

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

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

Petitioners

v.

KT CORPORATION (Patent Owner) and
PEGASUS WIRELESS INNOVATION LLC (Exclusive Licensee)

Case No. IPR2025-00293
Patent 10,009,161

DECLARATION OF CRAIG BISHOP

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I. INTRODUCTION

I, Craig Bishop, declare as follows:

1. I have been retained as an independent expert witness on behalf of GOOGLE LLC, CELLCO PARTNERSHIP D/B/A VERIZON WIRELESS, T-MOBILE USA, INC., AT&T SERVICES, INC., NOKIA OF AMERICA, CORP., and ERICSSON INC., (to whom I will refer to as Petitioners) for this *inter partes* review proceeding (which I may refer to at times as an “IPR”).

2. I am being compensated for my work in this matter at my accustomed hourly rate. I am also being reimbursed for reasonable and customary expenses associated with my work and testimony in this investigation. My compensation is not contingent on the results of my study, the substance of my opinions, or the outcome of this matter.

3. In the preparation of this expert report I have reviewed the documents cited herein, each of which is a type of material that experts in my field would reasonably rely upon when forming their opinions, as well as all of the Appendices attached hereto.

4. In forming the opinions expressed within this expert report, I have considered:

- The appendices listed above; and

- My own academic background, knowledge, and professional experiences in the field of wireless communications.

5. Although I have attempted to organize the information presented in this report into helpful sections and/or divisions, my opinions are supported by the information in the report in its entirety.

II. QUALIFICATIONS

6. My complete qualifications and professional experience are described in my *curriculum vitae*, a copy of which is attached as **Appendix 1 and is filed concurrently herewith as Exhibit 1011**. The following is a summary of my relevant qualifications and professional experience.

7. I earned my Bachelor of Electronic Engineering degree with Honors from Polytechnic of Central London in 1989. In 2006, I earned my MSC in Computer Science with Distinction from the University of Kent.

8. After graduating with my first degree, I worked as an operations engineer at the British Broadcasting Corporation (BBC) for 4 years, then as a civil servant at the UK Radiocommunications Agency until 1996, during which time I became involved in telecommunications standardization in the European Telecommunication Standards Institute (“ETSI”), working in particular in Technical Committee Radio Equipment and Systems (TC RES2) concerned with the standardization of Private Mobile Radio (PMR). From 1994 through 1996, I acted

as Rapporteur for voice and data related PMR standards ETS 300 113, ETS 300 219 and ETS 300 390. I participated as the only TC RES2 delegate on behalf of the UK Radiocommunications Agency, generating proposals in support of UK administration and business requirements, downloading and reviewing other meeting input documents, and proposing changes as necessary to ensure input documents and the resulting specifications were in line with said requirements.

9. In 1996, I joined Samsung Electronic Research Institute as a Senior Standards Engineer where I worked for 16 years, eventually becoming Director of Standards and Industry Affairs in 2011. My work at Samsung mainly focused on the standardization of Global System for Mobile Communications (GSM)/ General Packet Radio Service (GPRS), Universal Mobile Telecommunications System (UMTS), the IP Multimedia subsystem (IMS), and Long-Term Evolution (LTE)/ Evolved Packet System (EPS) systems. Initially, I participated in ETSI Special Mobile Group (SMG) committees SMG1, SMG2, SMG4, SMG5, and SMG9, and relevant UMTS related sub-committees working on the air interface radio access network protocols, service, and terminal aspects of UMTS and GSM/GPRS until 1999. In particular, I was a participant in the ETSI SMG2 meetings leading up to selection of Wideband Code Division Multiple Access (WCDMA) as the radio access technology for the Frequency Division Duplex (FDD) mode of UMTS.

10. Beginning in 1998, I worked as a Principal Standards Engineer on the 3rd Generation Partnership Project (3GPP) on UMTS. I attended the inaugural 3GPP Technical Specification Group (TSG) meetings held in December 1998, and I began attending Working Group (WG) meetings in 1999. Specifically, I was a regular participant in Radio Access Network (RAN) WG1, Services & System Aspects (SA) WG1, Terminals (T) WG2, but I also attended TSG RAN and T plenary meetings and sometimes other Working Groups and covering similar technical aspects as in my previous work in ETSI. As an example, RAN WG2 was, and is, a Working Group responsible for the specification of layer 2 and layer 3 Radio Resource, protocols for the UE. As part of this work, I would prepare meeting contributions in support of Samsung's research and development activities. Also, by way of preparation for each meeting, I would download all contributions and review those of interest to Samsung, and where necessary, prepare additional input to the meeting based on said review.

11. Beginning in 2000, I acted as project manager and then as system engineering manager at Samsung, providing technical requirements for the team working on Samsung's UMTS modem development. This involved scrutiny of ongoing standardization work, particularly in RAN WG1, RAN WG2, and TSG Core Network (CN) WG1, from which I would download, and assess the impact of, contributions on Samsung's development projects, ensuring that Samsung's

development team was kept informed about the latest developments as layers 2 and 3 of the UMTS standard were stabilized.

12. During this period, in addition to authoring and presenting technical contributions for the 3GPP standard, and producing technical requirements for the radio modem, I acted as Rapporteur for 3GPP Technical Reports covering User Equipment (“UE”) capability requirements (3GPP TR 21.904) from 1999–2000, and the Evolution of the 3GPP System (3GPP TR 21.902) in 2003 (the first Study Item to consider the 3GPP system beyond UMTS towards LTE/EPS).

13. In 2005, I became Head of Advanced Technologies, Standards, and Regulation (ATSR) at Samsung. In addition to my managerial duties which included responsibility for standards, research, and regulatory engineers—including three standards engineers who were regularly attending 3GPP RAN WG2 and Core Network and Terminals (CT) WG1 Working Groups—I personally continued to work on 3GPP standardization issues. From 2005 until 2008, I regularly attended and participated in SA WG2 meetings, mainly focusing on IP Multimedia Subsystem (IMS) including voice over IMS but also looking at wider Evolved Packet System (EPS) related issues. From 2008 until 2011, I regularly attended and participated in SA WG1 meetings. I also attended SA plenary meetings from 2008 until I left Samsung in 2013. As well as generating contributions in support of Samsung’s research and development as preparation for each meeting, I would download and

review documents from other 3GPP members, identifying those of interest to Samsung and, where necessary, preparing additional contributions on behalf of Samsung. The work required a sound working knowledge of the broader 3GPP system to ensure effective management of the ATSR team, effective participation in meeting discussions, expert assessment of third-party standards contributions, and provision of implementation guidance to Samsung developers.

14. From 2005 until I stopped attending SA WG1 meetings in 2011, I authored and presented over 100 contributions to SA WG2 and SA WG1 meetings at 3GPP and appeared as an author/co-author on 18 patent applications related to User Equipment operation in the IMS and the 3GPP Core Network.

15. In 2011, I became Director of Standards and Industry Affairs at Samsung, and in November of that year I was elected to the Board of ETSI on which I served for a term of 3 years until November 2014. In this position I gained further perspective on the organisation, management, and activities of ETSI and its Technical Committees and Partnership Projects including 3GPP.

16. Since leaving Samsung in January 2013, I have formed my own consulting company which is a member of ETSI, and as part of various projects undertaken, I have continued to regularly access the ETSI and 3GPP document servers, and to keep abreast of ETSI and 3GPP document handling and publication practices.

17. Through my extensive work in ETSI and on 3GPP standardization issues over the years, I have become very familiar with ETSI and 3GPP practices for when and how the technical standards (including revisions thereto) and other standards-related contributions are made publicly available, including in the 1999–2012 timeframe when I was attending or monitoring various 3GPP Working Groups, including RAN WG1 and RAN WG2, and since 2013 in support of my work as an independent standardisation consultant.

18. For purposes of my analysis in this declaration, I have been informed that a person of ordinary skill in the art (“POSITA”) would have had a bachelor’s degree in electrical engineering, computer engineering, or a related discipline, knowledge of the relevant 3GPP standards as of this time, and at least 2 years of experience working in a field involving wireless communications. A person with a different degree but with additional relevant experience could still qualify if the additional experience compensates for the different educational background. A person with less than 2 years of experience working in a field involving wireless communications could still qualify if the person has additional education that compensates for their lesser experience.

III. PUBLIC AVAILABILITY OF 3GPP STANDARDS PROPOSALS AND OTHER DOCUMENTS

19. Based on my years of experience working in various capacities in 3GPP and on 3GPP standards issues, I am familiar with the regular business practices of

the 3rd Generation Partnership Project (3GPP) relating to technical documents including specifications, draft standards and proposals, and standards-related technical contributions, as well as the business practices through which 3GPP makes these documents public.

A. Prominence and Purpose of 3GPP

20. 3GPP was inaugurated in December 1998 to produce Technical Specifications and Technical Reports for the Universal Mobile Telecommunications System (UMTS), a 3G Mobile System based on evolved GSM core networks and a new radio access network known as UTRA (UMTS Terrestrial Radio Access). **Appendix 2** at 2, 3 (“[3GPP] Partnership Project Description”); **Appendix 3** at 1; **Appendix 4** at 5. At that time, various standards organisations agreed to cooperate to produce a “complete set of globally applicable Technical Specifications” that would then be transposed into standards by the relevant standardization bodies (also known as Organizational Partners). **Appendix 2** at 3, 5 (“[3GPP] Partnership Project Description”). 3GPP “attracted a very strong commitment from organisations and companies around the world, reflecting the truly global nature of the project.” **Appendix 4** at 7.

21. 3GPP is a global initiative partnership made up of Organizational Partners, Market Representation Partners, and Individual Members. **Appendix 5** at 7, 8; **Appendix 2** at 10. Today, 3GPP unites seven telecommunications standard

development organisations (“Organizational Partners”) from around the world: the Association of Radio Industries and Businesses (ARIB) and the Telecommunication Technology Committee (TTC) from Japan, the China Communications Standards Association (CCSA) from China, the Telecommunications Standards Development Society, India (TSDSI) from India, the Telecommunications Technology Association (TTA) from Korea, the European Telecommunications Standards Institute (ETSI), and the Alliance for Telecommunications Industry Solutions (ATIS) from the United States. These Organizational Partners are regional standards organisations that have the authority to define, publish, and set standards for their respective regions. **Appendix 2** at 12. 3GPP also includes “Market Representation Partners” that represent various industry perspectives and offer market advice. **Appendix 5** at 8 (3GPP Working Procedures, “Market Representation Partnership”); **Appendix 2** at 14; **Appendix 4** at 5. Additionally, 3GPP includes individual member companies (“Individual Members”) that participate in 3GPP through their membership in a 3GPP Organizational Partner. **Appendix 5** at 8 (3GPP Working Procedures, “Individual Membership”); **Appendix 6** at 5 (textbook including a chart showing 3GPP structure at the time of publication); **Appendix 8** at 9, 10. As an example of how prominent 3GPP was (and remains) in the industry, there were 384 participating Individual Members in 2011. **Appendix 7** at 7 (3GPP

Project Coordination Group document showing 3GPP membership numbers to 2015). There were 835 individual members as of August 2024. **Appendix 9.**

22. As noted in paragraph 20, a primary goal of 3GPP is to provide an environment to produce Technical Specifications and Technical Reports that define and standardize technologies covering cellular telecommunications networks, including User Equipment or Mobile Device (UE) technologies, Radio Access Network (RAN) technologies, Core Network (CN) technologies, and service and system capabilities such as work on codecs, security, and quality of service. The specifications also provide hooks for interworking with non-3GPP networks including, but not limited to, Wi-Fi networks. **Appendix 2** at 32–40; **Appendix 3** at 2.

23. Given the prominence of 3GPP in the wireless communication industry, beginning in 1999 and continuing through today, interested POSITAs were tracking the developments of the latest 3GPP specifications and reports to ensure timely development of products and services by their companies that were consistent with the standards being developed. In other words, it is my opinion that a POSITA would have to be familiar with 3GPP and with the specification-related documents produced as part of the 3GPP process in order to properly perform his or her job. Without access to and knowledge of the 3GPP documentation, including, for example, the substantive contents of 3GPP technical specifications, an engineer

could not develop products that were interoperable with the worldwide 3G, 4G, and 5G standards. Because 3GPP documents were an important aspect of a POSITA's professional experience, textbooks and articles about cellular communications commonly directed readers to the 3GPP website for information regarding standards development. **Appendix 4** at 9 (directing readers to the 3GPP website at the conclusion of the chapter on the success of 3GPP in the standards development process). As a POSITA myself, I would regularly visit the 3GPP website for the latest developments in mobile communications standards setting and refer colleagues involved in the development of such devices to the 3GPP website as a valuable reference.

24. My personal experience at Samsung confirms 3GPP's prominence in the wireless industry. For example, engineers and managers at Samsung who were responsible for implementing 3GPP compliant modem software (and who were not attending 3GPP meetings or involved with development of the 3GPP standard in any direct way) would enquire as to which version of a given 3GPP specification they should be developing, or to the interpretation of specified requirements. Further, between 2000 and 2004, part of my role at Samsung involved advising software engineers implementing the 3GPP standard on the correct interpretation of the specifications and ensuring that they were made aware of any changes and proposals made during the 3GPP standards development process that would impact their work.

In short, the technical output of 3GPP was, and continues to be, well known at 3GPP member companies, even by engineers who were not directly involved with designing the 3GPP system or contributing to the 3GPP standard process.

B. 3GPP's Policy of Making Documents Public

25. 3GPP's policy was to make 3GPP documents available to the public, including to interested POSITAs. The free availability of 3GPP documents to any interested member of the public was widely recognized in the industry. As an example of the prominence of 3GPP and its place in the wireless standards industry, I note that textbooks directed readers to the 3GPP website for information about relevant standards. For example, **Appendix 6** at 6, 9 ("The latest specifications can be obtained from 3GPP [9]", "[9] <http://www.3GPP.org>"); **Appendix 8** at 10 ("3GPP TSs and TRs are publicly available at the 3GPP web site at either of the following URIs: <http://www.3gpp.org/specs/specs.htm> [or] <http://www.3gpp.org/ftp/Specs/archive/>"). Because the purpose of 3GPP is the worldwide adoption of a common standard, no restrictions on distribution or discussion have ever been placed on 3GPP documents. **Appendix 10** at 9 ("No password is needed to access any information on the 3GPP Web site, all information is openly published").

C. 3GPP Structure and Standards Development Process

26. Within 3GPP, responsibility for producing specifications was delegated to the Technical Specification Groups (TSGs). **Appendix 5** at 9, 12 (3GPP Working Procedures, “TSG tasks”). At its inception, 3GPP was divided into four Technical Specification Groups (TSGs), each covering a particular category of technology. **Appendix 2** at 31 (3GPP Partnership Project Description); **Appendix 6** at 5, 6 (textbook listing four TSGs and noting the subsequent addition of a fifth TSG); **Appendix 4** at 6, 11, 12. Each TSG is further divided into a number of Working Groups (WGs). **Appendix 8** at 8, 9; **Appendix 4** at 6; *see also* **Appendix 5** at 12 (3GPP Working Procedures). Two of the TSGs from 1998 are still in existence in 2024: TSG Radio Access Networks (RAN) and TSG Service & Systems Aspects (SA). The activities of two other TSGs, TSG Core Networks (CN) and TSG Terminals (T), were amalgamated under Core Network and Terminals (CT) following the closure of TSG T in 2005, with responsibility for terminal test specifications being moved to a RAN working group (RAN WG5). The fifth TSG, GSM EDGE Radio Access Networks (GERAN), was responsible for evolution of the GSM radio technology from 2000 until that TSG closed in 2016 and its work was transferred to a RAN working group (RAN WG6) which was itself closed in July 2020.

27. The TSGs held quarterly plenary meetings where members' contributions, draft specifications/reports, and other documents that had been agreed upon by the Working Groups were presented for discussion and approval. **Appendix 5** at 20 (3GPP Working Procedures, "Deliverable types," stating that Technical Specifications and Technical Reports are "drawn up by the TSGs" and are approved by TSGs); **Appendix 8** at 9 ("3GPP Deliverables"). Once a Technical Specification was, or Change Requests creating a new version of a Technical Specification were, formally approved by TSG plenary, the latest version of said Technical Specification would be created by the Mobile Competence Centre (MCC) and uploaded to the file server. **Appendix 10** at 6, 7; **Appendix 11** at 1. In that way, the conclusion of 3GPP TSG plenary meetings serves as notice that new versions of specifications incorporating Change Requests approved by the TSG meeting will shortly be made available on the public 3GPP server.

28. As part of the standards development process, delegates could submit contributions on behalf of the Individual Members. Members had an incentive to stay updated on 3GPP developments because those members usually wanted to contribute to the standard and make suggestions as to what technology and/or features should (or should not) be included. Delegates also attended 3GPP meetings to keep their employers abreast of developments related to the standards that would ultimately apply to those members and the products those members (*e.g.*, companies)

produced. 3GPP members around the world, and the interested POSITAs employed by them, would have been motivated to stay up to date regarding 3GPP technology evolution to ensure their research and development programmes remained relevant to the systems being specified and that their products were compliant with the published 3GPP specifications. In light of this need to follow the standards development process, delegates often distributed 3GPP-related documents far beyond the attendees at 3GPP meetings. This was certainly my experience at Samsung.

D. 3GPP Documents

1. Technical Specifications and Reports

29. The Technical Specifications and Reports developed by 3GPP were, and still are, driven by the technical contributions of 3GPP members. As part of that development process, various types of documents were produced. The 3GPP process involved the consideration of temporary documents (“TDocs,” also referred to as “contributions”), many of which constituted technical proposals for how the system should be implemented and some of which were adopted as the basis for parts of the Technical Specifications.

30. As I noted in paragraphs 20 and 22, a primary purpose of 3GPP is to prepare, approve, and maintain globally applicable Technical Specifications and Technical Reports. **Appendix 5** at 6 (3GPP Working Procedures, “Purpose”). A

“Technical Specification” as defined by 3GPP is “[a] 3GPP output document containing normative provisions approved by a Technical Specification Group.”

Appendix 5 at 28. 3GPP would (and still does) periodically freeze a complete set of standards (referred to as a “Release”), and each set would include new specifications.

Appendix 10 at 6. 3GPP would also make publicly available draft specifications that would usually be included as part of the next Release once approved.

31. It was widely known that Technical Specifications (and Technical Reports) were publicly available on 3GPP’s website. It was also well known that the latest version of a given specification that was under change control would be made available following each TSG Plenary meeting responsible for that specification, and that TSG Plenary meetings usually occur four times per year. **Appendix 10** at 6; **Appendix 11** at 1.

32. Latest and previous versions of Technical Specifications could be easily accessed from the 3GPP website. The specifications page provided direct links to the specifications area in the 3GPP website’s file repository. **Appendix 11** at 1. In the 2011 timeframe, the specifications page listed the specifications by the date of the approval of the latest versions reflecting the TSG plenary meeting date. *E.g.*, **Appendix 11** at 1.

33. Additionally, the 3GPP specifications followed a clear numbering scheme to help the public, including interested POSITAs, identify the subject matter

of each specification. **Appendix 12** at 1. As described on the 3GPP Numbering Scheme webpage, all 3G and GSM specifications had a specification number of 4 or 5 digits, where the first two digits defined the series. **Appendix 12** at 1. The Numbering Scheme webpage included a table showing the subject matter corresponding to each series. **Appendix 12** at 1. For example, the “36 series” focused on “LTE (Evolved UTRA) and LTE-Advanced radio technology” aspects (*i.e.*, 4G or LTE). **Appendix 12** at 1. An interested POSITA could narrow down the relevant specifications based on whether the specification applied to only evolved UTRA (*i.e.*, 4G or LTE), 3G, GSM, or to GSM, 3G and evolved UTRA (GSM-only specifications were transferred from ETSI to 3GPP in July 2000). **Appendix 12** at 1. For a specification in the 21–35 series, this could be determined based on the third digit of the specification number, where a “0” indicates that the specification applies to both systems. Specifications outside the 21–36 series in 2014 applied only to GSM systems. **Appendix 12** at 1.

34. The specifications were stored on the 3GPP website’s file repository as zipped files, where the filenames followed the structure: SM[-P[-Q]]-V.zip. This format corresponded to the numbering scheme discussed in paragraph 33. **Appendix 12** at 2. “S” represented the series number; “M” represented the mantissa (the part after the series number); “P” represented an optional part number; “Q” represented

an optional sub-part number; and “V” represented the version number (without the separating dots). **Appendix 12** at 2.

35. The Working Groups would create incremental versions of the draft specifications (*e.g.*, V0.2.1, V1.0.0, V1.1.0, etc.). These versions were made available on the 3GPP website’s file repository which is accessible from the 3GPP specifications page. The version numbering scheme for Technical Specifications and Technical Reports was standardized by 3GPP. The version number included three fields: the major version field, the technical version field, and the editorial version field. **Appendix 13** at 3. The major version field reflects the stage of the specification, with “0” representing an immature draft and a value of “3” or greater representing a specification that has been approved by the relevant TSG and thus placed under change control. **Appendix 13** at 3. The technical version field begins at zero and is incremented every time a technical change is made to the specification (either as part of the drafting process or as part of an approved change request). **Appendix 13** at 3. The editorial version field begins at zero and is incremented each time a non-technical change is made to the specification (*e.g.*, to fix a typographical or formatting issue). **Appendix 13** at 3.

