $\left(\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil - \lceil \log_2(P) \rceil - 1 \right)$ bits provide the resource allocation

  where the value of P depends on the number of DL resource blocks as indicated in section [7.1.6.1] of [3]

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2.

Petitioners' Exhibit 1003, p. 1399
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- HARQ process number - 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)

- Scrambling identity– 1 bit as defined in section 6.10.3.1 of [2]

- SRS request – [0-1] bit. This field can only be present for TDD operation and if present is defined in section 8.2 of [3]

In addition, for transport block 1:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

In addition, for transport block 2:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If both transport blocks are enabled, the number of layers equals two; transport block 1 is mapped to codeword 0; and transport block 2 is mapped to codeword 1. Antenna ports 7 and 8 are used for spatial multiplexing.

In case one of the transport blocks is disabled, the number of layers equals one; the transport block to codeword mapping is specified according to Table 5.3.3.1.5-2; and the antenna port for single-antenna port transmission is according to Table 5.3.3.1.5B-1.

Table 5.3.3.1.5B-1: Antenna port for single-antenna port transmission (one transport block disabled).

New data indicator of the disabled transport block	Antenna port
0	7
1	8

If the number of information bits in format 2B carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one zero bit shall be appended to format 2B.

5.3.3.1.5C Format 2C

The following information is transmitted by means of the DCI format 2C:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].

- Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3]

  If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed.

- Resource block assignment:

  - For resource allocation type 0 as defined in section 7.1.6.1 of [3]

    - $\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil$ bits provide the resource allocation

  - For resource allocation type 1 as defined in section 7.1.6.2 of [3]

Petitioners' Exhibit 1003, p. 1400
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- $\lceil \log_2(P) \rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset

- 1 bit indicates a shift of the resource allocation span

- $\left(\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil - \lceil \log_2(P) \rceil - 1 \right)$ bits provide the resource allocation

where the value of P depends on the number of DL resource blocks as indicated in section [7.1.6.1] of [3]

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2.

- HARQ process number - 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)

- Antenna port(s), scrambling identity and number of layers – 3 bits as specified in Table 5.3.3.1.5C-1 where n_{SCID} is the scrambling identity for antenna ports 7 and 8 defined in section 6.10.3.1 of [2], or 4bits as specified in Table 5.3.3.1.5C-2 where n_{SCID} is the scrambling identity for antenna ports 7, 8, 11 and 13 defined in section 6.10.3.1 of [2] when higher layer parameter *dmrs-tableAlt* is set to 1.

- SRS request – [0-1] bit. This field can only be present for TDD operation and if present is defined in section 8.2 of [3]

In addition, for transport block 1:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

In addition, for transport block 2:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If both transport blocks are enabled; transport block 1 is mapped to codeword 0; and transport block 2 is mapped to codeword 1.

In case one of the transport blocks is disabled; the transport block to codeword mapping is specified according to Table 5.3.3.1.5-2. For the single enabled codeword, Value = 4, 5, 6 in Table 5.3.3.1.5C-1 are only supported for retransmission of the corresponding transport block if that transport block has previously been transmitted using two, three or four layers, respectively.

If the number of information bits in format 2C carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one zero bit shall be appended to format 2C.

Table 5.3.3.1.5C-1: Antenna port(s), scrambling identity and number of layers indication

One Codeword: Codeword 0 enabled, Codeword 1 disabled		**Two Codewords: Codeword 0 enabled, Codeword 1 enabled**	
Value	**Message**	**Value**	**Message**
0	1 layer, port 7, n_{SCID}=0	0	2 layers, ports 7-8, n_{SCID}=0

Petitioners' Exhibit 1003, p. 1401
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

1	1 layer, port 7, n_{SCID}=1	1	2 layers, ports 7-8, n_{SCID}=1
2	1 layer, port 8, n_{SCID}=0	2	3 layers, ports 7-9
3	1 layer, port 8, n_{SCID}=1	3	4 layers, ports 7-10
4	2 layers, ports 7-8	4	5 layers, ports 7-11
5	3 layers, ports 7-9	5	6 layers, ports 7-12
6	4 layers, ports 7-10	6	7 layers, ports 7-13
7	Reserved	7	8 layers, ports 7-14

Table 5.3.3.1.5C-2: Antenna port(s), scrambling identity and number of layers indication

One Codeword: Codeword 0 enabled, Codeword 1 disabled		**Two Codewords: Codeword 0 enabled, Codeword 1 enabled**	
Value	**Message**	**Value**	**Message**
0	1 layer, port 7, n_{SCID}=0 (OCC=2)	0	2 layer, port 7-8, n_{SCID}=0 (OCC=2)
1	1 layer, port 7, n_{SCID}=1 (OCC=2)	1	2 layer, port 7-8, n_{SCID}=1 (OCC=2)
2	1 layer, port 8, n_{SCID}=0 (OCC=2)	2	2 layer, port 7-8, n_{SCID}=0 (OCC=4)
3	1 layer, port 8, n_{SCID}=1 (OCC=2)	3	2 layer, port 7-8, n_{SCID}=1 (OCC=4)
4	1 layer, port 7, n_{SCID}=0 (OCC=4)	4	2 layer, port 11,13, n_{SCID}=0 (OCC=4)
5	1 layer, port 7, n_{SCID}=1 (OCC=4)	5	2 layer, port 11,13, n_{SCID}=1 (OCC=4)
6	1 layer, port 8, n_{SCID}=0 (OCC=4)	6	3 layer, port 7-9
7	1 layer, port 8, n_{SCID}=1 (OCC=4)	7	4 layer, port 7-10
8	1 layer, port 11, n_{SCID}=0 (OCC=4)	8	5 layer, port 7-11
9	1 layer, port 11, n_{SCID}=1 (OCC=4)	9	6 layer, port 7-12
10	1 layer, port 13, n_{SCID}=0 (OCC=4)	10	7 layers, ports 7-13
11	1 layer, port 13, n_{SCID}=1 (OCC=4)	11	8 layers, ports 7-14
12	2 layers, ports 7-8	12	Reserved
13	3 layers, ports 7-9	13	Reserved
14	4 layers, ports 7-10	14	Reserved
15	Reserved	15	Reserved

5.3.3.1.5D Format 2D

The following information is transmitted by means of the DCI format 2D:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].

- Resource allocation header (resource allocation type 0 / type 1) – 1 bit as defined in section 7.1.6 of [3]

  If downlink bandwidth is less than or equal to 10 PRBs, there is no resource allocation header and resource allocation type 0 is assumed.

- Resource block assignment:

  - For resource allocation type 0 as defined in section 7.1.6.1 of [3]

    - $\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil$ bits provide the resource allocation

  - For resource allocation type 1 as defined in section 7.1.6.2 of [3]

    - $\lceil \log_2(P) \rceil$ bits of this field are used as a header specific to this resource allocation type to indicate the selected resource blocks subset

    - 1 bit indicates a shift of the resource allocation span

Petitioners' Exhibit 1003, p. 1402
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- $\left(\left\lceil N_{\mathrm{RB}}^{\mathrm{DL}} / P \right\rceil - \lceil \log_2(P) \rceil - 1\right)$ bits provide the resource allocation

where the value of P depends on the number of DL resource blocks as indicated in section [7.1.6.1] of [3]

- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]

- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2.