36. I understand that the alleged invention in the ’161 patent relates to cellular telecommunications networks, and more particularly to the transmission and reception of channel state information. Any POSITA interested in the transmission

and reception of channel state information would have been monitoring 3GPP's activities in this area and would probably have been already participating as a full or associate member or observer in the standard development process, or would have at least known that information regarding the proposed revisions to the technical specifications under discussion were available through 3GPP.

2. 3GPP TDocs

37. As mentioned in paragraph 29, the technical specifications and reports developed by 3GPP were and are driven by the technical contributions of 3GPP member companies. As part of that development process, various types of documents were produced and submitted. Relevant to this case, the 3GPP process involved the consideration of temporary documents or "TDocs," which are also referred to as proposals, contributions, or change requests. The agreement of proposals submitted as TDocs results in the production of technical specifications.

38. Prior to each Working Group meeting, members of the Working Group would prepare TDocs to identify, discuss, and/or propose a new feature or change(s) to an existing feature or to identify a technical issue for discussion. Interested POSITAs would have known that TDocs could be a helpful source of technical information regarding the 3GPP specifications.

39. Each TDoc was assigned a TDoc number, according to a standard format set by 3GPP.¹ As described in the 3GPP Working Procedures, the numbering system followed the format xminnzzzz. **Appendix 5** at 17. This general naming convention has been in use since at least 1999 with only minor variations. Within that format, “x” referred to the relevant TSG. **Appendix 5** at 17. For example, “R” was used for TSG RAN. **Appendix 5** at 17. Likewise, “m” referred to the relevant Working Group. **Appendix 5** at 17. A document for RAN WG1 would therefore begin with “R1.” **Appendix 5** at 17. The “i” is normally a hyphen character but may take on other values depending on the meeting to which the Tdoc is subbmited. The two digits “nn” represented the year (*e.g.*, 17), and the digits “zzzz” represented the unique document number. **Appendix 5** at 17. This document number was used as the TDoc’s filename. **Appendix 5** at 17.

40. Each TDoc would include in its header the meeting at which the contributor intended the TDoc to be discussed. Most TDocs were uploaded to the 3GPP website for public viewing prior to the relevant Working Group meeting listed on the TDoc, although some TDocs, including those created at meetings, were

¹ Documents other than technical contributions (such as meeting reports) were also assigned TDoc numbers for ease of reference.

uploaded during or after the meeting. **Appendix 10** at 10. The documents were uploaded to the public file repository in an area allocated to the particular Working Group, *e.g.*, **Appendix 14** at 2 (RAN WG1 homepage with link to WG1's "Documents area"). Immediately upon upload, any member of the public could download and access the TDocs and other documents offered for discussion. This process has been in place since I began attending Working Group meetings in 1999.

E. The 3GPP Website's Public File Repository

41. All TDocs, Technical Reports, and Technical Specifications were also freely available to interested members of the public through the public file repository accessible via the 3GPP website. Interested members of the public would have been well aware of 3GPP and of the 3GPP website. 3GPP documents were accessible to any member of the public through the 3GPP website without providing any login credentials or other exclusive access criteria. **Appendix 10** at 9.

42. It is my recollection that in the 2011 to 2014 timeframe, any interested member of the public could locate relevant documents of interest on the 3GPP website using reasonable diligence based on the website's indexing scheme, the specification numbering, and/or the TDoc's naming convention. The TDocs on the 3GPP website file server were (and remain) organized according to the relevant Working Groups within 3GPP (each of which focused on particular subject matter) and then further organized based on the meetings of those groups. The Technical

Specifications and Reports were (and remain) organized according to their subject matter as indicated by their series number and version. POSITAs would have known which Working Groups focused on particular subject matter.

43. An interested member of the public could locate documents of interest by first navigating a web browser to the 3GPP website (www.3gpp.org). In the 2011 to 2014 timeframe, to locate documents from the 3GPP home page, a user could have clicked “Specification Groups” **Appendix 15**. The corresponding webpages contained links to the 3GPP’s public file repository (*e.g.*, through the “Documents area” link of a Working Group page). **Appendix 14**. To locate specifications, a user could have clicked “Specifications” and followed links as described in section III.D.1 above. Instead of accessing the 3GPP file repository from the 3GPP website home page, a user could have also accessed the file repository through the web address www.3gpp.org/ftp or directly using ftp client software connected to [ftp.3gpp.org](ftp://ftp.3gpp.org). A POSITA was also able to search for relevant documents using keywords on the search facility on the 3GPP website from at least 2000, and from at least 2015 using the 3GPP search portal (<https://portal.3gpp.org/#/>), where an interested person could search for documents by title and source, among other things.

44. The top two levels of indexing within the file repository were based wholly on subject matter, as reflected by the division of subject matter among the various TSGs and Working Groups, or into various Specifications. Specifically, an

individual could select the relevant TSG (or specification series) covering the subject matter of interest. **Appendix 16.**

45. For example, if the individual were interested in the specifications of 3GPP, they would click “specs.” From there, the individual could click on, for example, a particular (dated) collection of the specifications, the latest versions for each release (“latest”), or an archive containing all versions of the specifications (“archive”). **Appendix 17.**

46. For example, if the individual were interested in the radio access aspects of 3GPP, they would click “tsg_ran.” From there, the individual would click on the particular RAN Working Group covering the subject matter of interest. **Appendix 21.**

47. Then, if the individual were interested in the Radio Interface Radio layer 1, the individual would know to choose the folder for WG1. **Appendix 21.** Once a user is in the relevant Working Group folder (RAN WG1 in this example), an individual would see a list of all meetings held by RAN WG1. **Appendix 22.**

48. As shown in **Appendix 22**, a folder existed for each meeting. For example, “TSGR1_76b” corresponded to the TSG RAN WG1 #76bis meeting.

49. A POSITA would know which meeting(s) would have covered particular subject matter based on the working groups area of responsibility (e.g., for RAN WG1 - **Appendix 14**), and from publicly available meeting agendas. See e.g.,

Agenda link in **Appendix 23**. Many POSITAs received notification of the meeting agenda directly via the 3GPP Working Group email reflector lists. **Appendix 24**. Further, an individual could ascertain what subject matter was addressed at each meeting by reviewing the report issued after each meeting. **Appendix 25**.

50. 3GPP's public file repository provides a reliable mechanism for identifying the date and time a document was uploaded to the website and then available to download for public viewing. When a document is uploaded, the file server automatically assigns the document a time stamp—*i.e.*, an accurate and automatically computer-generated electronic record of when the document was uploaded—as part of the regular business practices of 3GPP. **Appendix 10** at 10 (3GPP FAQs). This has been the practice regarding uploading documents to the 3GPP file repository since 3GPP was inaugurated, and my personal experience confirms that the timestamps have always been a reliable way to determine when a file was uploaded to the 3GPP website and immediately available for public download.

51. In my experience, whilst the servers used for 3GPP file repository and many of its directories have been updated since 1999, and directories may as a result have later dates associated with them (*e.g.*, reflecting the last time they were modified in some way or their contents were updated), the original upload date for

files including specifications has always been preserved, providing a true and accurate indication of their earliest availability for download.

52. Following each 3GPP meeting, the secretary would usually distribute a draft meeting report or the chairman's notes of the meeting via the corresponding email list,. *E.g.*, **Appendix 18**. Such emails would effectively inform subscribers that the meeting had taken place, would inform subscribers of the documents that had been treated (or not), and in the event that the meeting was a TSG plenary meeting, would serve as notice that new versions of specifications incorporating approved Change Requests, would shortly be made available on the 3GPP public server. Further, an interested member of the public following a certain topic would have known to check said report for related contributions.

IV. 3GPP EXHIBITS

A. EXHIBIT 1013: 3GPP TS 36.213 v10.4.0 (2011-12) 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (Release 10)

54. 3GPP TS 36.213 v10.4.0 is a Technical Specification titled "3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (Release 10)".

55. The date on the face of the specification ("2011-12") corresponds to the year (2011) and month (December) that this version of the specification having been

approved by 3GPP TSG RAN was made publicly available.

56. 3GPP TS 36.213 v10.4.0 being an approved version of the Release 10 Physical layer procedures specification, was approved by TSG RAN #54 held December 6 – 9, 2011. An interested member of the public would know that the latest version of an approved specification or report would be available following the plenary meeting responsible for that specification (in this case TSG RAN) in accordance with 3GPP standard practice as described in paragraph 31. The approval of the TS 36.213 v10.4.0 is confirmed by the approval of the Change Request to TS 36.213 v10.3.0 documented in the meeting report from TSG RAN #54 (**Appendix 19** at 95).

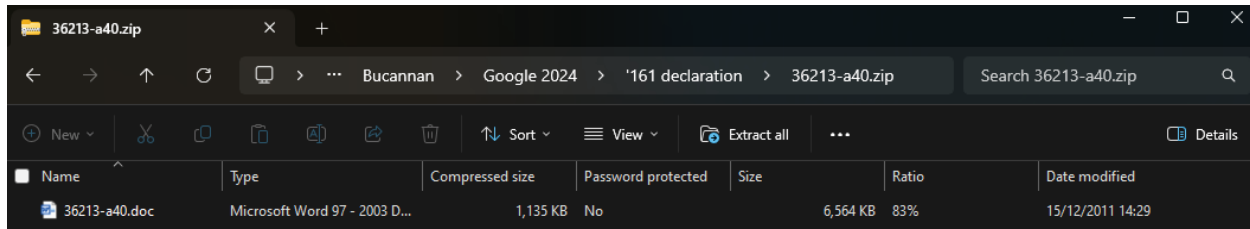
57. The 3GPP file server is and always has been open to all and free from restriction such as username or password. By way of example of how an interested member of the public could access the TS 36.213 v10.4.0 technical specification from the 3GPP website, I accessed the file server by going to the 3GPP website at <http://www.3gpp.org/>, selected “Specifications & Technologies” from the menu bar, and then selected “Specifications by series” from the dropdown menu. I then selected the “36 Series” link to access the public file server where the specifications are stored. I then searched for “36.213” in the specification number search bar, and for the TS 36.213 specification selected the eyeglasses icon that says “See details” when a cursor is placed on it. From there, I selected “Click to see all versions of this

specification,” which took me to the archive housing all versions of TS 36.213 found at the following URL: https://www.3gpp.org/ftp/Specs/archive/36_series/36.213. A true and correct copy of the relevant portion of the directory listing produced by the file server website is provided below and in **Appendix 20** at 1

 36213-a30.zip	2011/09/25 21:03	1033,9 KB
 36213-a40.zip	2011/12/15 13:29	1134,7 KB
 36213-a50.zip	2012/03/07 16:47	1139 KB

58. The archive directory index stated that TS 36.213 v10.4.0 was uploaded on “2011/12/15”. Selecting the link for “36213-a40.zip”, I downloaded a zip file of the same name. The zip file contained a Microsoft Word document with the filename “36213-a40” and having date stamps of “15/12/2011” (European date format)². An excerpt of the zip file directory is provided below.

² The apparent later time of the date modified field for the Word document is explained by the time zone of the PC on which the Word document was last saved, prior to being compressed and uploaded, being later than the time-zone of the 3GPP server.



59. I have confirmed that the Word document with the filename “36213-a60” is TS 36.213 v10.4.0. A true and correct copy of the compiled Microsoft Word documents with the filename “36213-a40” is the TS 36.213 v10.4.0 that is provided in EX1013.

60. Based on my experience, I understand these date stamps to mean that 36213-a40.zip was uploaded to 3GPP’s publicly available website on December 15, 2011, and that an interested member of the public could have downloaded the zip file, extracted the Word document enclosed, viewed the contents of the Word document, and further disseminated said document without restriction on December 15, 2011 and thereafter.

B. EXHIBIT 1030: 3GPP R1-141366 “Discussion on CQI/MCS table design for 256QAM”

61. R1-141366 is a technical contribution submitted to 3GPP TSG RAN WG1 meeting TSGR1 #76bis, which was held between March 31 – April 4, 2014. It follows the general naming format (“xminnz”) described in paragraph 39. Accordingly, “R1” indicates that the contribution was submitted to RAN WG1, “14” indicates the year (2014) that this technical contribution was submitted, and “1366” is the unique number that was assigned to this contribution document. It is titled

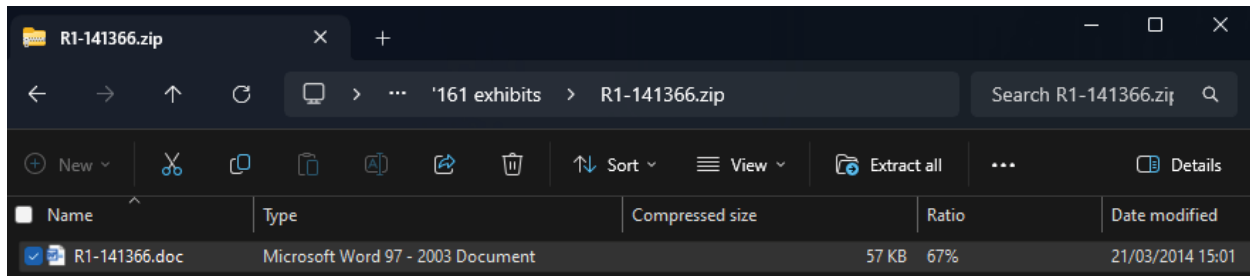
“Discussion on CQI/MCS table design for 256QAM”.

62. As I mention in paragraph 41 above, 3GPP meeting documents have always been and were in the 2014 timeframe, made publicly available on the 3GPP public file server from where an interested member of the public exercising reasonable diligence could freely access them. To confirm the availability of R1-141366 on the 3GPP document server in 2014, I navigated to the 3GPP website at <http://www.3gpp.org>, selected “3GPP Groups” from the drop down menu, and then selected the “RAN1 – Radio Layer 1” from the 3GPP Groups page, and the “Documents area” link to access the public file server where documents for the TSG-RAN Working Group 1 are stored, and from where I navigated to the documents for RAN WG1 #76bis. A true and correct copy of the relevant portion of the Documents directory listing produced by the file server website is provided below and in **Appendix 26** at 23.

 R1-141365.zip	2014/03/21 19:49	33 KB
 R1-141366.zip	2014/03/21 19:49	56,6 KB
 R1-141367.zip	2014/03/21 19:49	225,4 KB

63. The Docs directory index stated that R1-141366 was uploaded on “2014/03/21”. I selected the link for “R1-141366.zip” and downloaded a zip file of the same name. The zip file contained a Microsoft Word document, “R1-141366.docx”, with a date stamp of “21/03/2014” (European date format) the same

date that the zip file was uploaded.



64. A true and correct copy of the document within the zip file (R1-141366.zip) is provided as EX1030. Based on my experience, I understand that these date stamps mean that R1-141366.zip was uploaded to 3GPP's publicly available website on March 21, 2014, prior to the RAN WG1 #76bis meeting, and that any member of the public could have downloaded the zip file, extracted the Word document enclosed, and viewed the contents of said document without restriction on March 21, 2014 and thereafter. The report from RAN WG1 #76bis confirms the availability of R1-141366 at the meeting (**Appendix 27** at 32). I have no reason to believe that either the date stamp or the report from RAN WG1 #76bis is inaccurate. I have therefore determined that R1-141366 was publicly available on the file server no later than March 21, 2014.

65. Based on the information above, it is my opinion that R1-141366 titled "Discussion on CQI/MCS table design for 256QAM" and provided as EX1030 was publicly available to download from the 3GPP file server no later than March 21, 2014 and could have been distributed thereafter without restriction.

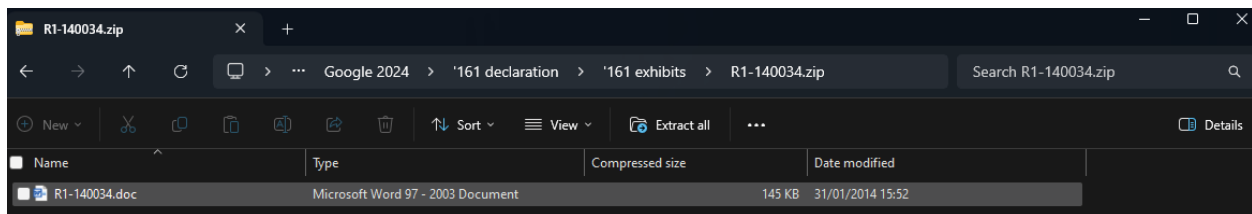
C. EXHIBIT 1029: 3GPP R1-140034 “CQI/MCS table design for 256QAM”

66. R1-140034 is a technical contribution submitted to 3GPP TSG RAN WG1 meeting TSGR1 #76, which was held between 10 – 14 February, 2014. It follows the general naming format (“xminnnzzzz”) described in paragraph 39. Accordingly, “R1” indicates that the contribution was submitted to RAN WG1, “14” indicates the year (2014) that this technical contribution was submitted, and “0034” is the unique number that was assigned to this contribution document. It is titled “CQI/MCS table design for 256QAM”.

67. As I mention in paragraph 41 above, 3GPP meeting documents have always been and were in the 2014 timeframe, made publicly available on the 3GPP public file server from where an interested member of the public exercising reasonable diligence could freely access them. To confirm the availability of R1-140034 on the 3GPP document server in 2014, I navigated to the 3GPP website at <http://www.3gpp.org>, selected “3GPP Groups” from the drop down menu, and then selected the “RAN1 – Radio Layer 1” from the 3GPP Groups page, and the “Documents area” link to access the public file server where documents for the TSG-RAN Working Group 1 are stored, and from where I navigated to the documents for RAN WG1 #76. A true and correct copy of the relevant portion of the Documents directory listing produced by the file server website is provided below and in **Appendix 28** at 1.

 R1-140033.zip	2014/02/01 10:48	58 KB
 R1-140034.zip	2014/02/01 10:48	144,5 KB
 R1-140035.zip	2014/02/01 10:48	95,8 KB

68. The Docs directory index stated that R1-140034 was uploaded on “2014/02/01”. I selected the link for “R1-140034.zip” and downloaded a zip file of the same name. The zip file contained a Microsoft Word document, “R1-140034.docx”, with a date stamp of “31/01/2014” (European date format).



69. A true and correct copy of the document within the zip file (R1-140034.zip) is provided as EX1029. Based on my experience, I understand that these date stamps mean that R1-140034.zip was uploaded to 3GPP’s publicly available website on February 1, 2014, prior to the RAN WG1 #76 meeting, and that any member of the public could have downloaded the zip file, extracted the Word document enclosed, and viewed the contents of said document without restriction on February 1, 2014 and thereafter. The report from RAN WG1 #76 confirms the availability of R1-140034 at the meeting (**Appendix 29** at 53). I have no reason to believe that either the date stamp or the report from RAN WG1 #76 is inaccurate. I have therefore determined that R1-140034 was publicly available on the file server no later than February 1, 2014.

70. Based on the information above, it is my opinion that R1-140034 titled “CQI/MCS table design for 256QAM” and provided as EX1029 was publicly available to download from the 3GPP file server no later than February 1, 2014 and could have been distributed thereafter without restriction.

D. EXHIBIT 1028: 3GPP R1-142638 “WF on 256QAM CQI table design”

71. R1-142638 is a technical contribution submitted to 3GPP TSG RAN WG1 meeting TSGR1 #77, which was held between 19 – 23 May, 2014. It follows the general naming format (“xminnz”) described in paragraph 39. Accordingly, “R1” indicates that the contribution was submitted to RAN WG1, “14” indicates the year (2014) that this technical contribution was submitted, and “2638” is the unique number that was assigned to this contribution document. It is titled “ WF on 256QAM CQI table design”.

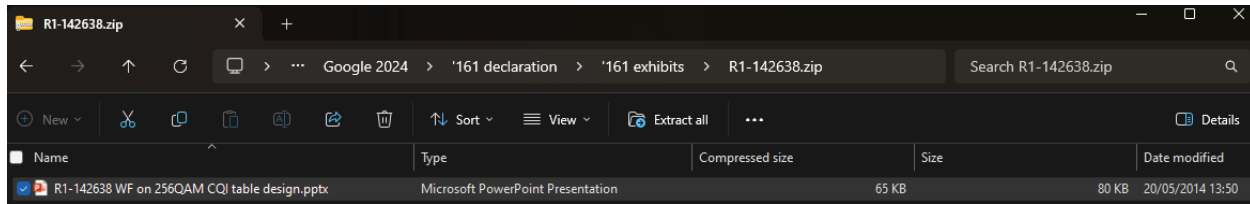
72. As I mention in paragraph 41 above, 3GPP meeting documents have always been and were in the 2014 timeframe, made publicly available on the 3GPP public file server from where an interested member of the public exercising reasonable diligence could freely access them. To confirm the availability of R1-142638 on the 3GPP document server in 2014, I navigated to the 3GPP website at <http://www.3gpp.org>, selected “3GPP Groups” from the drop down menu, and then selected the “RAN1 – Radio Layer 1” from the 3GPP Groups page, and the “Documents area” link to access the public file server where documents for the TSG-

RAN Working Group 1 are stored, and from where I navigated to the documents for RAN WG1 #77. A true and correct copy of the relevant portion of the Documents directory listing produced by the file server website is provided below and in **Appendix 30** at 22.

 R1-142637.zip	2014/05/20 12:03	27,6 KB
 R1-142638.zip	2014/05/20 12:03	64,9 KB
 R1-142639.zip	2014/05/20 12:03	61,2 KB

73. The Docs directory index stated that R1-142638 was uploaded on “2014/05/20”. I selected the link for “R1-142638.zip” and downloaded a zip file of the same name. The zip file contained a Microsoft PowerPoint document, “R1-142638 WF on 256QAM CQI table design.pptx”, with a date stamp of “20/05/2014” (European date format)³.

³ The apparent later time of the date modified field for the Word document is explained by the time zone of the PC on which the Word document was last saved, prior to being compressed and uploaded, being later than the time-zone of the 3GPP server.



74. A true and correct copy of the document within the zip file (R1-142638.zip) is provided as EX1028. Based on my experience, I understand that these date stamps mean that R1-142638.zip was uploaded to 3GPP’s publicly available website on May 20, 2014, during the RAN WG1 #77 meeting, and that any member of the public could have downloaded the zip file, extracted the Word document enclosed, and viewed the contents of said document without restriction on May 20, 2014 and thereafter. The report from RAN WG1 #77 confirms the availability of R1-142638 at the meeting (**Appendix 31** at 31). I have no reason to believe that either the date stamp or the report from RAN WG1 #77 is inaccurate. I have therefore determined that R1-142638 was publicly available on the file server no later than May 20, 2014.

75. Based on the information above, it is my opinion that R1-142638 titled “WF on 256QAM CQI table design” and provided as EX1028 was publicly available to download from the 3GPP file server no later than May 20, 2014 and could have been distributed thereafter without restriction.

V. CONCLUSION

76. In signing this Declaration, I recognize that the Declaration will be filed

as evidence in a case 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 case and that, if required, I will make myself available for cross-examination to take place within the United States, during the time allotted for cross-examination.

77. I hereby 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.

Date: December 23, 2024



Craig Bishop

3GPP TS 36.213 V10.4.0 (2011-12)

Technical Specification

3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (Release 10)



**Petitioners' Exhibit 1013
Google et al. v. KT Corporation et al.
IPR2025-00293**

The present document has been developed within the 3rd Generation Partnership Project (3GPPTM) and may be further elaborated for the purposes of 3GPP.

The present document has not been subject to any approval process by the 3GPP Organisational Partners and shall not be implemented. This Specification is provided for future development work within 3GPP only. The Organisational Partners accept no liability for any use of this Specification. Specifications and reports for implementation of the 3GPPTM system should be obtained via the 3GPP Organisational Partners' Publications Offices.

Keywords

UMTS, radio, layer 1

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Foreword

This Technical Specification (TS) has been produced by the 3rd Generation Partnership Project (3GPP).

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where:

- x the first digit:
 - 1 presented to TSG for information;
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- 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.

1 Scope

The present document specifies and establishes the characteristics of the physicals layer procedures in the FDD and TDD modes of 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 36.201: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Layer – General Description"
- [3] 3GPP TS 36.211: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation"
- [4] 3GPP TS 36.212: "Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding"
- [5] 3GPP TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer – Measurements"
- [6] 3GPP TS 36.101: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception"
- [7] 3GPP TS 36.104: "Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception"
- [8] 3GPP TS36.321, "Evolved Universal Terrestrial Radio Access (E-UTRA); Medium Access Control (MAC) protocol specification"
- [9] 3GPP TS36.423, "Evolved Universal Terrestrial Radio Access (E-UTRA); X2 Application Protocol (X2AP)"
- [10] 3GPP TS36.133, "Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management"
- [11] 3GPP TS36.331, "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) protocol specification"
- [12] 3GPP TS 36.306: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities".

3 Definitions, symbols, and abbreviations

3.1 Symbols

For the purposes of the present document, the following symbols apply:

n_f	System frame number as defined in [3]
n_s	Slot number within a radio frame as defined in [3]
N_{cells}^{DL}	Number of configured cells
N_{RB}^{DL}	Downlink bandwidth configuration, expressed in units of N_{sc}^{RB} as defined in [3]
N_{RB}^{UL}	Uplink bandwidth configuration, expressed in units of N_{sc}^{RB} as defined in [3]
N_{symb}^{UL}	Number of SC-FDMA symbols in an uplink slot as defined in [3]
N_{sc}^{RB}	Resource block size in the frequency domain, expressed as a number of subcarriers as defined in [3]
T_s	Basic time unit as defined in [3]

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply.

ACK	Acknowledgement
BCH	Broadcast Channel
CCE	Control Channel Element
CIF	Carrier Indicator Field
CQI	Channel Quality Indicator
CRC	Cyclic Redundancy Check
CSI	Channel State Information
DAI	Downlink Assignment Index
DCI	Downlink Control Information
DL	Downlink
DL-SCH	Downlink Shared Channel
DTX	Discontinuous Transmission
EPRE	Energy Per Resource Element
MCS	Modulation and Coding Scheme
NACK	Negative Acknowledgement
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
PMI	Precoding Matrix Indicator
PRACH	Physical Random Access Channel
PRS	Positioning Reference Symbol
PRB	Physical Resource Block
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
PTI	Precoding Type Indicator
QoS	Quality of Service
RBG	Resource Block Group
RE	Resource Element
RI	Rank Indication
RPF	Repetition Factor
RS	Reference Signal

SIR	Signal-to-Interference Ratio
SINR	Signal to Interference plus Noise Ratio
SPS C-RNTI	Semi-Persistent Scheduling C-RNTI
SR	Scheduling Request
SRS	Sounding Reference Symbol
TA	Time alignment
TTI	Transmission Time Interval
UCI	Uplink Control Information
UE	User Equipment
UL	Uplink
UL-SCH	Uplink Shared Channel
VRB	Virtual Resource Block

4 Synchronisation procedures

4.1 Cell search

Cell search is the procedure by which a UE acquires time and frequency synchronization with a cell and detects the physical layer Cell ID of that cell. E-UTRA cell search supports a scalable overall transmission bandwidth corresponding to 6 resource blocks and upwards.

The following signals are transmitted in the downlink to facilitate cell search: the primary and secondary synchronization signals.

4.2 Timing synchronisation

4.2.1 Radio link monitoring

The downlink radio link quality of the primary cell shall be monitored by the UE for the purpose of indicating out-of-sync/in-sync status to higher layers.

In non-DRX mode operation, the physical layer in the UE shall every radio frame assess the radio link quality, evaluated over the previous time period defined in [10], against thresholds (Q_{out} and Q_{in}) defined by relevant tests in [10].

In DRX mode operation, the physical layer in the UE shall at least once every DRX period assess the radio link quality, evaluated over the previous time period defined in [10], against thresholds (Q_{out} and Q_{in}) defined by relevant tests in [10].

If higher-layer signalling indicates certain subframes for restricted radio link monitoring, the radio link quality shall not be monitored in any subframe other than those indicated.

The physical layer in the UE shall in radio frames where the radio link quality is assessed indicate out-of-sync to higher layers when the radio link quality is worse than the threshold Q_{out} . When the radio link quality is better than the threshold Q_{in} , the physical layer in the UE shall in radio frames where the radio link quality is assessed indicate in-sync to higher layers.

4.2.2 Inter-cell synchronisation

No functionality is specified in this section in this release.

4.2.3 Transmission timing adjustments

Upon reception of a timing advance command, the UE shall adjust its uplink transmission timing for PUCCH/PUSCH/SRS of the primary cell. The timing advance command indicates the change of the uplink timing relative to the current uplink timing as multiples of $16 T_s$. The start timing of the random access preamble is specified in [3]. The UL transmission timing for PUSCH/SRS of a secondary cell is the same as the primary cell.

In case of random access response, 11-bit timing advance command [8], T_A , indicates N_{TA} values by index values of $T_A = 0, 1, 2, \dots, 1282$, where an amount of the time alignment is given by $N_{TA} = T_A \times 16$. N_{TA} is defined in [3].

In other cases, 6-bit timing advance command [8], T_A , indicates adjustment of the current N_{TA} value, $N_{TA,old}$, to the new N_{TA} value, $N_{TA,new}$, by index values of $T_A = 0, 1, 2, \dots, 63$, where $N_{TA,new} = N_{TA,old} + (T_A - 31) \times 16$. Here, adjustment of N_{TA} value by a positive or a negative amount indicates advancing or delaying the uplink transmission timing by a given amount respectively.

For a timing advance command received on subframe n , the corresponding adjustment of the timing shall apply from the beginning of subframe $n+6$. When the UE's uplink PUCCH/PUSCH/SRS transmissions in subframe n and subframe $n+1$ are overlapped due to the timing adjustment, the UE shall transmit complete subframe n and not transmit the overlapped part of subframe $n+1$.

If the received downlink timing changes and is not compensated or is only partly compensated by the uplink timing adjustment without timing advance command as specified in [10], the UE changes N_{TA} accordingly.

4.3 Timing for Secondary Cell Activation / Deactivation

When a UE receives an activation command [8] for a secondary cell in subframe n , the corresponding actions in [8] shall be applied in subframe $n+8$.

When a UE receives a deactivation command [8] for a secondary cell or a secondary cell's deactivation timer expires in subframe n , the corresponding actions in [8] shall apply no later than subframe $n+8$, except for the actions related to CSI reporting which shall be applied in subframe $n+8$.

5 Power control

Downlink power control determines the energy per resource element (EPRE). The term resource element energy denotes the energy prior to CP insertion. The term resource element energy also denotes the average energy taken over all constellation points for the modulation scheme applied. Uplink power control determines the average power over a SC-FDMA symbol in which the physical channel is transmitted.

5.1 Uplink power control

Uplink power control controls the transmit power of the different uplink physical channels.

For PUSCH, the transmit power $\hat{P}_{PUSCH,c}(i)$ defined in section 5.1.1, is first scaled by the ratio of the number of antennas ports with a non-zero PUSCH transmission to the number of configured antenna ports for the transmission scheme. The resulting scaled power is then split equally across the antenna ports on which the non-zero PUSCH is transmitted.

For PUCCH or SRS, the transmit power $\hat{P}_{PUCCH}(i)$, defined in Section 5.1.1.1, or $\hat{P}_{SRS,c}(i)$ is split equally across the configured antenna ports for PUCCH or SRS. $\hat{P}_{SRS,c}(i)$ is the linear value of $P_{SRS,c}(i)$ defined in Section 5.1.3.

A cell wide overload indicator (OI) and a High Interference Indicator (HII) to control UL interference are defined in [9].

5.1.1 Physical uplink shared channel

5.1.1.1 UE behaviour

The setting of the UE Transmit power for a physical uplink shared channel (PUSCH) transmission is defined as follows.

If the UE transmits PUSCH without a simultaneous PUCCH for the serving cell c , then the UE transmit power $P_{PUSCH,c}(i)$ for PUSCH transmission in subframe i for the serving cell c is given by

$$P_{\text{PUSCH},c}(i) = \min \left\{ P_{\text{CMAX},c}(i), 10 \log_{10}(M_{\text{PUSCH},c}(i)) + P_{\text{O_PUSCH},c}(j) + \alpha_c(j) \cdot PL_c + \Delta_{\text{TF},c}(i) + f_c(i) \right\} \text{ [dBm]}$$

If the UE transmits PUSCH simultaneous with PUCCH for the serving cell c , then the UE transmit power $P_{\text{PUSCH},c}(i)$ for the PUSCH transmission in subframe i for the serving cell c is given by

$$P_{\text{PUSCH},c}(i) = \min \left\{ 10 \log_{10}(\hat{P}_{\text{CMAX},c}(i) - \hat{P}_{\text{PUCCH}}(i)), 10 \log_{10}(M_{\text{PUSCH},c}(i)) + P_{\text{O_PUSCH},c}(j) + \alpha_c(j) \cdot PL_c + \Delta_{\text{TF},c}(i) + f_c(i) \right\} \text{ [dBm]}$$

If the UE is not transmitting PUSCH for the serving cell c , for the accumulation of TPC command received with DCI format 3/3A for PUSCH, the UE shall assume that the UE transmit power $P_{\text{PUSCH},c}(i)$ for the PUSCH transmission in subframe i for the serving cell c is computed by

$$P_{\text{PUSCH},c}(i) = \min \{ P_{\text{CMAX},c}(i), P_{\text{O_PUSCH},c}(1) + \alpha_c(1) \cdot PL_c + f_c(i) \} \text{ [dBm]}$$

where,

- $P_{\text{CMAX},c}(i)$ is the configured UE transmit power defined in [6] in subframe i for serving cell c and $\hat{P}_{\text{CMAX},c}(i)$ is the linear value of $P_{\text{CMAX},c}(i)$. If the UE transmits PUCCH without PUSCH in subframe i for the serving cell c , for the accumulation of TPC command received with DCI format 3/3A for PUSCH, the UE shall assume $P_{\text{CMAX},c}(i)$ as given by section 5.1.2.1. If the UE does not transmit PUCCH and PUSCH in subframe i for the serving cell c , for the accumulation of TPC command received with DCI format 3/3A for PUSCH, the UE shall compute $P_{\text{CMAX},c}(i)$ assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and $\Delta T_c = 0$ dB, where MPR, A-MPR, P-MPR and ΔT_c are defined in [6].
- $\hat{P}_{\text{PUCCH}}(i)$ is the linear value of $P_{\text{PUCCH}}(i)$ defined in section 5.1.2.1
- $M_{\text{PUSCH},c}(i)$ is the bandwidth of the PUSCH resource assignment expressed in number of resource blocks valid for subframe i and serving cell c .
- $P_{\text{O_PUSCH},c}(j)$ is a parameter composed of the sum of a component $P_{\text{O_NOMINAL_PUSCH},c}(j)$ provided from higher layers for $j=0$ and 1 and a component $P_{\text{O_UE_PUSCH},c}(j)$ provided by higher layers for $j=0$ and 1 for serving cell c . For PUSCH (re)transmissions corresponding to a semi-persistent grant then $j=0$, for PUSCH (re)transmissions corresponding to a dynamic scheduled grant then $j=1$ and for PUSCH (re)transmissions corresponding to the random access response grant then $j=2$. $P_{\text{O_UE_PUSCH},c}(2) = 0$ and $P_{\text{O_NOMINAL_PUSCH},c}(2) = P_{\text{O_PRE}} + \Delta_{\text{PREAMBLE_Msg3}}$, where the parameter *preambleInitialReceivedTargetPower* [8] ($P_{\text{O_PRE}}$) and $\Delta_{\text{PREAMBLE_Msg3}}$ are signalled from higher layers.
- For $j=0$ or 1 , $\alpha_c \in \{0, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1\}$ is a 3-bit parameter provided by higher layers for serving cell c . For $j=2$, $\alpha_c(j) = 1$.
- PL_c is the downlink pathloss estimate calculated in the UE for serving cell c in dB and $PL_c = \text{referenceSignalPower} - \text{higher layer filtered RSRP}$, where *referenceSignalPower* is provided by higher layers and RSRP is defined in [5] for the reference serving cell and the higher layer filter configuration is defined in [11] for the reference serving cell. The serving cell chosen as the reference serving cell and used for determining *referenceSignalPower* and higher layer filtered RSRP is configured by the higher layer parameter *pathlossReferenceLinking*.
- $\Delta_{\text{TF},c}(i) = 10 \log_{10} \left(\left(2^{BP_{\text{PRE}} \cdot K_S} - 1 \right) \cdot \beta_{\text{offset}}^{\text{PUSCH}} \right)$ for $K_S = 1.25$ and 0 for $K_S = 0$ where K_S is given by the parameter *deltaMCS-Enabled* provided by higher layers for each serving cell c . BP_{PRE} and $\beta_{\text{offset}}^{\text{PUSCH}}$, for each serving cell c , are computed as below. $K_S = 0$ for transmission mode 2.

- $BPRE = O_{CQI} / N_{RE}$ for control data sent via PUSCH without UL-SCH data and $\sum_{r=0}^{C-1} K_r / N_{RE}$ for other cases.
 - where C is the number of code blocks, K_r is the size for code block r , O_{CQI} is the number of CQI/PMI bits including CRC bits and N_{RE} is the number of resource elements determined as $N_{RE} = M_{sc}^{PUSCH-initial} \cdot N_{symb}^{PUSCH-initial}$, where C , K_r , $M_{sc}^{PUSCH-initial}$ and $N_{symb}^{PUSCH-initial}$ are defined in [4].
- $\beta_{offset}^{PUSCH} = \beta_{offset}^{CQI}$ for control data sent via PUSCH without UL-SCH data and 1 for other cases.
- $\delta_{PUSCH,c}$ is a correction value, also referred to as a TPC command and is included in PDCCH with DCI format 0/4 for serving cell c or jointly coded with other TPC commands in PDCCH with DCI format 3/3A whose CRC parity bits are scrambled with TPC-PUSCH-RNTI. The current PUSCH power control adjustment state for serving cell c is given by $f_c(i)$ which is defined by:
 - $f_c(i) = f_c(i-1) + \delta_{PUSCH,c}(i - K_{PUSCH})$ if accumulation is enabled based on the parameter *Accumulation-enabled* provided by higher layers or if the TPC command $\delta_{PUSCH,c}$ is included in a PDCCH with DCI format 0 for serving cell c where the CRC is scrambled by the Temporary C-RNTI
 - where $\delta_{PUSCH,c}(i - K_{PUSCH})$ was signalled on PDCCH with DCI format 0/4 or 3/3A on subframe $i - K_{PUSCH}$, and where $f_c(0)$ is the first value after reset of accumulation.
 - The value of K_{PUSCH} is
 - For FDD, $K_{PUSCH} = 4$
 - For TDD UL/DL configurations 1-6, K_{PUSCH} is given in Table 5.1.1.1-1
 - For TDD UL/DL configuration 0
 - If the PUSCH transmission in subframe 2 or 7 is scheduled with a PDCCH of DCI format 0/4 in which the LSB of the UL index is set to 1, $K_{PUSCH} = 7$
 - For all other PUSCH transmissions, K_{PUSCH} is given in Table 5.1.1.1-1.
 - For serving cell c the UE attempts to decode a PDCCH of DCI format 0/4 with the UE's CRNTI or DCI format 0 for SPS C-RNTI and a PDCCH of DCI format 3/3A with this UE's TPC-PUSCH-RNTI in every subframe except when in DRX or where serving cell c is deactivated.
 - If DCI format 0/4 for serving cell c and DCI format 3/3A are both detected in the same subframe, then the UE shall use the $\delta_{PUSCH,c}$ provided in DCI format 0/4.
 - $\delta_{PUSCH,c} = 0$ dB for a subframe where no TPC command is decoded for serving cell c or where DRX occurs or i is not an uplink subframe in TDD.
 - The $\delta_{PUSCH,c}$ dB accumulated values signalled on PDCCH with DCI format 0/4 are given in Table 5.1.1.1-2. If the PDCCH with DCI format 0 is validated as a SPS activation or release PDCCH, then $\delta_{PUSCH,c}$ is 0dB.
 - The δ_{PUSCH} dB accumulated values signalled on PDCCH with DCI format 3/3A are one of SET1 given in Table 5.1.1.1-2 or SET2 given in Table 5.1.1.1-3 as determined by the parameter *TPC-Index* provided by higher layers.
 - If UE has reached $P_{CMAX,c}(i)$ for serving cell c , positive TPC commands for serving cell c shall not be accumulated

- If UE has reached minimum power, negative TPC commands shall not be accumulated
- UE shall reset accumulation
 - For serving cell c , when $P_{O_UE_PUSCH,c}$ value is changed by higher layers
 - For the primary cell, when the UE receives random access response message
- $f_c(i) = \delta_{PUSCH,c}(i - K_{PUSCH})$ if accumulation is not enabled for serving cell c based on the parameter *Accumulation-enabled* provided by higher layers
 - where $\delta_{PUSCH,c}(i - K_{PUSCH})$ was signalled on PDCCH with DCI format 0/4 for serving cell c on subframe $i - K_{PUSCH}$
 - The value of K_{PUSCH} is
 - For FDD, $K_{PUSCH} = 4$
 - For TDD UL/DL configurations 1-6, K_{PUSCH} is given in Table 5.1.1.1-1
 - For TDD UL/DL configuration 0
 - If the PUSCH transmission in subframe 2 or 7 is scheduled with a PDCCH of DCI format 0/4 in which the LSB of the UL index is set to 1, $K_{PUSCH} = 7$
 - For all other PUSCH transmissions, K_{PUSCH} is given in Table 5.1.1.1-1.
 - The $\delta_{PUSCH,c}$ dB absolute values signalled on PDCCH with DCI format 0/4 are given in Table 5.1.1.1-2. If the PDCCH with DCI format 0 is validated as a SPS activation or release PDCCH, then $\delta_{PUSCH,c}$ is 0dB.
 - $f_c(i) = f_c(i - 1)$ for a subframe where no PDCCH with DCI format 0/4 is decoded for serving cell c or where DRX occurs or i is not an uplink subframe in TDD.
- For both types of $f_c(*)$ (accumulation or current absolute) the first value is set as follows:
 - If $P_{O_UE_PUSCH,c}$ value is changed by higher layers and serving cell c is the primary cell or, if $P_{O_UE_PUSCH,c}$ value is received by higher layers and serving cell c is a Secondary cell
 - $f_c(0) = 0$
 - Else
 - If serving cell c is the primary cell
 - $f_c(0) = \Delta P_{rampup} + \delta_{msg2}$
 - where δ_{msg2} is the TPC command indicated in the random access response, see Section 6.2, and
 - ΔP_{rampup} is provided by higher layers and corresponds to the total power ramp-up from the first to the last preamble

Table 5.1.1.1-1 K_{PUSCH} for TDD configuration 0-6

TDD UL/DL Configuration	subframe number i									
	0	1	2	3	4	5	6	7	8	9

0	-	-	6	7	4	-	-	6	7	4
1	-	-	6	4	-	-	-	6	4	-
2	-	-	4	-	-	-	-	4	-	-
3	-	-	4	4	4	-	-	-	-	-
4	-	-	4	4	-	-	-	-	-	-
5	-	-	4	-	-	-	-	-	-	-
6	-	-	7	7	5	-	-	7	7	-

Table 5.1.1.1-2: Mapping of TPC Command Field in DCI format 0/3/4 to absolute and accumulated $\delta_{\text{PUSCH},c}$ values.