- HARQ process number - 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)

- Antenna port(s), scrambling identity and number of layers – 3 bits as specified in Table 5.3.3.1.5C-1 where n_{SCID} is the scrambling identity for antenna ports 7 and 8 defined in section 6.10.3.1 of [2], or 4bits as specified in Table 5.3.3.1.5C-2 where n_{SCID} is the scrambling identity for antenna ports 7, 8, 11 and 13 defined in section 6.10.3.1 of [2] when higher layer parameter *dmrs-tableAlt* is set to 1.

- SRS request – [0-1] bit. This field can only be present for TDD operation and if present is defined in section 8.2 of [3]

In addition, for transport block 1:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

In addition, for transport block 2:

- Modulation and coding scheme – 5 bits as defined in section 7.1.7 of [3]

- New data indicator – 1 bit

- Redundancy version – 2 bits

- PDSCH RE Mapping and Quasi-Co-Location Indicator – 2 bits as defined in sections 7.1.9 and 7.1.10 of [3]

- HARQ-ACK resource offset (this field is present when this format is carried by EPDCCH. This field is not present when this format is carried by PDCCH) – 2 bits as defined in section 10.1 of [3]. The 2 bits are set to 0 when this format is carried by EPDCCH on a secondary cell, or when this format is carried by EPDCCH on the primary cell scheduling PDSCH on a secondary cell and the UE is configured with PUCCH format 3 for HARQ-ACK feedback.

If both transport blocks are enabled; transport block 1 is mapped to codeword 0; and transport block 2 is mapped to codeword 1.

In case one of the transport blocks is disabled; the transport block to codeword mapping is specified according to Table 5.3.3.1.5-2. For the single enabled codeword, Value = 4, 5, 6 in Table 5.3.3.1.5C-1 are only supported for retransmission of the corresponding transport block if that transport block has previously been transmitted using two, three or four layers, respectively.

If the number of information bits in format 2D carried by PDCCH belongs to one of the sizes in Table 5.3.3.1.2-1, one zero bit shall be appended to format 2D.

5.3.3.1.6 Format 3

DCI format 3 is used for the transmission of TPC commands for PUCCH and PUSCH with 2-bit power adjustments.

The following information is transmitted by means of the DCI format 3:

- TPC command number 1, TPC command number 2,…, TPC command number N

where $N = \left\lfloor \frac{L_{\text{format 0}}}{2} \right\rfloor$, and where $L_{\text{format 0}}$ is equal to the payload size of format 0 before CRC attachment when format 0 is mapped onto the common search space, including any padding bits appended to format 0. The

Petitioners' Exhibit 1003, p. 1403
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

parameter *tpc-Index* or *tpc-Index-PUCCH-SCell-r13* provided by higher layers determines the index to the TPC command for a given UE.

If $\left\lfloor \frac{L_{\text{format 0}}}{2} \right\rfloor < \frac{L_{\text{format 0}}}{2}$, a bit of value zero shall be appended to format 3.

For BL/CE UE, $L_{\text{format 0}}$ and format 0 are replaced by $L_{\text{format 6-0A}}$ and format 6-0A, respectively, in the description above.

5.3.3.1.7 Format 3A

DCI format 3A is used for the transmission of TPC commands for PUCCH and PUSCH with single bit power adjustments.

The following information is transmitted by means of the DCI format 3A:

- TPC command number 1, TPC command number 2,…, TPC command number M

where $M = L_{\text{format 0}}$, and where $L_{\text{format 0}}$ is equal to the payload size of format 0 before CRC attachment when format 0 is mapped onto the common search space, including any padding bits appended to format 0. The parameter *tpc-Index* or *tpc-Index-PUCCH-SCell-r13* provided by higher layers determines the index to the TPC command for a given UE.

For BL/CE UE, $L_{\text{format 0}}$ and format 0 are replaced by $L_{\text{format 6-0A}}$ and format 6-0A, respectively, in the description above.

5.3.3.1.8 Format 4

DCI format 4 is used for the scheduling of PUSCH in one UL cell with multi-antenna port transmission mode,

The following information is transmitted by means of the DCI format 4:

- Carrier indicator – 0 or 3 bits. The field is present according to the definitions in [3].
- Resource block assignment - $\max\left(\left\lceil \log_2(N_{\text{RB}}^{\text{UL}}(N_{\text{RB}}^{\text{UL}}+1)/2) \right\rceil, \left\lceil \log_2\left(\left(\left\lceil N_{RB}^{UL}/P+1 \right\rceil \right) \right) \right\rceil \right)$ bits, where P is the UL RBG size as defined in section 8.1.2 of [3]
- For resource allocation type 0:
  - The $\left(\left\lceil \log_2(N_{\text{RB}}^{\text{UL}}(N_{\text{RB}}^{\text{UL}}+1)/2) \right\rceil \right)$ LSBs provide the resource allocation in the UL subframe as defined in section 8.1.1 of [3]
- For resource allocation type 1:
  - The $\left\lceil \log_2\left(\left(\left\lceil N_{RB}^{UL}/P+1 \right\rceil \right) \right) \right\rceil$ LSBs provide the resource allocation in the UL subframe as defined in section 8.1.2 of [3]
- TPC command for scheduled PUSCH – 2 bits as defined in section 5.1.1.1 of [3]
- Cyclic shift for DM RS and OCC index – 3 bits as defined in section 5.5.2.1.1 of [2]
- UL index – 2 bits as defined in sections 5.1.1.1, 7.2.1, 8 and 8.4 of [3] (this field is present only for TDD operation with uplink-downlink configuration 0)
- Downlink Assignment Index (DAI) – 2 bits as defined in section 7.3 of [3] (this field is present only for cases with TDD primary cell and either TDD operation with uplink-downlink configurations 1-6 or FDD operation)

Petitioners' Exhibit 1003, p. 1404
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- CSI request – 1, 2 or 3 bits as defined in section 7.2.1 of [3]. The 2-bit field applies to UEs configured with no more than five DL cells and to
  - UEs that are configured with more than one DL cell;
  - UEs that are configured by higher layers with more than one CSI process;
  - UEs that are configured with two CSI measurement sets by higher layers with the parameter *csi-MeasSubframeSet*;

  the 3-bit field applies to UEs that are configured with more than five DL cells;

  otherwise the 1-bit field applies
- SRS request – 2 bits as defined in section 8.2 of [3]
- Resource allocation type – 1 bit as defined in section 8.1 of [3]

In addition, for transport block 1:

- Modulation and coding scheme and redundancy version – 5 bits as defined in section 8.6 of [3]
- New data indicator – 1 bit

In addition, for transport block 2:

- Modulation and coding scheme and redundancy version – 5 bits as defined in section 8.6 of [3]
- New data indicator – 1 bit

Precoding information and number of layers: number of bits as specified in Table 5.3.3.1.8-1. Bit field as shown in Table 5.3.3.1.8-2 and Table 5.3.3.1.8- 3. Note that TPMI for 2 antenna ports indicates which codebook index is to be used in Table 5.3.3A.2-1 of [2], and TPMI for 4 antenna ports indicates which codebook index is to be used in Table 5.3.3A.2-2, Table 5.3.3A.2-3, Table 5.3.3A.2-4 and Table 5.3.3A.2-5 of [2]. If both transport blocks are enabled, transport block 1 is mapped to codeword 0; and transport block 2 is mapped to codeword 1. In case one of the transport blocks is disabled, the transport block to codeword mapping is specified according to Table 5.3.3.1.5-2. For a single enabled codeword, indices 24 to 39 in Table 5.3.3.1.8-3 are only supported for retransmission of the corresponding transport block if that transport block has previously been transmitted using two layers.