TPC Command Field in DCI format 0/3/4	Accumulated $\delta_{\text{PUSCH},c}$ [dB]	Absolute $\delta_{\text{PUSCH},c}$ [dB] only DCI format 0/4
0	-1	-4
1	0	-1
2	1	1
3	3	4

Table 5.1.1.1-3: Mapping of TPC Command Field in DCI format 3A to accumulated $\delta_{\text{PUSCH},c}$ values.

TPC Command Field in DCI format 3A	Accumulated $\delta_{\text{PUSCH},c}$ [dB]
0	-1
1	1

If the total transmit power of the UE would exceed $\hat{P}_{\text{CMAX}}(i)$, the UE scales $\hat{P}_{\text{PUSCH},c}(i)$ for the serving cell c in subframe i such that the condition

$$\sum_c w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) \leq \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUCCH}}(i) \right)$$

is satisfied where $\hat{P}_{\text{PUCCH}}(i)$ is the linear value of $P_{\text{PUCCH}}(i)$, $\hat{P}_{\text{PUSCH},c}(i)$ is the linear value of $P_{\text{PUSCH},c}(i)$, $\hat{P}_{\text{CMAX}}(i)$ is the linear value of the UE total configured maximum output power P_{CMAX} defined in [6] in subframe i and $w(i)$ is a scaling factor of $\hat{P}_{\text{PUSCH},c}(i)$ for serving cell c where $0 \leq w(i) \leq 1$. In case there is no PUCCH transmission in subframe i $\hat{P}_{\text{PUCCH}}(i) = 0$.

If the UE has PUSCH transmission with UCI on serving cell j and PUSCH without UCI in any of the remaining serving cells, and the total transmit power of the UE would exceed $\hat{P}_{\text{CMAX}}(i)$, the UE scales $\hat{P}_{\text{PUSCH},c}(i)$ for the serving cells without UCI in subframe i such that the condition

$$\sum_{c \neq j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) \leq \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUSCH},j}(i) \right)$$

is satisfied where $\hat{P}_{\text{PUSCH},j}(i)$ is the PUSCH transmit power for the cell with UCI and $w(i)$ is a scaling factor of $\hat{P}_{\text{PUSCH},c}(i)$ for serving cell c without UCI. In this case, no power scaling is applied to $\hat{P}_{\text{PUSCH},j}(i)$

unless $\sum_{c \neq j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) = 0$ and the total transmit power of the UE still would exceed $\hat{P}_{\text{CMAX}}(i)$. Note

that $w(i)$ values are the same across serving cells when $w(i) > 0$ but for certain serving cells $w(i)$ may be zero.

If the UE has simultaneous PUCCH and PUSCH transmission with UCI on serving cell j and PUSCH transmission without UCI in any of the remaining serving cells, and the total transmit power of the UE would exceed $\hat{P}_{\text{CMAX}}(i)$, the UE obtains $\hat{P}_{\text{PUSCH},c}(i)$ according to

$$\hat{P}_{\text{PUSCH},j}(i) = \min\left(\hat{P}_{\text{PUSCH},j}(i), \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUCCH}}(i)\right)\right)$$

and

$$\sum_{c \neq j} w(i) \cdot \hat{P}_{\text{PUSCH},c}(i) \leq \left(\hat{P}_{\text{CMAX}}(i) - \hat{P}_{\text{PUCCH}}(i) - \hat{P}_{\text{PUSCH},j}(i)\right)$$

5.1.1.2 Power headroom

There are two types of UE power headroom reports defined. A UE power headroom PH is valid for subframe i for serving cell c .

Type 1:

If the UE transmits PUSCH without PUCCH in subframe i for serving cell c , power headroom for a Type 1 report is computed using

$$PH_{\text{type1},c}(i) = P_{\text{CMAX},c}(i) - \left\{ 10 \log_{10}(M_{\text{PUSCH},c}(i)) + P_{\text{O_PUSCH},c}(j) + \alpha_c(j) \cdot PL_c + \Delta_{\text{TF},c}(i) + f_c(i) \right\} \text{ [dB]}$$

where, $P_{\text{CMAX},c}(i)$, $M_{\text{PUSCH},c}(i)$, $P_{\text{O_PUSCH},c}(j)$, $\alpha_c(j)$, PL_c , $\Delta_{\text{TF},c}(i)$ and $f_c(i)$ are defined in section 5.1.1.1.

If the UE transmits PUSCH with PUCCH in subframe i for serving cell c , power headroom for a Type 1 report is computed using

$$PH_{\text{type1},c}(i) = \tilde{P}_{\text{CMAX},c}(i) - \left\{ 10 \log_{10}(M_{\text{PUSCH},c}(i)) + P_{\text{O_PUSCH},c}(j) + \alpha_c(j) \cdot PL_c + \Delta_{\text{TF},c}(i) + f_c(i) \right\} \text{ [dB]}$$

where, $M_{\text{PUSCH},c}(i)$, $P_{\text{O_PUSCH},c}(j)$, $\alpha_c(j)$, PL_c , $\Delta_{\text{TF},c}(i)$ and $f_c(i)$ are defined in section 5.1.1.1.

$\tilde{P}_{\text{CMAX},c}(i)$ is computed based on the requirements in [6] assuming a PUSCH only transmission in subframe i . For this case, the physical layer delivers $\tilde{P}_{\text{CMAX},c}(i)$ instead of $P_{\text{CMAX},c}(i)$ to higher layers.

If the UE does not transmit PUSCH in subframe i for serving cell c , power headroom for a Type 1 report is computed using

$$PH_{\text{type1},c}(i) = \tilde{P}_{\text{CMAX},c}(i) - \left\{ P_{\text{O_PUSCH},c}(1) + \alpha_c(1) \cdot PL_c + f_c(i) \right\} \text{ [dB]}$$

where, $\tilde{P}_{\text{CMAX},c}(i)$ is computed assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and $\Delta T_c=0$ dB, where MPR, A-MPR, P-MPR and ΔT_c are defined in [6]. $P_{\text{O_PUSCH},c}(1)$, $\alpha_c(1)$, PL_c , and $f_c(i)$ are defined in section 5.1.1.1.

Type 2:

If the UE transmits PUSCH simultaneous with PUCCH in subframe i for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = P_{\text{CMAX},c}(i) - 10 \log_{10} \left(\frac{10^{(10 \log_{10}(M_{\text{PUSCH},c}(i)) + P_{\text{O_PUSCH},c}(j) + \alpha_c(j) \cdot PL_c + \Delta_{\text{TF},c}(i) + f_c(i))/10}}{+ 10^{(P_{\text{O_PUCCH}} + PL_c + h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}}) + \Delta_{\text{F_PUCCH}}(F) + \Delta_{\text{TxD}}(F') + g(i))/10}} \right) \text{ [dB]}$$

where, $P_{\text{CMAX},c}$, $M_{\text{PUSCH},c}(i)$, $P_{\text{O_PUSCH},c}(j)$, $\alpha_c(j)$, $\Delta_{\text{TF},c}(i)$ and $f_c(i)$ are the primary cell parameters as defined in section 5.1.1.1 and $P_{\text{O_PUCCH}}$, PL_c , $h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}})$, $\Delta_{\text{F_PUCCH}}(F)$, $\Delta_{\text{TxD}}(F')$ and $g(i)$ are defined in section 5.1.2.1

If the UE transmits PUSCH without PUCCH in subframe i for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = P_{\text{CMAX},c}(i) - 10 \log_{10} \left(\frac{10^{(10 \log_{10}(M_{\text{PUSCH},c}(i)) + P_{\text{O_PUSCH},c}(j) + \alpha_c(j) \cdot PL_c + \Delta_{\text{TF},c}(i) + f_c(i))/10}}{+ 10^{(P_{\text{O_PUCCH}} + PL_c + g(i))/10}} \right) \text{ [dB]}$$

where, $P_{\text{CMAX},c}(i)$, $M_{\text{PUSCH},c}(i)$, $P_{\text{O_PUSCH},c}(j)$, $\alpha_c(j)$, $\Delta_{\text{TF},c}(i)$ and $f_c(i)$ are the primary cell parameters as defined in section 5.1.1.1 and $P_{\text{O_PUCCH}}$, PL_c and $g(i)$ are defined in section 5.1.2.1.

If the UE transmits PUCCH without PUSCH in subframe i for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = P_{\text{CMAX},c}(i) - 10 \log_{10} \left(\frac{10^{(P_{\text{O_PUSCH},c}(1) + \alpha_c(1) \cdot PL_c + f_c(i))/10}}{+ 10^{(P_{\text{O_PUCCH}} + PL_c + h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}}) + \Delta_{\text{F_PUCCH}}(F) + \Delta_{\text{TxD}}(F') + g(i))/10}} \right) \text{ [dB]}$$

where, $P_{\text{O_PUSCH},c}(1)$, $\alpha_c(1)$ and $f_c(i)$ are the primary cell parameters as defined in section 5.1.1.1,

$P_{\text{CMAX},c}(i)$, $P_{\text{O_PUCCH}}$, PL_c , $h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}})$, $\Delta_{\text{F_PUCCH}}(F)$, $\Delta_{\text{TxD}}(F')$ and $g(i)$ are also defined in section 5.1.2.1.

If the UE does not transmit PUCCH or PUSCH in subframe i for the primary cell, power headroom for a Type 2 report is computed using

$$PH_{\text{type2}}(i) = \tilde{P}_{\text{CMAX},c}(i) - 10 \log_{10} \left(\frac{10^{(P_{\text{O_PUSCH},c}(1) + \alpha_c(1) \cdot PL_c + f_c(i))/10}}{+ 10^{(P_{\text{O_PUCCH}} + PL_c + g(i))/10}} \right) \text{ [dB]}$$

where, $\tilde{P}_{\text{CMAX},c}(i)$ is computed assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and $\Delta T_c=0$ dB, where MPR, A-MPR, P-MPR and ΔT_c are defined in [6], $P_{\text{O_PUSCH},c}(1)$, $\alpha_c(1)$ and $f_c(i)$ are the primary cell parameters as defined in section 5.1.1.1 and $P_{\text{O_PUCCH}}$, PL_c and $g(i)$ are defined in section 5.1.2.1.

The power headroom shall be rounded to the closest value in the range [40; -23] dB with steps of 1 dB and is delivered by the physical layer to higher layers.

5.1.2 Physical uplink control channel

5.1.2.1 UE behaviour

If serving cell c is the primary cell, the setting of the UE Transmit power P_{PUCCH} for the physical uplink control channel (PUCCH) transmission in subframe i is defined by

$$P_{\text{PUCCH}}(i) = \min \left\{ P_{\text{CMAX},c}(i), P_{0_ \text{PUCCH}} + PL_c + h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}}) + \Delta_{\text{F_PUCCH}}(F) + \Delta_{\text{TxD}}(F') + g(i) \right\} \quad [\text{dBm}]$$

If the UE is not transmitting PUCCH for the primary cell, for the accumulation of TPC command received with DCI format 3/3A for PUCCH, the UE shall assume that the UE transmit power P_{PUCCH} for the PUCCH transmission in subframe i is computed by

$$P_{\text{PUCCH}}(i) = \min \{ P_{\text{CMAX},c}(i), P_{0_ \text{PUCCH}} + PL_c + g(i) \} \quad [\text{dBm}]$$

where

- $P_{\text{CMAX},c}(i)$ is the configured UE transmit power defined in [6] in subframe i for serving cell c . If the UE transmits PUSCH without PUCCH in subframe i for the serving cell c , for the accumulation of TPC command received with DCI format 3/3A for PUCCH, the UE shall assume $P_{\text{CMAX},c}(i)$ as given by section 5.1.1.1. If the UE does not transmit PUCCH and PUSCH in subframe i for the serving cell c , for the accumulation of TPC command received with DCI format 3/3A for PUCCH, the UE shall compute $P_{\text{CMAX},c}(i)$ assuming MPR=0dB, A-MPR=0dB, P-MPR=0dB and $\Delta T_c = 0$ dB, where MPR, A-MPR, P-MPR and ΔT_c are defined in [6].
- The parameter $\Delta_{\text{F_PUCCH}}(F)$ is provided by higher layers. Each $\Delta_{\text{F_PUCCH}}(F)$ value corresponds to a PUCCH format (F) relative to PUCCH format 1a, where each PUCCH format (F) is defined in Table 5.4-1 of [3].
- If the UE is configured by higher layers to transmit PUCCH on two antenna ports, the value of $\Delta_{\text{TxD}}(F')$ is provided by higher layers where each PUCCH format F' is defined in Table 5.4-1 of [3]; otherwise, $\Delta_{\text{TxD}}(F') = 0$.
- $h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}})$ is a PUCCH format dependent value, where n_{CQI} corresponds to the number of information bits for the channel quality information defined in section 5.2.3.3 in [4]. $n_{\text{SR}} = 1$ if subframe i is configured for SR for the UE not having any associated transport block for UL-SCH, otherwise $n_{\text{SR}} = 0$. If the UE is configured with one serving cell n_{HARQ} is the number of HARQ-ACK bits sent in subframe i ; otherwise, the value of n_{HARQ} is defined in section 10.1.
 - For PUCCH format 1, 1a and 1b $h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}}) = 0$
 - For PUCCH format 1b with channel selection, if the UE is configured with more than one serving cell, $h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}}) = \frac{(n_{\text{HARQ}} - 1)}{2}$, otherwise, $h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}}) = 0$
 - For PUCCH format 2, 2a, 2b and normal cyclic prefix

$$h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}}) = \begin{cases} 10 \log_{10} \left(\frac{n_{\text{CQI}}}{4} \right) & \text{if } n_{\text{CQI}} \geq 4 \\ 0 & \text{otherwise} \end{cases}$$
 - For PUCCH format 2 and extended cyclic prefix

$$h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}}) = \begin{cases} 10 \log_{10} \left(\frac{n_{\text{CQI}} + n_{\text{HARQ}}}{4} \right) & \text{if } n_{\text{CQI}} + n_{\text{HARQ}} \geq 4 \\ 0 & \text{otherwise} \end{cases}$$

- For PUCCH format 3

- If the UE is configured by higher layers to transmit PUCCH on two antenna ports, or if the UE transmits more than 11 bits of HARQ-ACK/SR

$$h(n_{CQI}, n_{HARQ}, n_{SR}) = \frac{n_{HARQ} + n_{SR} - 1}{3}$$

- Otherwise

$$h(n_{CQI}, n_{HARQ}, n_{SR}) = \frac{n_{HARQ} + n_{SR} - 1}{2}$$

- P_{O_PUCCH} is a parameter composed of the sum of a parameter $P_{O_NOMINAL_PUCCH}$ provided by higher layers and a parameter $P_{O_UE_PUCCH}$ provided by higher layers.
- δ_{PUCCH} is a UE specific correction value, also referred to as a TPC command, included in a PDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C for the primary cell or sent jointly coded with other UE specific PUCCH correction values on a PDCCH with DCI format 3/3A whose CRC parity bits are scrambled with TPC-PUCCH-RNTI.
 - The UE attempts to decode a PDCCH of DCI format 3/3A with the UE's TPC-PUCCH-RNTI and one or several PDCCHs of DCI format 1A/1B/1D/1/2A/2/2B/2C with the UE's C-RNTI or SPS C-RNTI on every subframe except when in DRX.
 - If the UE decodes a PDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C for the primary cell and the corresponding detected RNTI equals the C-RNTI or SPS C-RNTI of the UE and the TPC field in the DCI format is not used to determine the PUCCH resource as in section 10.1, the UE shall use the δ_{PUCCH} provided in that PDCCH.

else

- if the UE decodes a PDCCH with DCI format 3/3A, the UE shall use the δ_{PUCCH} provided in that PDCCH
- else the UE shall set $\delta_{PUCCH} = 0$ dB.

- $g(i) = g(i-1) + \sum_{m=0}^{M-1} \delta_{PUCCH}(i - k_m)$ where $g(i)$ is the current PUCCH power control adjustment state and where $g(0)$ is the first value after reset.

- For FDD, $M = 1$ and $k_0 = 4$.
- For TDD, values of M and k_m are given in Table 10.1.3.1-1.
- The δ_{PUCCH} dB values signalled on PDCCH with DCI format 1A/1B/1D/1/2A/2/2B/2C are given in Table 5.1.2.1-1. If the PDCCH with DCI format 1/1A/2/2A/2B/2C is validated as an SPS activation PDCCH, or the PDCCH with DCI format 1A is validated as an SPS release PDCCH, then δ_{PUCCH} is 0dB.
- The δ_{PUCCH} dB values signalled on PDCCH with DCI format 3/3A are given in Table 5.1.2.1-1 or in Table 5.1.2.1-2 as semi-statically configured by higher layers.
- If $P_{O_UE_PUCCH}$ value is changed by higher layers,
 - $g(0) = 0$
- Else
 - $g(0) = \Delta P_{rampup} + \delta_{msg2}$

- where δ_{msg2} is the TPC command indicated in the random access response, see Section 6.2 and

- ΔP_{rampup} is the total power ramp-up from the first to the last preamble provided by higher layers
- If UE has reached $P_{\text{CMAX},c}(i)$ for the primary cell, positive TPC commands for the primary cell shall not be accumulated
- If UE has reached minimum power, negative TPC commands shall not be accumulated
- UE shall reset accumulation
 - when $P_{\text{O_UE_PUCCH}}$ value is changed by higher layers
 - when the UE receives a random access response message
- $g(i) = g(i-1)$ if i is not an uplink subframe in TDD.

Table 5.1.2.1-1: Mapping of TPC Command Field in DCI format 1A/1B/1D/1/2A/2B/2C/2/3 to δ_{PUCCH} values.

TPC Command Field in DCI format 1A/1B/1D/1/2A/2B/2C/2/3	δ_{PUCCH} [dB]
0	-1
1	0
2	1
3	3

Table 5.1.2.1-2: Mapping of TPC Command Field in DCI format 3A to δ_{PUCCH} values.

TPC Command Field in DCI format 3A	δ_{PUCCH} [dB]
0	-1
1	1

5.1.3 Sounding Reference Symbol

5.1.3.1 UE behaviour

The setting of the UE Transmit power P_{SRS} for the Sounding Reference Symbol transmitted on subframe i for serving cell c is defined by

$$P_{\text{SRS},c}(i) = \min \left\{ P_{\text{CMAX},c}(i), P_{\text{SRS_OFFSET},c}(m) + 10 \log_{10}(M_{\text{SRS},c}) + P_{\text{O_PUSCH},c}(j) + \alpha_c(j) \cdot PL_c + f_c(i) \right\} \text{ [dBm]}$$

where

- $P_{\text{CMAX},c}(i)$ is the configured UE transmit power defined in [6] in subframe i for serving cell c .
- $P_{\text{SRS_OFFSET},c}(m)$ is a 4-bit parameter semi-statically configured by higher layers for $m=0$ and $m=1$ for serving cell c . For SRS transmission given trigger type 0 then $m=0$ and for SRS transmission given trigger type 1 then $m=1$. For $K_S = 1.25$, $P_{\text{SRS_OFFSET},c}(m)$ has 1dB step size in the range [-3, 12] dB. For $K_S = 0$, $P_{\text{SRS_OFFSET},c}(m)$ has 1.5 dB step size in the range [-10.5, 12] dB.
- $M_{\text{SRS},c}$ is the bandwidth of the SRS transmission in subframe i for serving cell c expressed in number of resource blocks.
- $f_c(i)$ is the current PUSCH power control adjustment state for serving cell c , see Section 5.1.1.1.

- $P_{O_PUSCH,c}(j)$ and $\alpha_c(j)$ are parameters as defined in Section 5.1.1.1, where $j = 1$.

If the total transmit power of the UE for the Sounding Reference Symbol would exceed $\hat{P}_{CMAX}(i)$, the UE scales $\hat{P}_{SRS,c}(i)$ for the serving cell c in subframe i such that the condition

$$\sum_c w(i) \cdot \hat{P}_{SRS,c}(i) \leq \hat{P}_{CMAX}(i)$$

is satisfied where $\hat{P}_{SRS,c}(i)$ is the linear value of $P_{SRS,c}(i)$, $\hat{P}_{CMAX}(i)$ is the linear value of P_{CMAX} defined in [6] in subframe i and $w(i)$ is a scaling factor of $\hat{P}_{SRS,c}(i)$ for serving cell c where $0 < w(i) \leq 1$. Note that $w(i)$ values are the same across serving cells.

5.2 Downlink power allocation

The eNodeB determines the downlink transmit energy per resource element.

A UE may assume downlink cell-specific RS EPRE is constant across the downlink system bandwidth and constant across all subframes until different cell-specific RS power information is received. The downlink cell-specific reference-signal EPRE can be derived from the downlink reference-signal transmit power given by the parameter *referenceSignalPower* provided by higher layers. The downlink reference-signal transmit power is defined as the linear average over the power contributions (in [W]) of all resource elements that carry cell-specific reference signals within the operating system bandwidth.

The ratio of PDSCH EPRE to cell-specific RS EPRE among PDSCH REs (not applicable to PDSCH REs with zero EPRE) for each OFDM symbol is denoted by either ρ_A or ρ_B according to the OFDM symbol index as given by Table 5.2-2 and Table 5.2-3. In addition, ρ_A and ρ_B are UE-specific.

For a UE in transmission mode 8 or 9 when UE-specific RSs are not present in the PRBs upon which the corresponding PDSCH is mapped or in transmission modes 1 – 7, the UE may assume that for 16 QAM, 64 QAM, spatial multiplexing with more than one layer or for PDSCH transmissions associated with the multi-user MIMO transmission scheme,

- ρ_A is equal to $\delta_{\text{power-offset}} + P_A + 10 \log_{10}(2)$ [dB] when the UE receives a PDSCH data transmission using precoding for transmit diversity with 4 cell-specific antenna ports according to Section 6.3.4.3 of [3];
- ρ_A is equal to $\delta_{\text{power-offset}} + P_A$ [dB] otherwise

where $\delta_{\text{power-offset}}$ is 0 dB for all PDSCH transmission schemes except multi-user MIMO and where P_A is a UE specific parameter provided by higher layers.

For transmission mode 7, if UE-specific RSs are present in the PRBs upon which the corresponding PDSCH is mapped, the ratio of PDSCH EPRE to UE-specific RS EPRE within each OFDM symbol containing UE-specific RSs shall be a constant, and that constant shall be maintained over all the OFDM symbols containing the UE-specific RSs in the corresponding PRBs. In addition, the UE may assume that for 16QAM or 64QAM, this ratio is 0 dB.

For transmission mode 8, if UE-specific RSs are present in the PRBs upon which the corresponding PDSCH is mapped, the UE may assume the ratio of PDSCH EPRE to UE-specific RS EPRE within each OFDM symbol containing UE-specific RSs is 0 dB.

For transmission mode 9, if UE-specific RSs are present in the PRBs upon which the corresponding PDSCH is mapped, the UE may assume the ratio of PDSCH EPRE to UE-specific RS EPRE within each OFDM symbol containing UE-specific RS is 0 dB for number of transmission layers less than or equal to two and -3 dB otherwise.

A UE may assume that downlink positioning reference signal EPRE is constant across the positioning reference signal bandwidth and across all OFDM symbols that contain positioning reference signals in a given positioning reference signal occasion [10].

If CSI-RS is configured in a serving cell then a UE shall assume downlink CSI-RS EPRE is constant across the downlink system bandwidth and constant across all subframes.

The cell-specific ratio ρ_B / ρ_A is given by Table 5.2-1 according to cell-specific parameter P_B signalled by higher layers and the number of configured eNodeB cell specific antenna ports.

Table 5.2-1: The cell-specific ratio ρ_B / ρ_A for 1, 2, or 4 cell specific antenna ports

P_B	ρ_B / ρ_A	
	One Antenna Port	Two and Four Antenna Ports
0	1	5/4
1	4/5	1
2	3/5	3/4
3	2/5	1/2

For PMCH with 16QAM or 64QAM, the UE may assume that the ratio of PMCH EPRE to MBSFN RS EPRE is equal to 0 dB.

Table 5.2-2: OFDM symbol indices within a slot of a non-MBSFN subframe where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A or ρ_B

Number of antenna ports	OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A		OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_B	
	Normal cyclic prefix	Extended cyclic prefix	Normal cyclic prefix	Extended cyclic prefix
One or two	1, 2, 3, 5, 6	1, 2, 4, 5	0, 4	0, 3
Four	2, 3, 5, 6	2, 4, 5	0, 1, 4	0, 1, 3

Table 5.2-3: OFDM symbol indices within a slot of an MBSFN subframe where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A or ρ_B

Number of antenna ports	OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A				OFDM symbol indices within a slot where the ratio of the corresponding PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_B			
	Normal cyclic prefix		Extended cyclic prefix		Normal cyclic prefix		Extended cyclic prefix	
	$n_s \bmod 2 = 0$	$n_s \bmod 2 = 1$	$n_s \bmod 2 = 0$	$n_s \bmod 2 = 1$	$n_s \bmod 2 = 0$	$n_s \bmod 2 = 1$	$n_s \bmod 2 = 0$	$n_s \bmod 2 = 1$
One or two	1, 2, 3, 4, 5, 6	0, 1, 2, 3, 4, 5, 6	1, 2, 3, 4, 5	0, 1, 2, 3, 4, 5	0	-	0	-
Four	2, 3, 4, 5, 6	0, 1, 2, 3, 4, 5, 6	2, 4, 3, 5	0, 1, 2, 3, 4, 5	0, 1	-	0, 1	-

5.2.1 eNodeB Relative Narrowband TX Power restrictions

The determination of reported Relative Narrowband TX Power indication $RNTP(n_{PRB})$ is defined as follows:

$$RNTP(n_{PRB}) = \begin{cases} 0 & \text{if } \frac{E_A(n_{PRB})}{E_{\max_nom}^{(p)}} \leq RNTP_{\text{threshold}} \\ 1 & \text{if no promise about the upper limit of } \frac{E_A(n_{PRB})}{E_{\max_nom}^{(p)}} \text{ is made} \end{cases}$$

where $E_A(n_{PRB})$ is the maximum intended EPRE of UE-specific PDSCH REs in OFDM symbols not containing RS in this physical resource block on antenna port p in the considered future time interval; n_{PRB} is the physical resource

block number $n_{PRB} = 0, \dots, N_{RB}^{DL} - 1$; $RNTP_{threshold}$ takes on one of the following values $RNTP_{threshold} \in \{-\infty, -11, -10, -9, -8, -7, -6, -5, -4, -3, -2, -1, 0, +1, +2, +3\}$ [dB] and

$$E_{max_nom}^{(p)} = \frac{P_{max}^{(p)} \cdot \frac{1}{\Delta f}}{N_{RB}^{DL} \cdot N_{SC}^{RB}}$$

where $P_{max}^{(p)}$ is the base station maximum output power described in [7], and Δf , N_{RB}^{DL} and N_{SC}^{RB} are defined in [3].

6 Random access procedure

Prior to initiation of the non-synchronized physical random access procedure, Layer 1 shall receive the following information from the higher layers:

1. Random access channel parameters (PRACH configuration and frequency position)
2. Parameters for determining the root sequences and their cyclic shifts in the preamble sequence set for the primary cell (index to logical root sequence table, cyclic shift (N_{CS}), and set type (unrestricted or restricted set))

6.1 Physical non-synchronized random access procedure

From the physical layer perspective, the L1 random access procedure encompasses the transmission of random access preamble and random access response. The remaining messages are scheduled for transmission by the higher layer on the shared data channel and are not considered part of the L1 random access procedure. A random access channel occupies 6 resource blocks in a subframe or set of consecutive subframes reserved for random access preamble transmissions. The eNodeB is not prohibited from scheduling data in the resource blocks reserved for random access channel preamble transmission.

The following steps are required for the L1 random access procedure:

1. Layer 1 procedure is triggered upon request of a preamble transmission by higher layers.
2. A preamble index, a target preamble received power (PREAMBLE_RECEIVED_TARGET_POWER), a corresponding RA-RNTI and a PRACH resource are indicated by higher layers as part of the request.
3. A preamble transmission power P_{PRACH} is determined as $P_{PRACH} = \min\{P_{CMAX,c}(i), \text{PREAMBLE_RECEIVED_TARGET_POWER} + PL_c\}$ [dBm], where $P_{CMAX,c}(i)$ is the configured UE transmit power defined in [6] for subframe i of the primary cell and PL_c is the downlink pathloss estimate calculated in the UE for the primary cell.
4. A preamble sequence is selected from the preamble sequence set using the preamble index.
5. A single preamble is transmitted using the selected preamble sequence with transmission power P_{PRACH} on the indicated PRACH resource.
6. Detection of a PDCCH with the indicated RA-RNTI is attempted during a window controlled by higher layers (see [8], clause 5.1.4). If detected, the corresponding DL-SCH transport block is passed to higher layers. The higher layers parse the transport block and indicate the 20-bit uplink grant to the physical layer, which is processed according to section 6.2.

6.1.1 Timing

For the L1 random access procedure, UE's uplink transmission timing after a random access preamble transmission is as follows.

- a. If a PDCCH with associated RA-RNTI is detected in subframe n , and the corresponding DL-SCH transport block contains a response to the transmitted preamble sequence, the UE shall, according to the information in the response, transmit an UL-SCH transport block in the first subframe $n + k_1$, $k_1 \geq 6$, if the UL delay field in section 6.2 is set to zero where $n + k_1$ is the first available UL subframe for PUSCH transmission. The UE shall postpone the PUSCH transmission to the next available UL subframe after $n + k_1$ if the field is set to 1.
- b. If a random access response is received in subframe n , and the corresponding DL-SCH transport block does not contain a response to the transmitted preamble sequence, the UE shall, if requested by higher layers, be ready to transmit a new preamble sequence no later than in subframe $n + 5$.
- c. If no random access response is received in subframe n , where subframe n is the last subframe of the random access response window, the UE shall, if requested by higher layers, be ready to transmit a new preamble sequence no later than in subframe $n + 4$.

In case a random access procedure is initiated by a PDCCH order in subframe n , the UE shall, if requested by higher layers, transmit random access preamble in the first subframe $n + k_2$, $k_2 \geq 6$, where a PRACH resource is available.

6.2 Random Access Response Grant

The higher layers indicate the 20-bit UL Grant to the physical layer, as defined in [8]. This is referred to the Random Access Response Grant in the physical layer. The content of these 20 bits starting with the MSB and ending with the LSB are as follows:

- Hopping flag – 1 bit
- Fixed size resource block assignment – 10 bits
- Truncated modulation and coding scheme – 4 bits
- TPC command for scheduled PUSCH – 3 bits
- UL delay – 1 bit
- CSI request – 1 bit

The UE shall use the single-antenna port uplink transmission scheme for the PUSCH transmission corresponding to the Random Access Response Grant and the PUSCH retransmission for the same transport block.

The UE shall perform PUSCH frequency hopping if the single bit frequency hopping (FH) field in a corresponding Random Access Response Grant is set as 1 and the uplink resource block assignment is type 0, otherwise no PUSCH frequency hopping is performed. When the hopping flag is set, the UE shall perform PUSCH hopping as indicated via the fixed size resource block assignment detailed below.

The fixed size resource block assignment field is interpreted as follows:

if $N_{RB}^{UL} \leq 44$

Truncate the fixed size resource block assignment to its b least significant bits, where

$b = \left\lceil \log_2 \left(N_{RB}^{UL} \cdot (N_{RB}^{UL} + 1) / 2 \right) \right\rceil$, and interpret the truncated resource block assignment according to the rules for a regular DCI format 0

else

Insert b most significant bits with value set to '0' after the N_{UL_hop} hopping bits in the fixed size resource block assignment, where the number of hopping bits N_{UL_hop} is zero when the hopping flag bit is not set to 1, and is defined in Table 8.4-1 when the hopping flag bit is set to 1, and $b = \left(\left\lceil \log_2 \left(N_{RB}^{UL} \cdot (N_{RB}^{UL} + 1) / 2 \right) \right\rceil - 10 \right)$, and interpret the expanded resource block assignment according to the rules for a regular DCI format 0

end if

The truncated modulation and coding scheme field is interpreted such that the modulation and coding scheme corresponding to the Random Access Response grant is determined from MCS indices 0 through 15 in Table 8.6.1-1.

The TPC command δ_{msg2} shall be used for setting the power of the PUSCH, and is interpreted according to Table 6.2-1.

Table 6.2-1: TPC Command δ_{msg2} for Scheduled PUSCH

TPC Command	Value (in dB)
0	-6
1	-4
2	-2
3	0
4	2
5	4
6	6
7	8

In non-contention based random access procedure, the CSI request field is interpreted to determine whether an aperiodic CQI, PMI, and RI report is included in the corresponding PUSCH transmission according to section 7.2.1. In contention based random access procedure, the CSI request field is reserved.

The UL delay applies for both TDD and FDD and this field can be set to 0 or 1 to indicate whether the delay of PUSCH is introduced as shown in section 6.1.1.

7 Physical downlink shared channel related procedures

For FDD, there shall be a maximum of 8 downlink HARQ processes per serving cell.

For TDD, the maximum number of downlink HARQ processes per serving cell shall be determined by the UL/DL configuration (Table 4.2-2 of [3]), as indicated in Table 7-1.

The dedicated broadcast HARQ process defined in [8] is not counted as part of the maximum number of HARQ processes for both FDD and TDD.

Table 7-1: Maximum number of DL HARQ processes for TDD

TDD UL/DL configuration	Maximum number of HARQ processes
0	4
1	7
2	10
3	9
4	12
5	15
6	6

7.1 UE procedure for receiving the physical downlink shared channel

Except the subframes indicated by the higher layer parameter *mbsfn-SubframeConfigList*, a UE shall upon detection of a PDCCH of a serving cell with DCI format 1, 1A, 1B, 1C, 1D, 2, 2A, 2B or 2C intended for the UE in a subframe,

decode the corresponding PDSCH in the same subframe with the restriction of the number of transport blocks defined in the higher layers.

A UE may assume that positioning reference signals are not present in resource blocks in which it shall decode PDSCH according to a detected PDCCH with CRC scrambled by the SI-RNTI or P-RNTI with DCI format 1A or 1C intended for the UE.

A UE configured with the carrier indicator field for a given serving cell shall assume that the carrier indicator field is not present in any PDCCH of the serving cell in the common search space that is described in section 9.1. Otherwise, the configured UE shall assume that for the given serving cell the carrier indicator field is present in PDCCH located in the UE specific search space described in section 9.1 when the PDCCH CRC is scrambled by C-RNTI or SPS C-RNTI.

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the SI-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to any of the combinations defined in Table 7.1-1. The scrambling initialization of PDSCH corresponding to these PDCCHs is by SI-RNTI.

Table 7.1-1: PDCCH and PDSCH configured by SI-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1C	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used, otherwise Transmit diversity.
DCI format 1A	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used, otherwise Transmit diversity

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the P-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to any of the combinations defined in Table 7.1-2. The scrambling initialization of PDSCH corresponding to these PDCCHs is by P-RNTI.

Table 7.1-2: PDCCH and PDSCH configured by P-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1C	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
DCI format 1A	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the RA-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to any of the combinations defined in Table 7.1-3. The scrambling initialization of PDSCH corresponding to these PDCCHs is by RA-RNTI.

When RA-RNTI and either C-RNTI or SPS C-RNTI are assigned in the same subframe, UE is not required to decode a PDSCH indicated by a PDCCH with a CRC scrambled by C-RNTI or SPS C-RNTI.

Table 7.1-3: PDCCH and PDSCH configured by RA-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1C	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
DCI format 1A	Common	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)

The UE is semi-statically configured via higher layer signalling to receive PDSCH data transmissions signalled via PDCCH according to one of nine transmission modes, denoted mode 1 to mode 9.

For frame structure type 1,

- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5 in any subframe in which the number of OFDM symbols for PDCCH with normal CP is equal to four;
- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5, 7, 8, 9, 10, 11, 12, 13 or 14 in the two PRBs to which a pair of VRBs is mapped if either one of the two PRBs overlaps in frequency with a transmission of either PBCH or primary or secondary synchronisation signals in the same subframe;
- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 7 for which distributed VRB resource allocation is assigned.
- The UE may skip decoding the transport block(s) if it does not receive all assigned PDSCH resource blocks. If the UE skips decoding, the physical layer indicates to higher layer that the transport block(s) are not successfully decoded.

For frame structure type 2,

- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5 in any subframe in which the number of OFDM symbols for PDCCH with normal CP is equal to four;
- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 5 in the two PRBs to which a pair of VRBs is mapped if either one of the two PRBs overlaps in frequency with a transmission of PBCH in the same subframe;
- the UE is not expected to receive PDSCH resource blocks transmitted on antenna port 7, 8, 9, 10, 11, 12, 13 or 14 in the two PRBs to which a pair of VRBs is mapped if either one of the two PRBs overlaps in frequency with a transmission of primary or secondary synchronisation signals in the same subframe;
- with normal CP configuration, the UE is not expected to receive PDSCH on antenna port 5 for which distributed VRB resource allocation is assigned in the special subframe with configuration #1 or #6;
- the UE is not expected to receive PDSCH on antenna port 7 for which distributed VRB resource allocation is assigned.
- The UE may skip decoding the transport block(s) if it does not receive all assigned PDSCH resource blocks. If the UE skips decoding, the physical layer indicates to higher layer that the transport block(s) are not successfully decoded.

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the C-RNTI, the UE shall decode the PDCCH and any corresponding PDSCH according to the respective combinations defined in Table 7.1-5. The scrambling initialization of PDSCH corresponding to these PDCCHs is by C-RNTI.

If the UE is configured with the carrier indicator field for a given serving cell and, if the UE is configured by higher layers to decode PDCCH with CRC scrambled by the C-RNTI, then the UE shall decode PDSCH of the serving cell indicated by the carrier indicator field value in the decoded PDCCH.

When a UE configured in transmission mode 3, 4, 8 or 9 receives a DCI Format 1A assignment, it shall assume that the PDSCH transmission is associated with transport block 1 and that transport block 2 is disabled.

When a UE is configured in transmission mode 7, scrambling initialization of UE-specific reference signals corresponding to these PDCCHs is by C-RNTI.

The UE does not support transmission mode 8 if extended cyclic prefix is used in the downlink.

When a UE is configured in transmission mode 9, in the subframes indicated by the higher layer parameter *mbsfn-SubframeConfigList* except in subframes for the serving cell

- indicated by higher layers to decode PMCH or,
- configured by higher layers to be part of a positioning reference signal occasion and the positioning reference signal occasion is only configured within MBSFN subframes and the cyclic prefix length used in subframe #0 is normal cyclic prefix,

the UE shall upon detection of a PDCCH with CRC scrambled by the C-RNTI with DCI format 1A or 2C intended for the UE, decode the corresponding PDSCH in the same subframe.

Table 7.1-5: PDCCH and PDSCH configured by C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
Mode 1	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 0 (see subclause 7.1.1)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 0 (see subclause 7.1.1)
Mode 2	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 1	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 3	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 2A	UE specific by C-RNTI	Large delay CDD (see subclause 7.1.3) or Transmit diversity (see subclause 7.1.2)
Mode 4	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 2	UE specific by C-RNTI	Closed-loop spatial multiplexing (see subclause 7.1.4) or Transmit diversity (see subclause 7.1.2)
Mode 5	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 1D	UE specific by C-RNTI	Multi-user MIMO (see subclause 7.1.5)
Mode 6	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 1B	UE specific by C-RNTI	Closed-loop spatial multiplexing (see subclause 7.1.4) using a single transmission layer
Mode 7	DCI format 1A	Common and UE specific by C-RNTI	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 5 (see subclause 7.1.1)
Mode 8	DCI format 1A	Common and UE specific by C-RNTI	If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
	DCI format 2B	UE specific by C-RNTI	Dual layer transmission, port 7 and 8 (see subclause 7.1.5A) or single-antenna port, port 7 or 8 (see subclause 7.1.1)
Mode 9	DCI format 1A	Common and UE specific by C-RNTI	Non-MBSFN subframe: If the number of PBCH antenna ports is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2) MBSFN subframe: Single-antenna port, port 7 (see subclause 7.1.1)
	DCI format 2C	UE specific by C-RNTI	Up to 8 layer transmission, ports 7-14 (see subclause 7.1.5B)

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the SPS C-RNTI, the UE shall decode the PDCCH on the primary cell and any corresponding PDSCH on the primary cell according to the respective combinations defined in Table 7.1-6. The same PDSCH related configuration applies in the case that a PDSCH is transmitted without a corresponding PDCCH. The scrambling initialization of PDSCH corresponding to these PDCCHs and PDSCH without a corresponding PDCCH is by SPS C-RNTI.

When a UE is configured in transmission mode 7, scrambling initialization of UE-specific reference signals corresponding to these PDCCHs is by SPS C-RNTI.

When a UE is configured in transmission mode 9, in the subframes indicated by the higher layer parameter *mbsfn-SubframeConfigList* except in subframes for the serving cell

- indicated by higher layers to decode PMCH or,
- configured by higher layers to be part of a positioning reference signal occasion and the positioning reference signal occasion is only configured within MBSFN subframes and the cyclic prefix length used in subframe #0 is normal cyclic prefix,

the UE shall upon detection of a PDCCH with CRC scrambled by the SPS C-RNTI with DCI format 1A or 2C or for a configured PDSCH without PDCCH intended for the UE, decode the corresponding PDSCH in the same subframe.

Table 7.1-6: PDCCH and PDSCH configured by SPS C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
Mode 1	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 0 (see subclause 7.1.1)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 0 (see subclause 7.1.1)
Mode 2	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 1	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 3	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 2A	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 4	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
	DCI format 2	UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 5	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 6	DCI format 1A	Common and UE specific by C-RNTI	Transmit diversity (see subclause 7.1.2)
Mode 7	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 5 (see subclause 7.1.1)
	DCI format 1	UE specific by C-RNTI	Single-antenna port, port 5 (see subclause 7.1.1)
Mode 8	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 7 (see subclause 7.1.1)
	DCI format 2B	UE specific by C-RNTI	Single-antenna port, port 7 or 8 (see subclause 7.1.1)
Mode 9	DCI format 1A	Common and UE specific by C-RNTI	Single-antenna port, port 7 (see subclause 7.1.1)
	DCI format 2C	UE specific by C-RNTI	Single-antenna port, port 7 or 8, (see subclause 7.1.1)

If a UE is configured by higher layers to decode PDCCH with CRC scrambled by the Temporary C-RNTI and is not configured to decode PDCCH with CRC scrambled by the C-RNTI, the UE shall decode the PDCCH and the corresponding PDSCH according to the combination defined in Table 7.1-7. The scrambling initialization of PDSCH corresponding to these PDCCHs is by Temporary C-RNTI.