Table 5.3.3.1.8-1: Number of bits for precoding information.

Number of antenna ports at UE	Number of bits for precoding information
2	3
4	6

Table 5.3.3.1.8-2: Content of precoding information field for 2 antenna ports

One codeword: Codeword 0 enabled Codeword 1 disabled		Two codewords: Codeword 0 enabled Codeword 1 enabled	
Bit field mapped to index	**Message**	**Bit field mapped to index**	**Message**
0	1 layer: TPMI=0	0	2 layers: TPMI=0
1	1 layer: TPMI=1	1-7	reserved
2	1 layer: TPMI=2		
…	…		
5	1 layer: TPMI=5		
6-7	reserved		

Table 5.3.3.1.8-3: Content of precoding information field for 4 antenna ports

Petitioners' Exhibit 1003, p. 1405
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

One codeword: Codeword 0 enabled Codeword 1 disabled		Two codewords: Codeword 0 enabled Codeword 1 enabled	
Bit field mapped to index	**Message**	**Bit field mapped to index**	**Message**
0	1 layer: TPMI=0	0	2 layers: TPMI=0
1	1 layer: TPMI=1	1	2 layers: TPMI=1
…	…	…	…
23	1 layer: TPMI=23	15	2 layers: TPMI=15
24	2 layers: TPMI=0	16	3 layers: TPMI=0
25	2 layers: TPMI=1	17	3 layers: TPMI=1
…	…	…	…
39	2 layers: TPMI=15	27	3 layers: TPMI=11
40-63	reserved	28	4 layers: TPMI=0
		29 - 63	Reserved

If the number of information bits in format 4 is equal to the payload size for DCI format 1, 2, 2A, 2B, 2C or 2D associated with the configured DL transmission mode in the same serving cell, one zero bit shall be appended to format 4.

5.3.3.1.9 Format 5

DCI format 5 is used for the scheduling of PSCCH, and also contains several SCI format 0 fields used for the scheduling of PSSCH.

The following information is transmitted by means of the DCI format 5:

- Resource for PSCCH – 6 bits as defined in section 14.2.1 of [3]

-TPC command for PSCCH and PSSCH – 1 bit as defined in sections 14.2.1 and 14.1.1 of [3]

- SCI format 0 fields according to 5.4.3.1.1:

  - Frequency hopping flag

  - Resource block assignment and hopping resource allocation

  - Time resource pattern

If the number of information bits in format 5 mapped onto a given search space is less than the payload size of format 0 for scheduling the same serving cell, zeros shall be appended to format 5 until the payload size equals that of format 0 including any padding bits appended to format 0.

5.3.3.1.10 Format 6-0A

DCI format 6-0A is used for the scheduling of PUSCH in one UL cell.

The following information is transmitted by means of the DCI format 6-0A:

- Flag format 6-0A/format 6-1A differentiation – 1 bit, where value 0 indicates format 6-0A and value 1 indicates format 6-1A

- Frequency hopping flag – 1 bit as defined in section 5.3.4 of [2]

- Resource block assignment – $\left\lceil \log_2 \left\lfloor \frac{N_{RB}^{UL}}{6} \right\rfloor \right\rceil$ +5 bits for PUSCH as defined in [3]:

  - $\left\lceil \log_2 \left\lfloor \frac{N_{RB}^{UL}}{6} \right\rfloor \right\rceil$ MSB bits provide the narrowband index as defined in section 5.2.4 of [2]

  - 5 bits provide the resource allocation using UL resource allocation type 0 within the indicated narrowband

Petitioners' Exhibit 1003, p. 1406
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Modulation and coding scheme – 4 bits as defined in section 8.6 of [3]
- Repetition number – 2 bits as defined in section 8.0 of [3]
- HARQ process number – 3 bits
- New data indicator – 1 bit
- Redundancy version – 2 bits
- TPC command for scheduled PUSCH – 2 bits as defined in section 5.1.1.1 of [3]
- UL index – 2 bits as defined in sections 5.1.1.1, 7.2.1, 8 and 8.4 of [3] (this field is present only for TDD operation with uplink-downlink configuration 0)
- Downlink Assignment Index (DAI) – 2 bits as defined in section 7.3 of [3] (This field is present only for cases with TDD primary cell and either TDD operation with uplink-downlink configurations 1-6 or FDD operation. This field is reserved when the configured maximum repetition number is larger than 1 for either PDSCH or MPDCCH.)
- CSI request – 1 bit as defined in section 7.2.1 of [3]
- SRS request –1 bit. The interpretation of this field is provided in section 8.2 of [3]
- DCI subframe repetition number – 2 bits as defined in section 9.1.5 of [3]

If the number of information bits in format 6-0A mapped onto a given search space is less than the payload size of format 6-1A for scheduling the same serving cell and mapped onto the same search space (including any padding bits appended to format 6-1A), zeros shall be appended to format 6-0A until the payload size equals that of format 6-1A.

5.3.3.1.11 Format 6-0B

DCI format 6-0B is used for the scheduling of PUSCH in one UL cell.

The following information is transmitted by means of the DCI format 6-0B:

- Flag for format 6-0B/format 6-1B differentiation – 1 bit, where value 0 indicates format 6-0B and value 1 indicates format 6-1B
- Resource block assignment – $\left\lceil \log_2\left\lfloor \frac{N_{RB}^{UL}}{6} \right\rfloor \right\rceil$ +3 bits for PUSCH as defined in [3]:
  - $\left\lceil \log_2\left\lfloor \frac{N_{RB}^{UL}}{6} \right\rfloor \right\rceil$ MSB bits provide the narrowband index as defined in section 5.2.4 of [2]
  - 3 bits provide the resource allocation within the indicated narrowband as specified in section 8.1.3 of [3]
- Modulation and coding scheme – 4 bits as defined in section 8.6 of [3]
- Repetition number – 3 bits as defined in section 8.0 of [3]
- HARQ process number – 1 bit
- New data indicator – 1 bit
- DCI subframe repetition number – 2 bits as defined in section 9.1.5 of [3]

If the number of information bits in format 6-0B mapped onto a given search space is less than the payload size of format 6-1B for scheduling the same serving cell and mapped onto the same search space (including any padding bits appended to format 6-1B), zeros shall be appended to format 6-0B until the payload size equals that of format 6-1B.

Petitioners' Exhibit 1003, p. 1407
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.3.3.1.12 Format 6-1A

DCI format 6-1A is used for the compact scheduling of one PDSCH codeword in one cell and random access procedure initiated by a PDCCH order. The DCI corresponding to a PDCCH order can be carried by MPDCCH.