Table 7.1-7: PDCCH and PDSCH configured by Temporary C-RNTI

DCI format	Search Space	Transmission scheme of PDSCH corresponding to PDCCH
DCI format 1A	Common and UE specific by Temporary C-RNTI	If the number of PBCH antenna port is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)
DCI format 1	UE specific by Temporary C-RNTI	If the number of PBCH antenna port is one, Single-antenna port, port 0 is used (see subclause 7.1.1), otherwise Transmit diversity (see subclause 7.1.2)

The transmission schemes of the PDSCH are described in the following sub-clauses.

7.1.1 Single-antenna port scheme

For the single-antenna port transmission schemes (port 0, port 5, port 7 or port 8) of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to Section 6.3.4.1 of [3].

In case an antenna port $p \in \{7,8\}$ is used, the UE cannot assume that the other antenna port in the set $\{7,8\}$ is not associated with transmission of PDSCH to another UE.

7.1.2 Transmit diversity scheme

For the transmit diversity transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to Section 6.3.4.3 of [3].

7.1.3 Large delay CDD scheme

For the large delay CDD transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to large delay CDD as defined in Section 6.3.4.2.2 of [3].

7.1.4 Closed-loop spatial multiplexing scheme

For the closed-loop spatial multiplexing transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed according to the applicable number of transmission layers as defined in Section 6.3.4.2.1 of [3].

7.1.5 Multi-user MIMO scheme

For the multi-user MIMO transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed on one layer and according to Section 6.3.4.2.1 of [3]. The $\delta_{\text{power-offset}}$ dB value signalled on PDCCH with DCI format 1D using the downlink power offset field is given in Table 7.1.5-1.

Table 7.1.5-1: Mapping of downlink power offset field in DCI format 1D to the $\delta_{\text{power-offset}}$ value.

Downlink power offset field	$\delta_{\text{power-offset}}$ [dB]
0	$-10\log_{10}(2)$
1	0

7.1.5A Dual layer scheme

For the dual layer transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed with two transmission layers on antenna ports 7 and 8 as defined in Section 6.3.4.4 of [3].

7.1.5B Up to 8 layer transmission scheme

For the up to 8 layer transmission scheme of the PDSCH, the UE may assume that an eNB transmission on the PDSCH would be performed with up to 8 transmission layers on antenna ports 7 - 14 as defined in Section 6.3.4.4 of [3].

7.1.6 Resource allocation

The UE shall interpret the resource allocation field depending on the PDCCH DCI format detected. A resource allocation field in each PDCCH includes two parts, a resource allocation header field and information consisting of the

actual resource block assignment. PDCCH DCI formats 1, 2, 2A, 2B and 2C with type 0 and PDCCH DCI formats 1, 2, 2A, 2B and 2C with type 1 resource allocation have the same format and are distinguished from each other via the single bit resource allocation header field which exists depending on the downlink system bandwidth (section 5.3.3.1 of [4]), where type 0 is indicated by 0 value and type 1 is indicated otherwise. PDCCH with DCI format 1A, 1B, 1C and 1D have a type 2 resource allocation while PDCCH with DCI format 1, 2, 2A, 2B and 2C have type 0 or type 1 resource allocation. PDCCH DCI formats with a type 2 resource allocation do not have a resource allocation header field.

7.1.6.1 Resource allocation type 0

In resource allocations of type 0, resource block assignment information includes a bitmap indicating the resource block groups (RBGs) that are allocated to the scheduled UE where a RBG is a set of consecutive virtual resource blocks (VRBs) of localized type as defined in section 6.2.3.1 of [3]. Resource block group size (P) is a function of the system bandwidth as shown in Table 7.1.6.1-1. The total number of RBGs (N_{RBG}) for downlink system bandwidth of N_{RB}^{DL} is given by $N_{RBG} = \lceil N_{RB}^{DL} / P \rceil$ where $\lfloor N_{RB}^{DL} / P \rfloor$ of the RBGs are of size P and if $N_{RB}^{DL} \bmod P > 0$ then one of the RBGs is of size $N_{RB}^{DL} - P \cdot \lfloor N_{RB}^{DL} / P \rfloor$. The bitmap is of size N_{RBG} bits with one bitmap bit per RBG such that each RBG is addressable. The RBGs shall be indexed in the order of increasing frequency and non-increasing RBG sizes starting at the lowest frequency. The order of RBG to bitmap bit mapping is in such way that RBG 0 to RBG $N_{RBG} - 1$ are mapped to MSB to LSB of the bitmap. The RBG is allocated to the UE if the corresponding bit value in the bitmap is 1, the RBG is not allocated to the UE otherwise.

Table 7.1.6.1-1: Type 0 Resource Allocation RBG Size vs. Downlink System Bandwidth

System Bandwidth N_{RB}^{DL}	RBG Size (P)
≤ 10	1
11 – 26	2
27 – 63	3
64 – 110	4

7.1.6.2 Resource allocation type 1

In resource allocations of type 1, a resource block assignment information of size N_{RBG} indicates to a scheduled UE the VRBs from the set of VRBs from one of P RBG subsets. The virtual resource blocks used are of localized type as defined in section 6.2.3.1 of [3]. Also P is the RBG size associated with the system bandwidth as shown in Table 7.1.6.1-1. A RBG subset p , where $0 \leq p < P$, consists of every P th RBG starting from RBG p . The resource block assignment information consists of three fields [4].

The first field with $\lceil \log_2(P) \rceil$ bits is used to indicate the selected RBG subset among P RBG subsets.

The second field with one bit is used to indicate a shift of the resource allocation span within a subset. A bit value of 1 indicates shift is triggered. Shift is not triggered otherwise.

The third field includes a bitmap, where each bit of the bitmap addresses a single VRB in the selected RBG subset in such a way that MSB to LSB of the bitmap are mapped to the VRBs in the increasing frequency order. The VRB is allocated to the UE if the corresponding bit value in the bit field is 1, the VRB is not allocated to the UE otherwise. The portion of the bitmap used to address VRBs in a selected RBG subset has size N_{RB}^{TYPE1} and is defined as

$$N_{RB}^{TYPE1} = \lceil N_{RB}^{DL} / P \rceil - \lceil \log_2(P) \rceil - 1$$

The addressable VRB numbers of a selected RBG subset start from an offset, $\Delta_{\text{shift}}(p)$ to the smallest VRB number within the selected RBG subset, which is mapped to the MSB of the bitmap. The offset is in terms of the number of VRBs and is done within the selected RBG subset. If the value of the bit in the second field for shift of the resource

allocation span is set to 0, the offset for RBG subset p is given by $\Delta_{\text{shift}}(p) = 0$. Otherwise, the offset for RBG subset p is given by $\Delta_{\text{shift}}(p) = N_{\text{RB}}^{\text{RBG subset}}(p) - N_{\text{RB}}^{\text{TYPE1}}$, where the LSB of the bitmap is justified with the highest VRB number within the selected RBG subset. $N_{\text{RB}}^{\text{RBG subset}}(p)$ is the number of VRBs in RBG subset p and can be calculated by the following equation,

$$N_{\text{RB}}^{\text{RBG subset}}(p) = \begin{cases} \left\lfloor \frac{N_{\text{RB}}^{\text{DL}} - 1}{P^2} \right\rfloor \cdot P + P & , p < \left\lfloor \frac{N_{\text{RB}}^{\text{DL}} - 1}{P} \right\rfloor \bmod P \\ \left\lfloor \frac{N_{\text{RB}}^{\text{DL}} - 1}{P^2} \right\rfloor \cdot P + (N_{\text{RB}}^{\text{DL}} - 1) \bmod P + 1 & , p = \left\lfloor \frac{N_{\text{RB}}^{\text{DL}} - 1}{P} \right\rfloor \bmod P \\ \left\lfloor \frac{N_{\text{RB}}^{\text{DL}} - 1}{P^2} \right\rfloor \cdot P & , p > \left\lfloor \frac{N_{\text{RB}}^{\text{DL}} - 1}{P} \right\rfloor \bmod P \end{cases}$$

Consequently, when RBG subset p is indicated, bit i for $i = 0, 1, \dots, N_{\text{RB}}^{\text{TYPE1}} - 1$ in the bitmap field indicates VRB number,

$$n_{\text{VRB}}^{\text{RBG subset}}(p) = \left\lfloor \frac{i + \Delta_{\text{shift}}(p)}{P} \right\rfloor P^2 + p \cdot P + (i + \Delta_{\text{shift}}(p)) \bmod P.$$

7.1.6.3 Resource allocation type 2

In resource allocations of type 2, the resource block assignment information indicates to a scheduled UE a set of contiguously allocated localized virtual resource blocks or distributed virtual resource blocks. In case of resource allocation signalled with PDCCH DCI format 1A, 1B or 1D, one bit flag indicates whether localized virtual resource blocks or distributed virtual resource blocks are assigned (value 0 indicates Localized and value 1 indicates Distributed VRB assignment) while distributed virtual resource blocks are always assigned in case of resource allocation signalled with PDCCH DCI format 1C. Localized VRB allocations for a UE vary from a single VRB up to a maximum number of VRBs spanning the system bandwidth. For DCI format 1A the distributed VRB allocations for a UE vary from a single VRB up to $N_{\text{VRB}}^{\text{DL}}$ VRBs, where $N_{\text{VRB}}^{\text{DL}}$ is defined in [3], if the DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI. With PDCCH DCI format 1B, 1D, or 1A with a CRC scrambled with C-RNTI, distributed VRB allocations for a UE vary from a single VRB up to $N_{\text{VRB}}^{\text{DL}}$ VRBs if $N_{\text{RB}}^{\text{DL}}$ is 6-49 and vary from a single VRB up to 16 if $N_{\text{RB}}^{\text{DL}}$ is 50-110. With PDCCH DCI format 1C, distributed VRB allocations for a UE vary from $N_{\text{RB}}^{\text{step}}$ VRB(s) up to $\left\lfloor N_{\text{VRB}}^{\text{DL}} / N_{\text{RB}}^{\text{step}} \right\rfloor \cdot N_{\text{RB}}^{\text{step}}$ VRBs with an increment step of $N_{\text{RB}}^{\text{step}}$, where $N_{\text{RB}}^{\text{step}}$ value is determined depending on the downlink system bandwidth as shown in Table 7.1.6.3-1.

Table 7.1.6.3-1: $N_{\text{RB}}^{\text{step}}$ values vs. Downlink System Bandwidth

System BW ($N_{\text{RB}}^{\text{DL}}$)	$N_{\text{RB}}^{\text{step}}$
	DCI format 1C
6-49	2
50-110	4

For PDCCH DCI format 1A, 1B or 1D, a type 2 resource allocation field consists of a resource indication value (RIV) corresponding to a starting resource block (RB_{start}) and a length in terms of virtually contiguously allocated resource blocks L_{CRBs} . The resource indication value is defined by

$$\text{if } (L_{\text{CRBs}} - 1) \leq \left\lfloor N_{\text{RB}}^{\text{DL}} / 2 \right\rfloor \text{ then}$$

$$RIV = N_{\text{RB}}^{\text{DL}} (L_{\text{CRBs}} - 1) + RB_{\text{start}}$$

else

$$RIV = N_{RB}^{DL} (N_{RB}^{DL} - L_{CRBs} + 1) + (N_{RB}^{DL} - 1 - RB_{start})$$

where $L_{CRBs} \geq 1$ and shall not exceed $N_{VRB}^{DL} - RB_{start}$.

For PDCCH DCI format 1C, a type 2 resource block assignment field consists of a resource indication value (RIV) corresponding to a starting resource block ($RB_{start} = 0, N_{RB}^{step}, 2N_{RB}^{step}, \dots, (\lfloor N_{VRB}^{DL} / N_{RB}^{step} \rfloor - 1)N_{RB}^{step}$) and a length in terms of virtually contiguously allocated resource blocks ($L_{CRBs} = N_{RB}^{step}, 2N_{RB}^{step}, \dots, \lfloor N_{VRB}^{DL} / N_{RB}^{step} \rfloor \cdot N_{RB}^{step}$). The resource indication value is defined by

if $(L'_{CRBs} - 1) \leq \lfloor N_{VRB}^{DL} / 2 \rfloor$ then

$$RIV = N_{VRB}^{DL} (L'_{CRBs} - 1) + RB'_{start}$$

else

$$RIV = N_{VRB}^{DL} (N_{VRB}^{DL} - L'_{CRBs} + 1) + (N_{VRB}^{DL} - 1 - RB'_{start})$$

where $L'_{CRBs} = L_{CRBs} / N_{RB}^{step}$, $RB'_{start} = RB_{start} / N_{RB}^{step}$ and $N_{VRB}^{DL} = \lfloor N_{VRB}^{DL} / N_{RB}^{step} \rfloor$. Here,

$L'_{CRBs} \geq 1$ and shall not exceed $N_{VRB}^{DL} - RB'_{start}$.

7.1.6.4 PDSCH starting position

The starting OFDM symbol for the PDSCH of each activated serving cell given by index $l_{DataStart}$ in the first slot in a subframe is given by

- the higher-layer parameter *pdsch-Start* for the serving cell on which PDSCH is received if the UE is configured with carrier indicator field for the given serving cell and if PDSCH and the corresponding PDCCH are received on different serving cells,
- the span of the DCI given by the CFI of the serving cell according to Section 5.3.4 of [4] otherwise.

7.1.6.5 PRB bundling

A UE configured for transmission mode 9 for a given serving cell c may assume that precoding granularity is multiple resource blocks in the frequency domain when [if] PMI/RI feedback is configured. Fixed system bandwidth dependent Precoding Resource block Groups (PRGs) of size P' partition the system bandwidth and each PRG consists of consecutive PRBs. If $N_{RB}^{DL} \bmod P' > 0$ then one of the PRGs is of size $N_{RB}^{DL} - P' \lfloor N_{RB}^{DL} / P' \rfloor$. The PRG size is non-increasing starting at the lowest frequency. The UE may assume that the same precoder applies on all scheduled PRBs within a PRG.

The PRG size a UE may assume for a given system bandwidth is given by:

Table 7.1.6.5-1

System Bandwidth (N_{RB}^{DL})	PRG Size (P') (PRBs)
≤ 10	1
11 – 26	2
27 – 63	3
64 – 110	2

7.1.7 Modulation order and transport block size determination

To determine the modulation order and transport block size(s) in the physical downlink shared channel, the UE shall first

- read the 5-bit “modulation and coding scheme” field (I_{MCS}) in the DCI

and second if the DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI then

- for DCI format 1A:
 - set the Table 7.1.7.2.1-1 column indicator N_{PRB} to $N_{\text{PRB}}^{\text{1A}}$ from Section 5.3.3.1.3 in [4]
- for DCI format 1C:
 - use Table 7.1.7.2.3-1 for determining its transport block size.

else

- set N'_{PRB} to the total number of allocated PRBs based on the procedure defined in Section 7.1.6.

if the transport block is transmitted in DwPTS of the special subframe in frame structure type 2, then

$$\text{set the Table 7.1.7.2.1-1 column indicator } N_{\text{PRB}} = \max \left\{ \left\lfloor N'_{\text{PRB}} \times 0.75 \right\rfloor, 1 \right\},$$

else, set the Table 7.1.7.2.1-1 column indicator $N_{\text{PRB}} = N'_{\text{PRB}}$.

The UE may skip decoding a transport block in an initial transmission if the effective channel code rate is higher than 0.930, where the effective channel code rate is defined as the number of downlink information bits (including CRC bits) divided by the number of physical channel bits on PDSCH. If the UE skips decoding, the physical layer indicates to higher layer that the transport block is not successfully decoded. For the special subframe configurations 0 and 5 with normal downlink CP or configurations 0 and 4 with extended downlink CP, shown in Table 4.2-1 of [3], there shall be no PDSCH transmission in DwPTS of the special subframe.

7.1.7.1 Modulation order determination

The UE shall use $Q_m = 2$ if the DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI, otherwise, the UE shall use I_{MCS} and Table 7.1.7.1-1 to determine the modulation order (Q_m) used in the physical downlink shared channel.

Table 7.1.7.1-1: Modulation and TBS index table for PDSCH

MCS Index I_{MCS}	Modulation Order Q_m	TBS Index I_{TBS}
0	2	0
1	2	1
2	2	2
3	2	3
4	2	4
5	2	5
6	2	6
7	2	7
8	2	8
9	2	9
10	4	9
11	4	10
12	4	11
13	4	12
14	4	13
15	4	14
16	4	15
17	6	15
18	6	16
19	6	17
20	6	18
21	6	19
22	6	20
23	6	21
24	6	22
25	6	23
26	6	24
27	6	25
28	6	26
29	2	reserved
30	4	
31	6	

7.1.7.2 Transport block size determination

If the DCI CRC is scrambled by P-RNTI, RA-RNTI, or SI-RNTI then

- for DCI format 1A:
 - the UE shall set the TBS index (I_{TBS}) equal to I_{MCS} and determine its TBS by the procedure in Section 7.1.7.2.1.
- for DCI format 1C:
 - the UE shall set the TBS index (I_{TBS}) equal to I_{MCS} and determine its TBS from Table 7.1.7.2.3-1.

else

- for $0 \leq I_{\text{MCS}} \leq 28$, the UE shall first determine the TBS index (I_{TBS}) using I_{MCS} and Table 7.1.7.1-1 except if the transport block is disabled in DCI formats 2, 2A, 2B and 2C as specified below. For a transport block that is not mapped to more than single-layer spatial multiplexing, the TBS is determined by the procedure in Section 7.1.7.2.1. For a transport block that is mapped to two-layer spatial multiplexing, the TBS is determined by the procedure in Section 7.1.7.2.2. For a transport block that is mapped to three-layer spatial multiplexing, the TBS is determined by the procedure in Section 7.1.7.2.4. For a transport block that is mapped to four-layer spatial multiplexing, the TBS is determined by the procedure in Section 7.1.7.2.5.

- for $29 \leq I_{MCS} \leq 31$, the TBS is assumed to be as determined from DCI transported in the latest PDCCH for the same transport block using $0 \leq I_{MCS} \leq 28$. If there is no PDCCH for the same transport block using $0 \leq I_{MCS} \leq 28$, and if the initial PDSCH for the same transport block is semi-persistently scheduled, the TBS shall be determined from the most recent semi-persistent scheduling assignment PDCCH.
- In DCI formats 2, 2A, 2B and 2C a transport block is disabled if $I_{MCS} = 0$ and if $r_{v_{idx}} = 1$ otherwise the transport block is enabled.

The NDI and HARQ process ID, as signalled on PDCCH, and the TBS, as determined above, shall be delivered to higher layers.

7.1.7.2.1 Transport blocks not mapped to two or more layer spatial multiplexing

For $1 \leq N_{PRB} \leq 110$, the TBS is given by the (I_{TBS}, N_{PRB}) entry of Table 7.1.7.2.1-1.

Table 7.1.7.2.1-1: Transport block size table (dimension 27×110)

I_{TBS}	N_{PRB}									
	1	2	3	4	5	6	7	8	9	10
0	16	32	56	88	120	152	176	208	224	256
1	24	56	88	144	176	208	224	256	328	344
2	32	72	144	176	208	256	296	328	376	424
3	40	104	176	208	256	328	392	440	504	568
4	56	120	208	256	328	408	488	552	632	696
5	72	144	224	328	424	504	600	680	776	872
6	328	176	256	392	504	600	712	808	936	1032
7	104	224	328	472	584	712	840	968	1096	1224
8	120	256	392	536	680	808	968	1096	1256	1384
9	136	296	456	616	776	936	1096	1256	1416	1544
10	144	328	504	680	872	1032	1224	1384	1544	1736
11	176	376	584	776	1000	1192	1384	1608	1800	2024
12	208	440	680	904	1128	1352	1608	1800	2024	2280
13	224	488	744	1000	1256	1544	1800	2024	2280	2536
14	256	552	840	1128	1416	1736	1992	2280	2600	2856
15	280	600	904	1224	1544	1800	2152	2472	2728	3112
16	328	632	968	1288	1608	1928	2280	2600	2984	3240
17	336	696	1064	1416	1800	2152	2536	2856	3240	3624
18	376	776	1160	1544	1992	2344	2792	3112	3624	4008
19	408	840	1288	1736	2152	2600	2984	3496	3880	4264
20	440	904	1384	1864	2344	2792	3240	3752	4136	4584
21	488	1000	1480	1992	2472	2984	3496	4008	4584	4968
22	520	1064	1608	2152	2664	3240	3752	4264	4776	5352
23	552	1128	1736	2280	2856	3496	4008	4584	5160	5736
24	584	1192	1800	2408	2984	3624	4264	4968	5544	5992
25	616	1256	1864	2536	3112	3752	4392	5160	5736	6200
26	712	1480	2216	2984	3752	4392	5160	5992	6712	7480

I_{TBS}	N_{PRB}									
	11	12	13	14	15	16	17	18	19	20
0	288	328	344	376	392	424	456	488	504	536
1	376	424	456	488	520	568	600	632	680	712
2	472	520	568	616	648	696	744	776	840	872
3	616	680	744	808	872	904	968	1032	1096	1160
4	776	840	904	1000	1064	1128	1192	1288	1352	1416
5	968	1032	1128	1224	1320	1384	1480	1544	1672	1736
6	1128	1224	1352	1480	1544	1672	1736	1864	1992	2088
7	1320	1480	1608	1672	1800	1928	2088	2216	2344	2472

8	1544	1672	1800	1928	2088	2216	2344	2536	2664	2792
9	1736	1864	2024	2216	2344	2536	2664	2856	2984	3112
10	1928	2088	2280	2472	2664	2792	2984	3112	3368	3496
11	2216	2408	2600	2792	2984	3240	3496	3624	3880	4008
12	2472	2728	2984	3240	3368	3624	3880	4136	4392	4584
13	2856	3112	3368	3624	3880	4136	4392	4584	4968	5160
14	3112	3496	3752	4008	4264	4584	4968	5160	5544	5736
15	3368	3624	4008	4264	4584	4968	5160	5544	5736	6200
16	3624	3880	4264	4584	4968	5160	5544	5992	6200	6456
17	4008	4392	4776	5160	5352	5736	6200	6456	6712	7224
18	4392	4776	5160	5544	5992	6200	6712	7224	7480	7992
19	4776	5160	5544	5992	6456	6968	7224	7736	8248	8504
20	5160	5544	5992	6456	6968	7480	7992	8248	8760	9144
21	5544	5992	6456	6968	7480	7992	8504	9144	9528	9912
22	5992	6456	6968	7480	7992	8504	9144	9528	10296	10680
23	6200	6968	7480	7992	8504	9144	9912	10296	11064	11448
24	6712	7224	7992	8504	9144	9912	10296	11064	11448	12216
25	6968	7480	8248	8760	9528	10296	10680	11448	12216	12576
26	8248	8760	9528	10296	11064	11832	12576	13536	14112	14688

I_{TBS}	N_{PRB}									
	21	22	23	24	25	26	27	28	29	30
0	568	600	616	648	680	712	744	776	776	808
1	744	776	808	872	904	936	968	1000	1032	1064
2	936	968	1000	1064	1096	1160	1192	1256	1288	1320
3	1224	1256	1320	1384	1416	1480	1544	1608	1672	1736
4	1480	1544	1608	1736	1800	1864	1928	1992	2088	2152
5	1864	1928	2024	2088	2216	2280	2344	2472	2536	2664
6	2216	2280	2408	2472	2600	2728	2792	2984	2984	3112
7	2536	2664	2792	2984	3112	3240	3368	3368	3496	3624
8	2984	3112	3240	3368	3496	3624	3752	3880	4008	4264
9	3368	3496	3624	3752	4008	4136	4264	4392	4584	4776
10	3752	3880	4008	4264	4392	4584	4776	4968	5160	5352
11	4264	4392	4584	4776	4968	5352	5544	5736	5992	5992
12	4776	4968	5352	5544	5736	5992	6200	6456	6712	6712
13	5352	5736	5992	6200	6456	6712	6968	7224	7480	7736
14	5992	6200	6456	6968	7224	7480	7736	7992	8248	8504
15	6456	6712	6968	7224	7736	7992	8248	8504	8760	9144
16	6712	7224	7480	7736	7992	8504	8760	9144	9528	9912
17	7480	7992	8248	8760	9144	9528	9912	10296	10296	10680
18	8248	8760	9144	9528	9912	10296	10680	11064	11448	11832
19	9144	9528	9912	10296	10680	11064	11448	12216	12576	12960
20	9912	10296	10680	11064	11448	12216	12576	12960	13536	14112
21	10680	11064	11448	12216	12576	12960	13536	14112	14688	15264
22	11448	11832	12576	12960	13536	14112	14688	15264	15840	16416
23	12216	12576	12960	13536	14112	14688	15264	15840	16416	16992
24	12960	13536	14112	14688	15264	15840	16416	16992	17568	18336
25	13536	14112	14688	15264	15840	16416	16992	17568	18336	19080
26	15264	16416	16992	17568	18336	19080	19848	20616	21384	22152

I_{TBS}	N_{PRB}									
	31	32	33	34	35	36	37	38	39	40
0	840	872	904	936	968	1000	1032	1032	1064	1096
1	1128	1160	1192	1224	1256	1288	1352	1384	1416	1416
2	1384	1416	1480	1544	1544	1608	1672	1672	1736	1800
3	1800	1864	1928	1992	2024	2088	2152	2216	2280	2344
4	2216	2280	2344	2408	2472	2600	2664	2728	2792	2856
5	2728	2792	2856	2984	3112	3112	3240	3368	3496	3496
6	3240	3368	3496	3496	3624	3752	3880	4008	4136	4136

7	3752	3880	4008	4136	4264	4392	4584	4584	4776	4968
8	4392	4584	4584	4776	4968	4968	5160	5352	5544	5544
9	4968	5160	5160	5352	5544	5736	5736	5992	6200	6200
10	5544	5736	5736	5992	6200	6200	6456	6712	6712	6968
11	6200	6456	6712	6968	6968	7224	7480	7736	7736	7992
12	6968	7224	7480	7736	7992	8248	8504	8760	8760	9144
13	7992	8248	8504	8760	9144	9144	9528	9912	9912	10296
14	8760	9144	9528	9912	9912	10296	10680	11064	11064	11448
15	9528	9912	10296	10296	10680	11064	11448	11832	11832	12216
16	9912	10296	10680	11064	11448	11832	12216	12216	12576	12960
17	11064	11448	11832	12216	12576	12960	13536	13536	14112	14688
18	12216	12576	12960	13536	14112	14112	14688	15264	15264	15840
19	13536	13536	14112	14688	15264	15264	15840	16416	16992	16992
20	14688	14688	15264	15840	16416	16992	16992	17568	18336	18336
21	15840	15840	16416	16992	17568	18336	18336	19080	19848	19848
22	16992	16992	17568	18336	19080	19080	19848	20616	21384	21384
23	17568	18336	19080	19848	19848	20616	21384	22152	22152	22920
24	19080	19848	19848	20616	21384	22152	22920	22920	23688	24496
25	19848	20616	20616	21384	22152	22920	23688	24496	24496	25456
26	22920	23688	24496	25456	25456	26416	27376	28336	29296	29296

I_{TBS}	N_{PRB}									
	41	42	43	44	45	46	47	48	49	50
0	1128	1160	1192	1224	1256	1256	1288	1320	1352	1384
1	1480	1544	1544	1608	1608	1672	1736	1736	1800	1800
2	1800	1864	1928	1992	2024	2088	2088	2152	2216	2216
3	2408	2472	2536	2536	2600	2664	2728	2792	2856	2856
4	2984	2984	3112	3112	3240	3240	3368	3496	3496	3624
5	3624	3752	3752	3880	4008	4008	4136	4264	4392	4392
6	4264	4392	4584	4584	4776	4776	4968	4968	5160	5160
7	4968	5160	5352	5352	5544	5736	5736	5992	5992	6200
8	5736	5992	5992	6200	6200	6456	6456	6712	6968	6968
9	6456	6712	6712	6968	6968	7224	7480	7480	7736	7992
10	7224	7480	7480	7736	7992	7992	8248	8504	8504	8760
11	8248	8504	8760	8760	9144	9144	9528	9528	9912	9912
12	9528	9528	9912	9912	10296	10680	10680	11064	11064	11448
13	10680	10680	11064	11448	11448	11832	12216	12216	12576	12960
14	11832	12216	12216	12576	12960	12960	13536	13536	14112	14112
15	12576	12960	12960	13536	13536	14112	14688	14688	15264	15264
16	13536	13536	14112	14112	14688	14688	15264	15840	15840	16416
17	14688	15264	15264	15840	16416	16416	16992	17568	17568	18336
18	16416	16416	16992	17568	17568	18336	18336	19080	19080	19848
19	17568	18336	18336	19080	19080	19848	20616	20616	21384	21384
20	19080	19848	19848	20616	20616	21384	22152	22152	22920	22920
21	20616	21384	21384	22152	22920	22920	23688	24496	24496	25456
22	22152	22920	22920	23688	24496	24496	25456	25456	26416	27376
23	23688	24496	24496	25456	25456	26416	27376	27376	28336	28336
24	25456	25456	26416	26416	27376	28336	28336	29296	29296	30576
25	26416	26416	27376	28336	28336	29296	29296	30576	31704	31704
26	30576	30576	31704	32856	32856	34008	35160	35160	36696	36696

I_{TBS}	N_{PRB}									
	51	52	53	54	55	56	57	58	59	60
0	1416	1416	1480	1480	1544	1544	1608	1608	1608	1672
1	1864	1864	1928	1992	1992	2024	2088	2088	2152	2152
2	2280	2344	2344	2408	2472	2536	2536	2600	2664	2664
3	2984	2984	3112	3112	3240	3240	3368	3368	3496	3496
4	3624	3752	3752	3880	4008	4008	4136	4136	4264	4264
5	4584	4584	4776	4776	4776	4968	4968	5160	5160	5352

6	5352	5352	5544	5736	5736	5992	5992	5992	6200	6200
7	6200	6456	6456	6712	6712	6712	6968	6968	7224	7224
8	7224	7224	7480	7480	7736	7736	7992	7992	8248	8504
9	7992	8248	8248	8504	8760	8760	9144	9144	9144	9528
10	9144	9144	9144	9528	9528	9912	9912	10296	10296	10680
11	10296	10680	10680	11064	11064	11448	11448	11832	11832	12216
12	11832	11832	12216	12216	12576	12576	12960	12960	13536	13536
13	12960	13536	13536	14112	14112	14688	14688	14688	15264	15264
14	14688	14688	15264	15264	15840	15840	16416	16416	16992	16992
15	15840	15840	16416	16416	16992	16992	17568	17568	18336	18336
16	16416	16992	16992	17568	17568	18336	18336	19080	19080	19848
17	18336	19080	19080	19848	19848	20616	20616	20616	21384	21384
18	19848	20616	21384	21384	22152	22152	22920	22920	23688	23688
19	22152	22152	22920	22920	23688	24496	24496	25456	25456	25456
20	23688	24496	24496	25456	25456	26416	26416	27376	27376	28336
21	25456	26416	26416	27376	27376	28336	28336	29296	29296	30576
22	27376	28336	28336	29296	29296	30576	30576	31704	31704	32856
23	29296	29296	30576	30576	31704	31704	32856	32856	34008	34008
24	31704	31704	32856	32856	34008	34008	35160	35160	36696	36696
25	32856	32856	34008	34008	35160	35160	36696	36696	37888	37888
26	37888	37888	39232	40576	40576	40576	42368	42368	43816	43816

I_{TBS}	N_{PRB}									
	61	62	63	64	65	66	67	68	69	70
0	1672	1736	1736	1800	1800	1800	1864	1864	1928	1928
1	2216	2280	2280	2344	2344	2408	2472	2472	2536	2536
2	2728	2792	2856	2856	2856	2984	2984	3112	3112	3112
3	3624	3624	3624	3752	3752	3880	3880	4008	4008	4136
4	4392	4392	4584	4584	4584	4776	4776	4968	4968	4968
5	5352	5544	5544	5736	5736	5736	5992	5992	5992	6200
6	6456	6456	6456	6712	6712	6968	6968	6968	7224	7224
7	7480	7480	7736	7736	7992	7992	8248	8248	8504	8504
8	8504	8760	8760	9144	9144	9144	9528	9528	9528	9912
9	9528	9912	9912	10296	10296	10296	10680	10680	11064	11064
10	10680	11064	11064	11448	11448	11448	11832	11832	12216	12216
11	12216	12576	12576	12960	12960	13536	13536	13536	14112	14112
12	14112	14112	14112	14688	14688	15264	15264	15264	15840	15840
13	15840	15840	16416	16416	16992	16992	17568	17568	17568	18336
14	17568	17568	18336	18336	18336	19080	19080	19848	19848	19848
15	18336	19080	19080	19848	19848	20616	20616	20616	21384	21384
16	19848	19848	20616	20616	21384	21384	22152	22152	22152	22920
17	22152	22152	22920	22920	23688	23688	24496	24496	24496	25456
18	24496	24496	24496	25456	25456	26416	26416	27376	27376	27376
19	26416	26416	27376	27376	28336	28336	29296	29296	29296	30576
20	28336	29296	29296	29296	30576	30576	31704	31704	31704	32856
21	30576	31704	31704	31704	32856	32856	34008	34008	35160	35160
22	32856	34008	34008	34008	35160	35160	36696	36696	36696	37888
23	35160	35160	36696	36696	37888	37888	37888	39232	39232	40576
24	36696	37888	37888	39232	39232	40576	40576	42368	42368	42368
25	39232	39232	40576	40576	40576	42368	42368	43816	43816	43816
26	45352	45352	46888	46888	48936	48936	48936	51024	51024	52752

I_{TBS}	N_{PRB}									
	71	72	73	74	75	76	77	78	79	80
0	1992	1992	2024	2088	2088	2088	2152	2152	2216	2216
1	2600	2600	2664	2728	2728	2792	2792	2856	2856	2856
2	3240	3240	3240	3368	3368	3368	3496	3496	3496	3624
3	4136	4264	4264	4392	4392	4392	4584	4584	4584	4776
4	5160	5160	5160	5352	5352	5544	5544	5544	5736	5736

5	6200	6200	6456	6456	6712	6712	6712	6968	6968	6968
6	7480	7480	7736	7736	7736	7992	7992	8248	8248	8248
7	8760	8760	8760	9144	9144	9144	9528	9528	9528	9912
8	9912	9912	10296	10296	10680	10680	10680	11064	11064	11064
9	11064	11448	11448	11832	11832	11832	12216	12216	12576	12576
10	12576	12576	12960	12960	12960	13536	13536	13536	14112	14112
11	14112	14688	14688	14688	15264	15264	15840	15840	15840	16416
12	16416	16416	16416	16992	16992	17568	17568	17568	18336	18336
13	18336	18336	19080	19080	19080	19848	19848	19848	20616	20616
14	20616	20616	20616	21384	21384	22152	22152	22152	22920	22920
15	22152	22152	22152	22920	22920	23688	23688	23688	24496	24496
16	22920	23688	23688	24496	24496	24496	25456	25456	25456	26416
17	25456	26416	26416	26416	27376	27376	27376	28336	28336	29296
18	28336	28336	29296	29296	29296	30576	30576	30576	31704	31704
19	30576	30576	31704	31704	32856	32856	32856	34008	34008	34008
20	32856	34008	34008	34008	35160	35160	35160	36696	36696	36696
21	35160	36696	36696	36696	37888	37888	39232	39232	39232	40576
22	37888	39232	39232	40576	40576	40576	42368	42368	42368	43816
23	40576	40576	42368	42368	43816	43816	43816	45352	45352	45352
24	43816	43816	45352	45352	45352	46888	46888	46888	48936	48936
25	45352	45352	46888	46888	46888	48936	48936	48936	51024	51024
26	52752	52752	55056	55056	55056	55056	57336	57336	57336	59256

I_{TBS}	N_{PRB}									
	81	82	83	84	85	86	87	88	89	90
0	2280	2280	2280	2344	2344	2408	2408	2472	2472	2536
1	2984	2984	2984	3112	3112	3112	3240	3240	3240	3240
2	3624	3624	3752	3752	3880	3880	3880	4008	4008	4008
3	4776	4776	4776	4968	4968	4968	5160	5160	5160	5352
4	5736	5992	5992	5992	5992	6200	6200	6200	6456	6456
5	7224	7224	7224	7480	7480	7480	7736	7736	7736	7992
6	8504	8504	8760	8760	8760	9144	9144	9144	9144	9528
7	9912	9912	10296	10296	10296	10680	10680	10680	11064	11064
8	11448	11448	11448	11832	11832	12216	12216	12216	12576	12576
9	12960	12960	12960	13536	13536	13536	13536	14112	14112	14112
10	14112	14688	14688	14688	14688	15264	15264	15264	15840	15840
11	16416	16416	16992	16992	16992	17568	17568	17568	18336	18336
12	18336	19080	19080	19080	19080	19848	19848	19848	20616	20616
13	20616	21384	21384	21384	22152	22152	22152	22920	22920	22920
14	22920	23688	23688	24496	24496	24496	25456	25456	25456	25456
15	24496	25456	25456	25456	26416	26416	26416	27376	27376	27376
16	26416	26416	27376	27376	27376	28336	28336	28336	29296	29296
17	29296	29296	30576	30576	30576	30576	31704	31704	31704	32856
18	31704	32856	32856	32856	34008	34008	34008	35160	35160	35160
19	35160	35160	35160	36696	36696	36696	37888	37888	37888	39232
20	37888	37888	39232	39232	39232	40576	40576	40576	42368	42368
21	40576	40576	42368	42368	42368	43816	43816	43816	45352	45352
22	43816	43816	45352	45352	45352	46888	46888	46888	48936	48936
23	46888	46888	46888	48936	48936	48936	51024	51024	51024	51024
24	48936	51024	51024	51024	52752	52752	52752	52752	55056	55056
25	51024	52752	52752	52752	55056	55056	55056	55056	57336	57336
26	59256	59256	61664	61664	61664	63776	63776	63776	66592	66592

I_{TBS}	N_{PRB}									
	91	92	93	94	95	96	97	98	99	100
0	2536	2536	2600	2600	2664	2664	2728	2728	2728	2792
1	3368	3368	3368	3496	3496	3496	3496	3624	3624	3624
2	4136	4136	4136	4264	4264	4264	4392	4392	4392	4584
3	5352	5352	5352	5544	5544	5544	5736	5736	5736	5736

4	6456	6456	6712	6712	6712	6968	6968	6968	6968	7224
5	7992	7992	8248	8248	8248	8504	8504	8760	8760	8760
6	9528	9528	9528	9912	9912	9912	10296	10296	10296	10296
7	11064	11448	11448	11448	11448	11832	11832	11832	12216	12216
8	12576	12960	12960	12960	13536	13536	13536	13536	14112	14112
9	14112	14688	14688	14688	15264	15264	15264	15264	15840	15840
10	15840	16416	16416	16416	16992	16992	16992	16992	17568	17568
11	18336	18336	19080	19080	19080	19080	19848	19848	19848	19848
12	20616	21384	21384	21384	21384	22152	22152	22152	22920	22920
13	23688	23688	23688	24496	24496	24496	25456	25456	25456	25456
14	26416	26416	26416	27376	27376	27376	28336	28336	28336	28336
15	28336	28336	28336	29296	29296	29296	29296	30576	30576	30576
16	29296	30576	30576	30576	30576	31704	31704	31704	31704	32856
17	32856	32856	34008	34008	34008	35160	35160	35160	35160	36696
18	36696	36696	36696	37888	37888	37888	37888	39232	39232	39232
19	39232	39232	40576	40576	40576	40576	42368	42368	42368	43816
20	42368	42368	43816	43816	43816	45352	45352	45352	46888	46888
21	45352	46888	46888	46888	46888	48936	48936	48936	48936	51024
22	48936	48936	51024	51024	51024	51024	52752	52752	52752	55056
23	52752	52752	52752	55056	55056	55056	55056	57336	57336	57336
24	55056	57336	57336	57336	57336	59256	59256	59256	61664	61664
25	57336	59256	59256	59256	61664	61664	61664	61664	63776	63776
26	66592	68808	68808	68808	71112	71112	71112	73712	73712	75376

I_{TBS}	N_{PRB}									
	101	102	103	104	105	106	107	108	109	110
0	2792	2856	2856	2856	2984	2984	2984	2984	2984	3112
1	3752	3752	3752	3752	3880	3880	3880	4008	4008	4008
2	4584	4584	4584	4584	4776	4776	4776	4776	4968	4968
3	5992	5992	5992	5992	6200	6200	6200	6200	6456	6456
4	7224	7224	7480	7480	7480	7480	7736	7736	7736	7992
5	8760	9144	9144	9144	9144	9528	9528	9528	9528	9528
6	10680	10680	10680	10680	11064	11064	11064	11448	11448	11448
7	12216	12576	12576	12576	12960	12960	12960	12960	13536	13536
8	14112	14112	14688	14688	14688	14688	15264	15264	15264	15264
9	15840	16416	16416	16416	16416	16992	16992	16992	16992	17568
10	17568	18336	18336	18336	18336	18336	19080	19080	19080	19080
11	20616	20616	20616	21384	21384	21384	21384	22152	22152	22152
12	22920	23688	23688	23688	23688	24496	24496	24496	24496	25456
13	26416	26416	26416	26416	27376	27376	27376	27376	28336	28336
14	29296	29296	29296	29296	30576	30576	30576	30576	31704	31704
15	30576	31704	31704	31704	31704	32856	32856	32856	34008	34008
16	32856	32856	34008	34008	34008	34008	35160	35160	35160	35160
17	36696	36696	36696	37888	37888	37888	39232	39232	39232	39232
18	40576	40576	40576	40576	42368	42368	42368	42368	43816	43816
19	43816	43816	43816	45352	45352	45352	46888	46888	46888	46888
20	46888	46888	48936	48936	48936	48936	48936	51024	51024	51024
21	51024	51024	51024	52752	52752	52752	52752	55056	55056	55056
22	55056	55056	55056	57336	57336	57336	57336	59256	59256	59256
23	57336	59256	59256	59256	59256	61664	61664	61664	61664	63776
24	61664	61664	63776	63776	63776	63776	66592	66592	66592	66592
25	63776	63776	66592	66592	66592	66592	68808	68808	68808	71112
26	75376	75376	75376	75376	75376	75376	75376	75376	75376	75376

7.1.7.2.2 Transport blocks mapped to two-layer spatial multiplexing

For $1 \leq N_{\text{PRB}} \leq 55$, the TBS is given by the $(I_{\text{TBS}}, 2 \cdot N_{\text{PRB}})$ entry of Table 7.1.7.2.1-1.