The following information is transmitted by means of the DCI format 6-1A:

- Flag format 6-0A/format 6-1A differentiation – 1 bit, where value 0 indicates format 6-0A and value 1 indicates format 6-1A

Format 6-1A is used for random access procedure initiated by a PDCCH order only if format 6-1A CRC is scrambled with C-RNTI and all the remaining fields are set as follows:

- Resource block assignment – $\left\lceil \log_2\left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}}{6} \right\rfloor \right\rceil$ +5 bits, where all bits shall be set to 1
- Preamble Index – 6 bits
- PRACH Mask Index – 4 bits, [5]
- Starting CE level – 2 bits provide the PRACH starting CE level as defined in [5]
- All the remaining bits in format 6-1A for compact scheduling assignment of one PDSCH codeword are set to zero

Otherwise,

- Frequency hopping flag – 1 bit as defined in section 6.4.1 of [2]
- Resource block assignment – $\left\lceil \log_2\left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}}{6} \right\rfloor \right\rceil$ +5 bits for PDSCH as defined in [3]:
  - $\left\lceil \log_2\left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}}{6} \right\rfloor \right\rceil$ MSB bits provide the narrowband index as defined in section 6.2.7 of [2]
  - 5 bits provide the resource allocation using DL resource allocation type 2 within the indicated narrowband
- Modulation and coding scheme – 4 bits as defined in section 7.1.7 of [3]
- Repetition number – 2 bits as defined in section 7.1.11 of [3]
- HARQ process number – 3 bits (for cases with FDD primary cell), 4 bits (for cases with TDD primary cell)
- New data indicator – 1 bit
- Redundancy version – 2 bits
- TPC command for PUCCH – 2 bits as defined in section 5.1.2.1 of [3]
  - If the format 6-1A CRC is scrambled by RA-RNTI:
    - The most significant bit of the TPC command is reserved.
    - The least significant bit of the TPC command indicates column $N_{\mathrm{PRB}}^{1\mathrm{A}}$ of the TBS table defined of [3].
    - If least significant bit is 0 then $N_{\mathrm{PRB}}^{1\mathrm{A}} = 2$ else $N_{\mathrm{PRB}}^{1\mathrm{A}} = 3$.
  - Else
    - The two bits including the most significant bit indicate the TPC command
- Downlink Assignment Index – number of bits as specified in Table 5.3.3.1.2-2. This field is reserved when the configured maximum repetition number is larger than 1 for either PDSCH or MPDCCH.

Petitioners' Exhibit 1003, p. 1408
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Antenna port(s) and scrambling identity – 2 bits indicating the values 0 to 3, as specified in Table 5.3.3.1.5C-1. This field is present only if PDSCH transmission is configured with TM9.
- SRS request –1 bit. The interpretation of this field is provided in section 8.2 of [3]
- TPMI information for precoding – number of bits as specified in Table 5.3.3.1.3A-1.
  - TPMI information indicates which codebook index is used in Table 6.3.4.2.3-1 or Table 6.3.4.2.3-2 of [2] corresponding to the single-layer transmission. This field is present only if PDSCH transmission is configured with TM6.
- PMI confirmation for precoding – 1 bit as specified in Table 5.3.3.1.3A-2. This field is present only if PDSCH transmission is configured with TM6.
- HARQ-ACK resource offset – 2 bits as defined in section 10.1 of [3]
- DCI subframe repetition number – 2 bits as defined in section 9.1.5 of [3]

When the format 6-1A CRC is scrambled with a RA-RNTI, then the following fields among the fields above are reserved:

- HARQ process number
- New data indicator
- Downlink Assignment Index
- HARQ-ACK resource offset

5.3.3.1.13 Format 6-1B

DCI format 6-1B is used for the scheduling of one PDSCH codeword in one cell.

The following information is transmitted by means of the DCI format 6-1B:

- Flag for format 6-0B/format 6-1B differentiation – 1 bit, where value 0 indicates format 6-0B and value 1 indicates format 6-1B

Format 6-1B is used for random access procedure initiated by a PDCCH order only if format 6-1B CRC is scrambled with C-RNTI and all the remaining fields are set as follows:

- Resource block assignment – $\left\lceil \log_2\left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}}{6} \right\rfloor \right\rceil$ +1 bits, where all bits shall be set to 1
- Preamble Index – 6 bits
- PRACH Mask Index – 4 bits [5]
- Starting CE level – 2 bits provide the PRACH starting CE level as defined in [5]
- All the remaining bits in format 6-1B for compact scheduling assignment of one PDSCH codeword are set to zero

Otherwise,

- Resource block assignment – $\left\lceil \log_2\left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}}{6} \right\rfloor \right\rceil$ +1 bits for PDSCH as defined in [3]:
  - $\left\lceil \log_2\left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}}{6} \right\rfloor \right\rceil$ MSB bits provide the narrowband index as defined in section 6.2.7 of [2]
  - 1 bit provides the resource allocation within the indicated narrowband, where value 0 indicates RBs with PRB index {0, 1, 2, 3} and value 1 indicates that all 6 PRBs are used.

Petitioners' Exhibit 1003, p. 1409
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Modulation and coding scheme – 4 bits as defined in section 7.1.7 of [3]- Repetition number – 3 bits as defined in section 7.1.11 of [3]
- HARQ process number – 1 bit
- New data indicator – 1 bit
- HARQ-ACK resource offset – 2 bits as defined in section 10.1 of [3]
- DCI subframe repetition number –2 bits as defined in section 9.1.5 of [3]

When the format 6-1B CRC is scrambled with a RA-RNTI then the following fields among the fields above are reserved:

- HARQ process number
- New data indicator
- HARQ-ACK resource offset

5.3.3.1.14 Format 6-2

DCI format 6-2 is used for for paging and direct indication.

The following information is transmitted by means of the DCI format 6-2:

- Flag for paging/direct indication differentiation – 1 bit, with value 0 for direct indication and value 1 for paging
- If Flag=0:
  - Direct Indication information – 8 bits provide direct indication of system information update and other fields, as defined in [6]
  - Reserved information bits are added until the size is equal to that of format 6-2 with Flag=1
- If Flag=1:
  - Resource block assignment – $\left\lceil \log_2 \left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{DL}}}{6} \right\rfloor \right\rceil$ bits for the narrowband index as defined in section 7.1.6 of [3]
  - Modulation and coding scheme – 4 bits as defined in section 7.1.7 of [3]
  - Repetition number – 3 bits as defined in section 7.1.11 of [3]
  - DCI subframe repetition number – 2 bits as defined in section 9.1.5 of [3]

5.3.3.2 CRC attachment

Error detection is provided on DCI transmissions through a Cyclic Redundancy Check (CRC).

The entire payload is used to calculate the CRC parity bits. Denote the bits of the payload by $a_0, a_1, a_2, a_3, ..., a_{A-1}$, and the parity bits by $p_0, p_1, p_2, p_3, ..., p_{L-1}$. A is the payload size and L is the number of parity bits.

The parity bits are computed and attached according to section 5.1.1 setting L to 16 bits, resulting in the sequence $b_0, b_1, b_2, b_3, ..., b_{B-1}$, where $B = A + L$.

In the case where closed-loop UE transmit antenna selection is not configured or applicable, after attachment, the CRC parity bits are scrambled with the corresponding RNTI $x_{rnti,0}, x_{rnti,1}, ..., x_{rnti,15}$, where $x_{rnti,0}$ corresponds to the MSB of the RNTI, to form the sequence of bits $c_0, c_1, c_2, c_3, ..., c_{B-1}$. The relation between c_k and b_k is:

$c_k = b_k$ for k = 0, 1, 2, …, A-1

Petitioners' Exhibit 1003, p. 1410
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

$c_k = (b_k + x_{rnti,k-A}) \bmod 2$ for $k = A, A+1, A+2, ..., A+15$.

In the case where closed-loop UE transmit antenna selection is configured and applicable, after attachment, the CRC parity bits with DCI format 0 are scrambled with the antenna selection mask $x_{AS,0}, x_{AS,1}, ..., x_{AS,15}$ as indicated in Table 5.3.3.2-1 and the corresponding RNTI $x_{rnti,0}, x_{rnti,1}, ..., x_{rnti,15}$ to form the sequence of bits $c_0, c_1, c_2, c_3, ..., c_{B-1}$. The relation between c_k and b_k is:

$c_k = b_k$ for $k = 0, 1, 2, \ldots, A-1$

$c_k = (b_k + x_{rnti,k-A} + x_{AS,k-A}) \bmod 2$ for $k = A, A+1, A+2, ..., A+15$.

Table 5.3.3.2-1: UE transmit antenna selection mask.

UE transmit antenna selection	Antenna selection mask $< x_{AS,0}, x_{AS,1}, ..., x_{AS,15} >$
UE port 0	<0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0>
UE port 1	<0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1>

5.3.3.3 Channel coding

Information bits are delivered to the channel coding block. They are denoted by $c_0, c_1, c_2, c_3, ..., c_{K-1}$, where K is the number of bits, and they are tail biting convolutionally encoded according to section 5.1.3.1.

After encoding the bits are denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, d_3^{(i)}, ..., d_{D-1}^{(i)}$, with $i = 0,1,$ and 2, and where D is the number of bits on the i-th coded stream, i.e., $D = K$.

5.3.3.4 Rate matching

A tail biting convolutionally coded block is delivered to the rate matching block. This block of coded bits is denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, d_3^{(i)}, ..., d_{D-1}^{(i)}$, with $i = 0,1,$ and 2, and where i is the coded stream index and D is the number of bits in each coded stream. This coded block is rate matched according to section 5.1.4.2.

After rate matching, the bits are denoted by $e_0, e_1, e_2, e_3, ..., e_{E-1}$, where E is the number of rate matched bits.

5.3.4 Control format indicator

Data arrives each subframe to the coding unit in the form of an indicator for the time span, in units of OFDM symbols, of the DCI carried by PDCCH in that subframe of the corresponding DL cell. The CFI takes values CFI = 1, 2 or 3. For system bandwidths $N_{RB}^{DL} > 10$, the span of the DCI carried by PDCCH in units of OFDM symbols, 1, 2 or 3, is given by the CFI. For system bandwidths $N_{RB}^{DL} \leq 10$, the span of the DCI carried by PDCCH in units of OFDM symbols, 2, 3 or 4, is given by CFI+1.

The coding flow is shown in Figure 5.3.4-1.

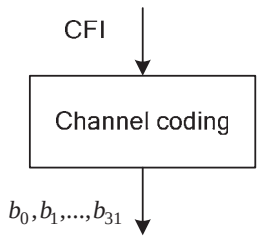


Figure 5.3.4-1 Coding for CFI.

Petitioners' Exhibit 1003, p. 1411
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.3.4.1 Channel coding

The control format indicator is coded according to Table 5.3.4-1.

Table 5.3.4-1: CFI code words.

CFI	CFI code word < b_0, b_1, …, b_{31} >
1	<0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1>
2	<1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0>
3	<1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1>
4 (Reserved)	<0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0>

5.3.5 HARQ indicator (HI)

Data arrives to the coding unit in the form of indicators for HARQ acknowledgement for one transport block.

The coding flow is shown in Figure 5.3.5-1.

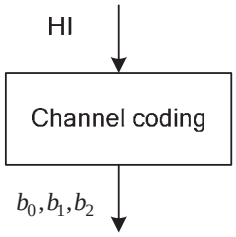


Figure 5.3.5-1 Coding for HI.

5.3.5.1 Channel coding

The HI is coded according to Table 5.3.5-1, where for a positive acknowledgement HI = 1 and for a negative acknowledgement HI = 0.

Table 5.3.5-1: HI code words.

HI	HI code word < b_0, b_1, b_2 >
0	< 0,0,0 >
1	< 1,1,1 >

5.4 Sidelink transport channels and control information

5.4.1 Sidelink broadcast channel

Figure 5.4.1-1 shows the processing structure for the SL-BCH transport channel. Data arrives to the coding unit in the form of a maximum of one transport block. The following coding steps can be identified:

- Add CRC to the transport block

Petitioners' Exhibit 1003, p. 1412
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Channel coding
- Rate matching

The coding steps for SL-BCH transport channel are shown in the figure below. In addition, after rate matching PUSCH interleaving is applied according to sections 5.2.2.7 and 5.2.2.8 without any control information in order to apply a time-first rather than frequency-first mapping, where $C_{mux} = 2 \cdot \left(N_{\text{symb}}^{\text{SL}} - 3\right)$ and the sequence of bits f is equal to e.

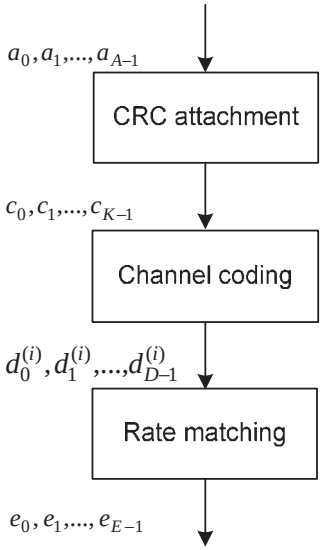


Figure 5.4.1-1: Transport channel processing for SL-BCH.

5.4.1.1 Transport block CRC attachment

Error detection is provided on transport blocks through a Cyclic Redundancy Check (CRC).

The entire transport block is used to calculate the CRC parity bits. Denote the bits in a transport block delivered to layer 1 by $a_0, a_1, a_2, a_3, ..., a_{A-1}$, and the parity bits by $p_0, p_1, p_2, p_3, ..., p_{L-1}$. A is the size of the transport block and L is the number of parity bits. The lowest order information bit a_0 is mapped to the most significant bit of the transport block as defined in section 6.1.1 of [5].

The parity bits are computed and attached according to section 5.1.1 setting L to 16 bits, resulting in the sequence of bits $c_0, c_1, c_2, c_3, ..., c_{K-1}$ where $c_k = b_k$ for k = 0, 1, 2, …, K-1 and K=A+L.

5.4.1.2 Channel coding

Information bits are delivered to the channel coding block. They are denoted by $c_0, c_1, c_2, c_3, ..., c_{K-1}$, where K is the number of bits, and they are tail biting convolutionally encoded according to section 5.1.3.1.

After encoding the bits are denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, d_3^{(i)}, ..., d_{D-1}^{(i)}$, with i = 0,1, and 2, and where D is the number of bits on the i-th coded stream, i.e., $D = K$.

5.4.1.3 Rate matching

A tail biting convolutionally coded block is delivered to the rate matching block. This block of coded bits is denoted by $d_0^{(i)}, d_1^{(i)}, d_2^{(i)}, d_3^{(i)}, ..., d_{D-1}^{(i)}$, with i = 0,1, and 2, and where i is the coded stream index and D is the number of bits in each coded stream. This coded block is rate matched according to section 5.1.4.2.

After rate matching, the bits are denoted by $e_0, e_1, e_2, e_3, ..., e_{E-1}$, where E is the number of rate matched bits as defined in section 9.6.1 of [2].

Petitioners' Exhibit 1003, p. 1413
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

5.4.2 Sidelink shared channel

The processing of the sidelink shared channel follows the downlink shared channel according to section 5.3.2, with the following differences:

- Data arrives to the coding unit in the form of a maximum of one transport block every transmission time interval (TTI)
- In the step of code block concatenation, the sequence of coded bits corresponding to one transport block after code block concatenation is referred to as one codeword in section 9.3.1 of [2].
- PUSCH interleaving is applied according to sections 5.2.2.7 and 5.2.2.8 without any control information in order to apply a time-first rather than frequency-first mapping, where $C_{mux} = 2 \cdot \left(N_{\text{symb}}^{\text{SL}} - 1\right)$.

5.4.3 Sidelink control information

An SCI transports sidelink scheduling information for one destination ID.

The processing for one SCI follows the downlink control information according to section 5.3.3, with the following differences:

- In the step of CRC attachment, no scrambling is performed.
- PUSCH interleaving is applied according to sections 5.2.2.7 and 5.2.2.8 without any control information in order to apply a time-first rather than frequency-first mapping, where $C_{mux} = 2 \cdot \left(N_{\text{symb}}^{\text{SL}} - 1\right)$ and the sequence of bits *f* is equal to *e*.

5.4.3.1 SCI formats

The fields defined in the SCI formats below are mapped to the information bits a_0 to a_{A-1} as follows.

Each field is mapped in the order in which it appears in the description, with the first field mapped to the lowest order information bit a_0 and each successive field mapped to higher order information bits. The most significant bit of each field is mapped to the lowest order information bit for that field, e.g. the most significant bit of the first field is mapped to a_0.

5.4.3.1.1 SCI format 0

SCI format 0 is used for the scheduling of PSSCH.

The following information is transmitted by means of the SCI format 0:

- Frequency hopping flag – 1 bit as defined in section 14.1.1 of [3].
- Resource block assignment and hopping resource allocation – $\left\lceil \log_2(N_{\text{RB}}^{\text{SL}}(N_{\text{RB}}^{\text{SL}}+1)/2) \right\rceil$ bits
  - For PSSCH hopping:
    - N_{SL_hop} MSB bits are used to obtain the value of $\tilde{n}_{PRB}(i)$ as indicated in section 8.4 of [3]
    - $\left(\left\lceil \log_2(N_{\text{RB}}^{\text{SL}}(N_{\text{RB}}^{\text{SL}}+1)/2) \right\rceil - N_{\text{SL\_hop}} \right)$ bits provide the resource allocation in the subframe
  - For non-hopping PSSCH:
    - $\left(\left\lceil \log_2(N_{\text{RB}}^{\text{SL}}(N_{\text{RB}}^{\text{SL}}+1)/2) \right\rceil \right)$ bits provide the resource allocation in the subframe as defined in section 8.1.1 of [3]
- Time resource pattern – 7 bits as defined in section 14.1.1 of [3].

Petitioners' Exhibit 1003, p. 1414
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

- Modulation and coding scheme – 5 bits as defined in section 14.1.1 of [3]

- Timing advance indication – 11 bits as defined in section 14.2.1 of [3]

- Group destination ID – 8 bits as defined by higher layers

5.4.4 Sidelink discovery channel

The processing of the sidelink discovery channel follows the downlink shared channel according to section 5.3.2, with the following differences:

- Data arrives to the coding unit in the form of a maximum of one transport block every transmission time interval (TTI)

- In the step of code block concatenation, the sequence of coded bits corresponding to one transport block after code block concatenation is referred to as one codeword in section 9.5.1 of [2].

- PUSCH interleaving is applied according to sections 5.2.2.7 and 5.2.2.8 without any control information in order to apply a time-first rather than frequency-first mapping, where $C_{mux} = 2 \cdot \left(N_{\text{symb}}^{\text{SL}} - 1 \right)$.

Petitioners' Exhibit 1003, p. 1415
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Annex A (informative): Change history

Petitioners' Exhibit 1003, p. 1416
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
2006-09					Skeleton		0.0.0
2006-10					Updated skeleton	0.0.0	0.0.1
2006-10					Endorsed skeleton	0.0.1	0.1.0
2006-11					Added TC. Added Broadcast, Paging and MBMS transport channels in Table 4.2-1.	0.1.0	0.1.1
2006-11					Endorsed v 0.2.0	0.1.1	0.2.0
2006-12					Added CC. Added type of coding for each transport channel or control information.	0.2.0	0.2.1
2007-01					Editor"s version	0.2.1	0.2.2
2007-01					Endorsed v 0.3.0	0.2.2	0.3.0
2007-02					Added QPP turbo Interleaver description.	0.3.0	0.3.1
2007-02					Editor"s version	0.3.1	0.3.2
2007-02					Endorsed v 0.4.0	0.3.2	0.4.0
2007-02					Added CRC details for PDSCH, PDCCH and PUSCH. Added QPP turbo-interleaver parameters. Set Z to 6144. Added details on code block segmentation.	0.4.0	0.4.1
2007-02					Editor"s version	0.4.1	0.4.2
2007-03	RAN#35	RP-070170			For information at RAN#35	0.4.2	1.0.0
2007-03					Editor"s version	1.0.0	1.0.1
2007-03					Editor"s version	1.0.1	1.1.0
2007-05					Editor"s version	1.1.0	1.1.1
2007-05					Editor"s version	1.1.1	1.1.2
2007-05					Editor"s version	1.1.2	1.2.0
2007-06					Added circular buffer rate matching for PDSCH and PUSCH. Miscellaneous changes.	1.2.0	1.2.1
2007-06					Editor"s version	1.2.1	1.2.2
2007-07					Editor"s version	1.2.2	1.2.3
2007-07					Endorsed by email following decision taken at RAN1#49b	1.2.3	1.3.0
2007-08					Editor"s version including decision from RAN1#49bis.	1.3.0	1.3.1
2007-08					Editor"s version	1.3.1	1.3.2
2007-08					Editor"s version	1.3.2	1.4.0
2007-09					Editor"s version with decisions from RAN1#50	1,4.0	1,4,1
2007-09					Editor"s version	1.4.1	1.4.2
10/09/07	RAN#37	RP-070730	-	-	For approval at RAN#37	1.4.2	2.0.0
12/09/07	RAN_37	RP-070730	-	-	Approved version	2.0.0	8.0.0
28/11/07	RAN_38	RP-070949	0001	-	Update of 36.212	8.0.0	8.1.0
05/03/08	RAN_39	RP-080145	0002	-	Update to 36.212 incorporating decisions from RAN1#51bis and RAN1#52	8.1.0	8.2.0
28/05/08	RAN_40	RP-080433	0003	-	Joint coding of CQI and ACK on PUCCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0004	1	ACK insertion into PUSCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0005	1	Introduction of format 1C	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0006	1	Miscellaneous fixes to 36.212	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0008	1	On multiplexing scheme for indicators	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0009	1	On the soft buffer split of MIMO and TDD	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0010	-	Resource assignment field for distributed VRB	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0011	-	Clarifying the use of the different DCI formats	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0012	1	Clarifying the value of N_L	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0013	-	Payload size for DCI formats 3 and 3A	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0014	-	Coding of ACK on PUSCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0015	1	Coding of RI on PUSCH and mapping	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0016	-	CRC for control information on PUSCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0017	-	Introduction of Downlink Assignment Index	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0018	-	Coding of CQI/PMI on PUSCH coming from PUCCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0019	-	Simultaneous transmission of aperiodic CQI and UL control	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0020	-	Encoding of antenna indicator on DCI format 0	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0021	-	PDCCH coverage in narrow bandwidths	8.2.0	8.3.0
28/05/08	RAN_40	RP-080433	0022	-	Closed-loop and open-loop spatial multiplexing	8.2.0	8.3.0
28/05/08	RAN_40	RP-080457	0023	-	Formula for linkage between PUSCH MCS and amount of resources used for control	8.2.0	8.3.0
09/09/08	RAN_41	RP-080669	0026	-	Correction to PUSCH Channel Interleaver	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0028	-	Correction of mapping of ACK/NAK to binary bit values	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0029	-	Correction to bit collection, selection and transmission	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0030	-	Padding one bit to DCI format 1 when format 1 and format 0/1A have the same size	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0031	-	Modification of M_limit	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0032	-	Definition of Formats 2 and 2A	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0033	2	Corrections to DCI formats	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0035	1	Format 1B confirmation flag	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0036	-	Corrections to Rank information scrambling in Uplink Shared Channel	8.3.0	8.4.0

Petitioners' Exhibit 1003, p. 1417
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
09/09/08	RAN_41	RP-080669	0037	2	Clarification of TPC commands signaled in DCI formats 3/3A	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0038	-	Clarification on UE transmit antenna selection mask	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0039	1	Linking of control resources in PUSCH to data MCS	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0041	-	Definition of Bit Mapping for DCI signalling	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0042	1	Clarification on resource allocation in DCI format 1/2/2A	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0043	-	DCI Format 1A changes needed for scheduling Broadcast Control	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0044	-	DCI format1C	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0045	-	Miscellaneous corrections	8.3.0	8.4.0
11/09/08	RAN_41	RP-080736	0046	1	Correction on downlink multi-user MIMO	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0047	-	Corrections to DL DCI Formats In case of Ambiguous Payload Sizes	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0048	-	CR for RE provisioning for the control information in case of CQI-only transmission on PUSCH	8.3.0	8.4.0
09/09/08	RAN_41	RP-080669	0091	2	Coding and multiplexing of multiple ACK/NACK in PUSCH	8.3.0	8.4.0
03/12/08	RAN_42	RP-080983	0050	2	Clarification of input bits corresponding to 2-bit HARQ-ACK and 2-bit RI	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0053	-	Editorial corrections to 36.212	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0055	-	Miscellaneous Corrections	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0057	-	Clarification of mapping of information bits	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0058	-	Completion of 36.212 CR47 (R1-083421) for 'new' DCI Formats	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0059	-	Change for determining DCI format 1A TBS table column indicator for broadcast control	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0061	2	Defining DCI format 1A for downlink data arrival	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0063	1	ACK/NACK transmission on PUSCH for LTE TDD	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0065	-	Correction in 36.212 related to TDD downlink HARQ processes	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0067	1	Correction of control MCS offset and SRS symbol puncturing	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0068	1	DCI format 2/2A	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0069	-	Correction to zero padding in DCI format 1	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0071	-	Clarification of RI bit field mapping for PUCCH	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0072	-	Clarifying RNTI bit mapping for PDCCH CRC scrambling	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0073	-	Clarification on BCH transport block size	8.4.0	8.5.0
03/12/08	RAN_42	RP-080983	0076	-	Clarification on the number of PUCCH-based CQI/PMI bits when reported on PUSCH	8.4.0	8.5.0
04/03/09	RAN_43	RP-090235	77	1	Corrections to Transmitted Rank Indication	8.5.0	8.6.0
04/03/09	RAN_43	RP-090235	79	1	Correction to the bundled ACK/NACK and DAI transmission	8.5.0	8.6.0
04/03/09	RAN_43	RP-090235	80	2	Corrections to transmission modes	8.5.0	8.6.0
04/03/09	RAN_43	RP-090235	81	1	Correction on ACKNACK transmission on PUSCH for LTE TDD	8.5.0	8.6.0
04/03/09	RAN_43	RP-090235	82	2	Corrections to CQI and RI fields description	8.5.0	8.6.0
04/03/09	RAN_43	RP-090235	83	-	Clarifying DCI format 1A and DCI Format 1B	8.5.0	8.6.0
04/03/09	RAN_43	RP-090235	92	1	Clarification on channel coding for UCI HARQ-ACK	8.5.0	8.6.0
27/05/09	RAN_44	RP-090528	87	-	Clarify some parameters for determining control resources on PUSCH	8.6.0	8.7.0
01/12/09	RAN_46	RP-091168	89	-	Clarification on bitwidth of RI	8.7.0	8.8.0
01/12/09	RAN_46	RP-091168	94	-	Correction to Channel interleaver for PUSCH RE Mapping	8.7.0	8.8.0
01/12/09	RAN_46	RP-091177	88	1	Editorial corrections to 36.212	8.8.0	9.0.0
01/12/09	RAN_46	RP-091257	95	1	Introduction of enhanced dual layer transmission	8.8.0	9.0.0
16/03/10	RAN_47	RP-100210	96	1	MCCH change notification using DCI format 1C	9.0.0	9.1.0
16/03/10	RAN_47	RP-100211	97	-	Addition of missing reference to DCI format 2B + typo corrections	9.0.0	9.1.0
01/06/10	RAN_48	RP-100589	98	-	Correction to TBS determination for DCI format 1C	9.1.0	9.2.0
14/09/10	RAN_49	RP-100899	99	-	Clarify soft buffer size determination for MCH	9.2.0	9.3.0
07/12/10	RAN_50	RP-101320	100	-	Introduction of Rel-10 LTE-Advanced features in 36.212	9.3.0	10.0.0
15/03/11	RAN_51	RP-110254	101	-	Correction on UE behavior upon receiving DCI format 1B	10.0.0	10.1.0
15/03/11	RAN_51	RP-110256	102	-	Corrections to Rel-10 LTE-Advanced features in 36.212	10.0.0	10.1.0
01/06/11	RAN_52	RP-110819	103	3	Correction of DCI format 0 and 4 resource allocation	10.1.0	10.2.0
01/06/11	RAN_52	RP-110819	104	2	Correction to Multi-cluster flag in DCI format 0	10.1.0	10.2.0
01/06/11	RAN_52	RP-110819	107	2	Corrections on HARQ-ACK Channel Coding in the PUSCH	10.1.0	10.2.0
01/06/11	RAN_52	RP-110820	108	3	A clarification for DCI format payload size	10.1.0	10.2.0
01/06/11	RAN_52	RP-110819	110	1	Correction the search space and RNTI for CQI and SRS request flag	10.1.0	10.2.0
01/06/11	RAN_52	RP-110819	111	-	Resource dimensioning for CQI only PUSCH transmission	10.1.0	10.2.0
01/06/11	RAN_52	RP-110820	112	1	Correction on bit representations of transport block processing for UL-SCH	10.1.0	10.2.0
01/06/11	RAN_52	RP-110818	113	-	Clarification on PMI indication in DCI format1B and format 2	10.1.0	10.2.0
01/06/11	RAN_52	RP-110820	114	1	Rate maching parameters for CA	10.1.0	10.2.0
01/06/11	RAN_52	RP-110819	116	-	HARQ-ACK on PUSCH for TDD with channel selection configured for 2 serving cells	10.1.0	10.2.0
01/06/11	RAN_52	RP-110823	117	-	Single codeword multiple layer transmission in uplink	10.1.0	10.2.0
15/09/11	RAN_53	RP-111228	119	1	Corrections on transport block processing for UL-SCH	10.2.0	10.3.0

Petitioners' Exhibit 1003, p. 1418
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
15/09/11	RAN_53	RP-111230	120	2	On correction of channel coding of control information	10.2.0	10.3.0
15/09/11	RAN_53	RP-111230	122	1	Size adjustment of DCI format 0, 1A and 1	10.2.0	10.3.0
15/09/11	RAN_53	RP-111232	123	1	Corrections on *Nsrs*	10.2.0	10.3.0
15/09/11	RAN_53	RP-111232	124	2	Corrections on DCI format 1B/1D	10.2.0	10.3.0
15/09/11	RAN_53	RP-111228	125	-	Minor Correction on DCI Format 1 Description	10.2.0	10.3.0
15/09/11	RAN_53	RP-111226	127	-	Correction on ACK/NACK mapping	10.2.0	10.3.0
15/09/11	RAN_53	RP-111231	128	-	Corrections on channel coding of control information and DCI Format 4.	10.2.0	10.3.0
15/09/11	RAN_53	RP-111229	129	-	Clarification and correction to configuration signalling condition for channel quality information formats	10.2.0	10.3.0
05/12/11	RAN_54	RP-111667	130	1	Corrections on codebook index indication in DCI format 4	10.3.0	10.4.0
05/12/11	RAN_54	RP-111666	131	-	HARQ-ACK on UCI-only PUSCH without UL-SCH data	10.3.0	10.4.0
28/02/12	RAN_55	RP-120283	132	2	Corrections on payload size adjustment for DCI format 1A and 1	10.4.0	10.5.0
28/02/12	RAN_55	RP-120283	133	1	Correction of two HARQ-ACK feedback on PUSCH	10.4.0	10.5.0
28/02/12	RAN_55	RP-120285	134	1	Miscellaneous corrections	10.4.0	10.5.0
13/06/12	RAN_56	RP-120739	136	-	Correction to Data and control multiplexing	10.5.0	10.6.0
13/06/12	RAN_56	RP-120737	138	-	Correction to CSI request field size in DCI format 0 and DCI format 4	10.5.0	10.6.0
04/09/12	RAN_57	RP-121272	139	-	Introduction of Rel-11 LTE-Advanced features in 36.212	10.6.0	11.0.0
04/12/12	RAN_58	RP-121839	143	-	Correction to the parameter ue-Category-v10xy	11.0.0	11.1.0
04/12/12	RAN_58	RP-121846	144	-	Finalisation for introducing Rel-11 features	11.0.0	11.1.0
26/02/13	RAN_59	RP-130255	145	-	Additional clarifications/corrections for introducing Rel-11 features	11.1.0	11.2.0
11/06/13	RAN_60	RP-130751	147	2	Correction on the RI bit width	11.2.0	11.3.0
11/06/13	RAN_60	RP-130747	148	-	CR on DCI Format 4 payload size	11.2.0	11.3.0
11/06/13	RAN_60	RP-130752	149	-	Correction on the time span of the DCI	11.2.0	11.3.0
11/06/13	RAN_60	RP-130752	150	-	Correction on ARO bit setting for DL DCIs carried by EPDCCH	11.2.0	11.3.0
11/06/13	RAN_60	RP-130750	151	-	Clarification on DL DAI usage in inter-band TDD CA	11.2.0	11.3.0
11/06/13	RAN_60	RP-130749	153	-	Correction to bit padding of DCI format 1A for secondary cell without uplink component carrier	11.2.0	11.3.0
03/12/13	RAN_62	RP-131893	155	1	Correction on parameter ue-Category	11.3.0	11.4.0
03/12/13	RAN_62	RP-131896	154	3	Introduction of Rel 12 feature for Downlink MIMO Enhancement	11.4.0	12.0.0
10/06/14	RAN_64	RP-140858	156	-	Clarification on UE antenna port based CRC masking	12.0.0	12.1.0
10/06/14	RAN_64	RP-140859	157	1	Correction on UCI multiplexing on PUSCH	12.0.0	12.1.0
10/06/14	RAN_64	RP-140862	158	-	Introduction of Rel 12 features of TDD-FDD CA and eIMTA	12.0.0	12.1.0
10/06/14	RAN_64	RP-140858	159	-	Clarification of downlink subframes	12.0.0	12.1.0
10/09/14	RAN_65	RP-141485	161	-	CR for 36.212 on 256QAM and LC-MTC	12.1.0	12.2.0
08/12/14	RAN_66	RP-142106	163	3	CR for 36.212 on 256QAM and LC-MTC	12.2.0	12.3.0
08/12/14	RAN_66	RP-142098	164	3	Clarification of PUSCH rate matching with SRS	12.2.0	12.3.0
08/12/14	RAN_66	RP-142107	166	-	Introduction of Dual Connectivity feature into 36.212	12.2.0	12.3.0
09/03/15	RAN_67	RP-150366	162	3	Introduction of D2D feature into 36.212	12.3.0	12.4.0
15/06/15	RAN_68	RP-150936	169	-	Corrections on eIMTA RRC parameter naming	12.4.0	12.5.0
15/06/15	RAN_68	RP-150937	171	1	Correction for 36.212 on soft buffer assumption	12.4.0	12.5.0
14/09/15	RAN_69	RP-151466	174	1	Introducing 4-layer MIMO transmission in TM3 and TM4	12.5.0	12.6.0
14/09/15	RAN_69	RP-151467	175	2	Introduction of MIMO capability signalling for intra-band contiguous CA	12.50	12.6.0
07/12/15	RAN_70	RP-152038	177	-	Correction on rank indication bit widths	12.6.0	12.7.0
07/12/15	RAN_70	RP-152027	178	1	Introduction of Rel 13 feature of eCA	12.7.0	13.0.0
07/12/15	RAN_70	RP-152025	179	1	Introduction of EB/FD-MIMO	12.7.0	13.0.0
07/12/15	RAN_70	RP-152026	180	2	Introduction of Rel 13 feature of LAA	12.7.0	13.0.0
07/12/15	RAN_70	RP-152031	182	-	Introduction of Rel 13 features for SC-PTM	12.7.0	13.0.0

Change history							
Date	Meeting	TDoc	CR	Rev	Cat	Subject/Comment	New version
2016-03	RAN#71	RP-160361	181	3	B	Introduction of Rel-13 features of eMTC in 36.212	13.1.0
2016-03	RAN#71	RP-160358	185	-	F	CR on mismatch between 36.212 and 36.331	13.1.0
2016-03	RAN#71	RP-160358	186	-	F	Clarification on Class B CSI report	13.1.0
2016-03	RAN#71	RP-160365	189	-	A	Correction to RI reporting for UE category with MIMO capability of 1 layer	13.1.0
2016-03	RAN#71	RP-160358	191	-	F	CR on CRI-RI payload restriction for non-eCA UE	13.1.0

Petitioners' Exhibit 1003, p. 1419
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121

History

Document history		
V13.0.0	January 2016	Publication
V13.1.0	April 2016	Publication

Petitioners' Exhibit 1003, p. 1420
AT&T et al v. Asustek Technology & Celerity
IPR2024-01121