For $56 \leq N_{\text{PRB}} \leq 110$, a baseline TBS_L1 is taken from the $(I_{\text{TBS}}, N_{\text{PRB}})$ entry of Table 7.1.7.2.1-1, which is then translated into TBS_L2 using the mapping rule shown in Table 7.1.7.2.2-1. The TBS is given by TBS_L2.

Table 7.1.7.2.2-1: One-layer to two-layer TBS translation table

TBS_L1	TBS_L2	TBS_L1	TBS_L2	TBS_L1	TBS_L2	TBS_L1	TBS_L2
1544	3112	3752	7480	10296	20616	28336	57336
1608	3240	3880	7736	10680	21384	29296	59256
1672	3368	4008	7992	11064	22152	30576	61664
1736	3496	4136	8248	11448	22920	31704	63776
1800	3624	4264	8504	11832	23688	32856	66592
1864	3752	4392	8760	12216	24496	34008	68808
1928	3880	4584	9144	12576	25456	35160	71112
1992	4008	4776	9528	12960	25456	36696	73712
2024	4008	4968	9912	13536	27376	37888	76208
2088	4136	5160	10296	14112	28336	39232	78704
2152	4264	5352	10680	14688	29296	40576	81176
2216	4392	5544	11064	15264	30576	42368	84760
2280	4584	5736	11448	15840	31704	43816	87936
2344	4776	5992	11832	16416	32856	45352	90816
2408	4776	6200	12576	16992	34008	46888	93800
2472	4968	6456	12960	17568	35160	48936	97896
2536	5160	6712	13536	18336	36696	51024	101840
2600	5160	6968	14112	19080	37888	52752	105528
2664	5352	7224	14688	19848	39232	55056	110136
2728	5544	7480	14688	20616	40576	57336	115040
2792	5544	7736	15264	21384	42368	59256	119816
2856	5736	7992	15840	22152	43816	61664	124464
2984	5992	8248	16416	22920	45352	63776	128496
3112	6200	8504	16992	23688	46888	66592	133208
3240	6456	8760	17568	24496	48936	68808	137792
3368	6712	9144	18336	25456	51024	71112	142248
3496	6968	9528	19080	26416	52752	73712	146856
3624	7224	9912	19848	27376	55056	75376	149776

7.1.7.2.3 Transport blocks mapped for DCI Format 1C

The TBS is given by the I_{TBS} entry of Table 7.1.7.2.3-1.

Table 7.1.7.2.3-1: Transport Block Size Table for DCI format 1C

I_{TBS}	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
TBS	40	56	72	120	136	144	176	208	224	256	280	296	328	336	392	488
I_{TBS}	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
TBS	552	600	632	696	776	840	904	1000	1064	1128	1224	1288	1384	1480	1608	1736

7.1.7.2.4 Transport blocks mapped to three-layer spatial multiplexing

For $1 \leq N_{\text{PRB}} \leq 36$, the TBS is given by the $(I_{\text{TBS}}, 3 \cdot N_{\text{PRB}})$ entry of Table 7.1.7.2.1-1.

For $37 \leq N_{\text{PRB}} \leq 110$, a baseline TBS_L1 is taken from the $(I_{\text{TBS}}, N_{\text{PRB}})$ entry of Table 7.1.7.2.1-1, which is then translated into TBS_L3 using the mapping rule shown in Table 7.1.7.2.4-1. The TBS is given by TBS_L3.

Table 7.1.7.2.4-1: One-layer to three-layer TBS translation table

TBS_L1	TBS_L3	TBS_L1	TBS_L3	TBS_L1	TBS_L3	TBS_L1	TBS_L3
1032	3112	2664	7992	8248	24496	26416	78704
1064	3240	2728	8248	8504	25456	27376	81176
1096	3240	2792	8248	8760	26416	28336	84760
1128	3368	2856	8504	9144	27376	29296	87936
1160	3496	2984	8760	9528	28336	30576	90816
1192	3624	3112	9144	9912	29296	31704	93800
1224	3624	3240	9528	10296	30576	32856	97896
1256	3752	3368	9912	10680	31704	34008	101840
1288	3880	3496	10296	11064	32856	35160	105528
1320	4008	3624	10680	11448	34008	36696	110136
1352	4008	3752	11064	11832	35160	37888	115040
1384	4136	3880	11448	12216	36696	39232	119816
1416	4264	4008	11832	12576	37888	40576	119816
1480	4392	4136	12576	12960	39232	42368	128496
1544	4584	4264	12960	13536	40576	43816	133208
1608	4776	4392	12960	14112	42368	45352	137792
1672	4968	4584	13536	14688	43816	46888	142248
1736	5160	4776	14112	15264	45352	48936	146856
1800	5352	4968	14688	15840	46888	51024	152976
1864	5544	5160	15264	16416	48936	52752	157432
1928	5736	5352	15840	16992	51024	55056	165216
1992	5992	5544	16416	17568	52752	57336	171888
2024	5992	5736	16992	18336	55056	59256	177816
2088	6200	5992	18336	19080	57336	61664	185728
2152	6456	6200	18336	19848	59256	63776	191720
2216	6712	6456	19080	20616	61664	66592	199824
2280	6712	6712	19848	21384	63776	68808	205880
2344	6968	6968	20616	22152	66592	71112	214176
2408	7224	7224	21384	22920	68808	73712	221680
2472	7480	7480	22152	23688	71112	75376	226416
2536	7480	7736	22920	24496	73712		
2600	7736	7992	23688	25456	76208		

7.1.7.2.5 Transport blocks mapped to four-layer spatial multiplexing

For $1 \leq N_{\text{PRB}} \leq 27$, the TBS is given by the $(I_{\text{TBS}}, 4 \cdot N_{\text{PRB}})$ entry of Table 7.1.7.2.1-1.

For $28 \leq N_{\text{PRB}} \leq 110$, a baseline TBS_L1 is taken from the $(I_{\text{TBS}}, N_{\text{PRB}})$ entry of Table 7.1.7.2.1-1, which is then translated into TBS_L4 using the mapping rule shown in Table 7.1.7.2.5-1. The TBS is given by TBS_L4.

Table 7.1.7.2.5-1: One-layer to four-layer TBS translation table

TBS_L1	TBS_L4	TBS_L1	TBS_L4	TBS_L1	TBS_L4	TBS_L1	TBS_L4
776	3112	2280	9144	7224	29296	24496	97896
808	3240	2344	9528	7480	29296	25456	101840
840	3368	2408	9528	7736	30576	26416	105528
872	3496	2472	9912	7992	31704	27376	110136
904	3624	2536	10296	8248	32856	28336	115040
936	3752	2600	10296	8504	34008	29296	115040
968	3880	2664	10680	8760	35160	30576	124464
1000	4008	2728	11064	9144	36696	31704	128496
1032	4136	2792	11064	9528	37888	32856	133208
1064	4264	2856	11448	9912	39232	34008	137792
1096	4392	2984	11832	10296	40576	35160	142248
1128	4584	3112	12576	10680	42368	36696	146856
1160	4584	3240	12960	11064	43816	37888	151376
1192	4776	3368	13536	11448	45352	39232	157432
1224	4968	3496	14112	11832	46888	40576	161760
1256	4968	3624	14688	12216	48936	42368	169544
1288	5160	3752	15264	12576	51024	43816	175600
1320	5352	3880	15264	12960	51024	45352	181656
1352	5352	4008	15840	13536	55056	46888	187712
1384	5544	4136	16416	14112	57336	48936	195816
1416	5736	4264	16992	14688	59256	51024	203704
1480	5992	4392	17568	15264	61664	52752	211936
1544	6200	4584	18336	15840	63776	55056	220296
1608	6456	4776	19080	16416	66592	57336	230104
1672	6712	4968	19848	16992	68808	59256	236160
1736	6968	5160	20616	17568	71112	61664	245648
1800	7224	5352	21384	18336	73712	63776	254328
1864	7480	5544	22152	19080	76208	66592	266440
1928	7736	5736	22920	19848	78704	68808	275376
1992	7992	5992	23688	20616	81176	71112	284608
2024	7992	6200	24496	21384	84760	73712	293736
2088	8248	6456	25456	22152	87936	75376	299856
2152	8504	6712	26416	22920	90816		
2216	8760	6968	28336	23688	93800		

7.1.7.3 Redundancy Version determination for Format 1C

If the DCI Format 1C CRC is scrambled by P-RNTI or RA-RNTI, then

- the UE shall set the Redundancy Version to 0

Else if the DCI Format 1C CRC is scrambled by SI-RNTI, then

- the UE shall set the Redundancy Version as defined in [8].

7.1.8 Storing soft channel bits

Both for FDD and TDD, if the UE is configured with more than one serving cell, then for each serving cell, for at least $K_{\text{MIMO}} \cdot \min(M_{\text{DL_HARQ}}, M_{\text{limit}})$ transport blocks, upon decoding failure of a code block of a transport block, the UE shall store received soft channel bits corresponding to a range of at least $w_k, w_{k+1}, \dots, w_{\text{mod}(k+n_{\text{SB}}-1, N_{\text{cb}})}$, where:

$$n_{SB} = \min \left(N_{cb}, \left\lfloor \frac{N'_{soft}}{C \cdot N_{cells}^{DL} \cdot K_{MIMO} \cdot \min(M_{DL_HARQ}, M_{limit})} \right\rfloor \right),$$

w_k , C , N_{cb} , K_{MIMO} , and M_{limit} are defined in Section 5.1.4.1.2 of [4].

M_{DL_HARQ} is the maximum number of DL HARQ processes.

N_{cells}^{DL} is the number of configured serving cells.

If the UE signals *ue-Category-v10xy*, N'_{soft} is the total number of soft channel bits [12] according to the UE category indicated by *ue-Category-v10xy* [11]. Otherwise, N'_{soft} is the total number of soft channel bits [12] according to the UE category indicated by *ue-Category*[11].

In determining k , the UE should give priority to storing soft channel bits corresponding to lower values of k . w_k shall correspond to a received soft channel bit. The range $w_k, w_{k+1}, \dots, w_{\text{mod}(k+n_{SB}-1, N_{cb})}$ may include subsets not containing received soft channel bits.

7.2 UE procedure for reporting Channel State Information (CSI)

The time and frequency resources that can be used by the UE to report CSI which consists of channel quality indicator (CQI), precoding matrix indicator (PMI), precoding type indicator (PTI), and/or rank indication (RI) are controlled by the eNB. For spatial multiplexing, as given in [3], the UE shall determine a RI corresponding to the number of useful transmission layers. For transmit diversity as given in [3], RI is equal to one.

A UE in transmission mode 8 or 9 is configured with or without PMI/RI reporting by the higher layer parameter *pmi-RI-Report*.

A UE is configured with resource-restricted CSI measurements if the subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ are configured by higher layers.

CSI reporting is periodic or aperiodic.

If the UE is configured with more than one serving cell, it transmits CSI for activated serving cell(s) only.

If a UE is not configured for simultaneous PUSCH and PUCCH transmission, it shall transmit periodic CSI reporting on PUCCH as defined hereafter in subframes with no PUSCH allocation.

If a UE is not configured for simultaneous PUSCH and PUCCH transmission, it shall transmit periodic CSI reporting on PUSCH of the serving cell with smallest *ServCellIndex* as defined hereafter in subframes with a PUSCH allocation, where the UE shall use the same PUCCH-based periodic CSI reporting format on PUSCH.

A UE shall transmit aperiodic CSI reporting on PUSCH if the conditions specified hereafter are met. For aperiodic CQI/PMI reporting, RI reporting is transmitted only if the configured CSI feedback type supports RI reporting.

The CSI transmissions on PUCCH and PUSCH for various scheduling modes are summarized in the following table:

Table 7.2-1: Physical Channels for Aperiodic or Periodic CSI reporting

Scheduling Mode	Periodic CSI reporting channels	Aperiodic CSI reporting channel
Frequency non-selective	PUCCH	
Frequency selective	PUCCH	PUSCH

In case both periodic and aperiodic CSI reporting would occur in the same subframe, the UE shall only transmit the aperiodic CSI report in that subframe.

When reporting RI the UE reports a single instance of the number of useful transmission layers. For each RI reporting interval when the UE is configured in transmission modes 4 or when the UE is configured in transmission mode 8 or 9 with PMI/RI reporting, a UE shall determine a RI from the supported set of RI values for the corresponding eNodeB antenna configuration and UE category and report the number in each RI report. For each RI reporting interval when the UE is configured in transmission mode 3, a UE shall determine RI for the corresponding eNodeB antenna configuration and UE category in each reporting interval and report the detected number in each RI report to support selection between transmit diversity and large delay CDD.

When reporting PMI the UE reports either a single or a multiple PMI report. The number of RBs represented by a single UE PMI report can be N_{RB}^{DL} or a smaller subset of RBs. The number of RBs represented by a single PMI report is semi-statically configured by higher layer signalling. A UE is restricted to report PMI, RI and PTI within a precoder codebook subset specified by a bitmap parameter *codebookSubsetRestriction* configured by higher layer signalling. For a specific precoder codebook and associated transmission mode, the bitmap can specify all possible precoder codebook subsets from which the UE can assume the eNB may be using when the UE is configured in the relevant transmission mode. Codebook subset restriction is supported for transmission modes 3, 4, 5, 6 and for transmission modes 8 and 9 with PMI/RI reporting. The resulting number of bits for each transmission mode is given in Table 7.2-1b. The bitmap forms the bit sequence $a_{A_c-1}, \dots, a_3, a_2, a_1, a_0$ where a_0 is the LSB and a_{A_c-1} is the MSB and where a bit value of zero indicates that the PMI and RI reporting is not allowed to correspond to precoder(s) associated with the bit. The association of bits to precoders for the relevant transmission modes are given as follows:

1. Transmission mode 3
 - a. 2 antenna ports: bit $a_{\nu-1}$, $\nu = 2$ is associated with the precoder in Table 6.3.4.2.3-1 of [3] corresponding to ν layers and codebook index 0 while bit a_0 is associated with the precoder for 2 antenna ports in Section 6.3.4.3 of [3].
 - b. 4 antenna ports: bit $a_{\nu-1}$, $\nu = 2, 3, 4$ is associated with the precoders in Table 6.3.4.2.3-2 of [3] corresponding to ν layers and codebook indices 12, 13, 14, and 15 while bit a_0 is associated with the precoder for 4 antenna ports in Section 6.3.4.3 of [3].
2. Transmission mode 4
 - a. 2 antenna ports: see Table 7.2-1c
 - b. 4 antenna ports: bit $a_{16(\nu-1)+i_c}$ is associated with the precoder for ν layers and with codebook index i_c in Table 6.3.4.2.3-2 of [3].
3. Transmission modes 5 and 6
 - a. 2 antenna ports: bit a_{i_c} is associated with the precoder for $\nu = 1$ layer with codebook index i_c in Table 6.3.4.2.3-1 of [3].
 - b. 4 antenna ports: bit a_{i_c} is associated with the precoder for $\nu = 1$ layer with codebook index i_c in Table 6.3.4.2.3-2 of [3].
4. Transmission mode 8
 - a. 2 antenna ports: see Table 7.2-1c
 - b. 4 antenna ports: bit $a_{16(\nu-1)+i_c}$ is associated with the precoder for ν layers and with codebook index i_c in Table 6.3.4.2.3-2 of [3], $\nu = 1, 2$.
5. Transmission mode 9
 - a. 2 antenna ports: see Table 7.2-1c
 - b. 4 antenna ports: bit $a_{16(\nu-1)+i_c}$ is associated with the precoder for ν layers and with codebook index i_c in Table 6.3.4.2.3-2 of [3].

- c. 8 antenna ports: bit $a_{f1(v-1)+i_{c1}}$ is associated with the precoder for v layers ($v \in \{1,2,3,4,5,6,7,8\}$) and codebook index i_{c1} where $f1(\cdot) = \{0,16,32,36,40,44,48,52\}$ and bit $a_{53+g1(v-1)+i_{c2}}$ is associated with the precoder for v layers ($v \in \{1,2,3,4\}$) and codebook index i_{c2} where $g1(\cdot) = \{0,16,32,48\}$. Codebook indices i_{c1} and i_{c2} are given in Table 7.2.4-1, 7.2.4-2, 7.2.4-3, 7.2.4-4, 7.2.4-5, 7.2.4-6, 7.2.4-7, or 7.2.4-8, for $v=1,2,3,4,5,6,7$, or 8 respectively.

Table 7.2-1b: Number of bits in codebook subset restriction bitmap for applicable transmission modes.

	Number of bits A_c		
	2 antenna ports	4 antenna ports	8 antenna ports
Transmission mode 3	2	4	
Transmission mode 4	6	64	
Transmission mode 5	4	16	
Transmission mode 6	4	16	
Transmission mode 8	6	32	
Transmission mode 9	6	64	109

Table 7.2-1c: Association of bits in *codebookSubSetRestriction* bitmap to precoders in the 2 antenna port codebook of Table 6.3.4.2.3-1 in [3].

Codebook index i_c	Number of layers v	
	1	2
0	a_0	-
1	a_1	a_4
2	a_2	a_5
3	a_3	-

The set of subbands (S) a UE shall evaluate for CQI reporting spans the entire downlink system bandwidth. A subband is a set of k contiguous PRBs where k is a function of system bandwidth. Note the last subband in set S may have fewer than k contiguous PRBs depending on N_{RB}^{DL} . The number of subbands for system bandwidth given by N_{RB}^{DL} is defined by $N = \lceil N_{RB}^{DL} / k \rceil$. The subbands shall be indexed in the order of increasing frequency and non-increasing sizes starting at the lowest frequency.

- For transmission modes 1, 2, 3 and 5, as well as transmission modes 8 and 9 without PMI/RI reporting, transmission mode 4 with RI=1, and transmission modes 8 and 9 with PMI/RI reporting and RI=1, a single 4-bit wideband CQI is reported according to Table 7.2.3-1.
- For transmission modes 3 and 4, as well as transmission modes 8 and 9 with PMI/RI reporting, CQI is calculated assuming transmission of one codeword for RI=1 and two codewords for RI > 1.

- For $RI > 1$ with transmission mode 4, as well as transmission modes 8 and 9 with PMI/RI reporting, PUSCH based triggered reporting includes reporting a wideband CQI which comprises:
 - A 4-bit wideband CQI for codeword 0 according to Table 7.2.3-1
 - A 4-bit wideband CQI for codeword 1 according to Table 7.2.3-1
- For $RI > 1$ with transmission mode 4, as well as transmission modes 8 and 9 with PMI/RI reporting, PUCCH based reporting includes reporting a 4-bit wideband CQI for codeword 0 according to Table 7.2.3-1 and a wideband spatial differential CQI. The wideband spatial differential CQI value comprises:
 - A 3-bit wideband spatial differential CQI value for codeword 1 offset level
 - Codeword 1 offset level = wideband CQI index for codeword 0 – wideband CQI index for codeword 1.
 - The mapping from the 3-bit wideband spatial differential CQI value to the offset level is shown in Table 7.2-2.

Table 7.2-2 Mapping spatial differential CQI value to offset level

Spatial differential CQI value	Offset level
0	0
1	1
2	2
3	≥ 3
4	≤ -4
5	-3
6	-2
7	-1

7.2.1 Aperiodic CSI Reporting using PUSCH

A UE shall perform aperiodic CSI reporting using the PUSCH in subframe $n+k$ on serving cell c , upon decoding in subframe n either:

- an uplink DCI format, or
- a Random Access Response Grant,

for serving cell c if the respective CSI request field is set to trigger a report and is not reserved. If the CSI request field is 1 bit [4], a report is triggered for serving cell c if the CSI request field is set to '1'. If the CSI request field size is 2 bits [4], a report is triggered according to the value in Table 7.2.1-1A corresponding to aperiodic CSI reporting.

A UE is not expected to receive more than one aperiodic CSI report request for a given subframe.

Table 7.2.1-1A: CSI Request field for PDCCH with uplink DCI format in UE specific search space

Value of CSI request field	Description
'00'	No aperiodic CSI report is triggered
'01'	Aperiodic CSI report is triggered for serving cell c
'10'	Aperiodic CSI report is triggered for a 1 st set of serving cells configured by higher layers
'11'	Aperiodic CSI report is triggered for a 2 nd set of serving cells configured by higher layers

Note: PDCCH with DCI formats used to grant PUSCH transmissions as given by DCI format 0 and DCI format 4 are herein referred to as uplink DCI format when common behaviour is addressed.

When the CSI request field from an uplink DCI format is set to trigger a report, for FDD $k=4$, and for TDD UL/DL configuration 1-6, k is given in Table 8-2. For TDD UL/DL configuration 0, if the MSB of the UL index is set to 1 and LSB of the UL index is set to 0, k is given in Table 8-2; or if MSB of the UL index is set to 0 and LSB of the UL index is set to 1, k is equal to 7; or if both MSB and LSB of the UL index is set to 1, k is given in Table 8-2.

When the CSI request field from a Random Access Response Grant is set to trigger a report and is not reserved, k is equal to k_1 if the UL delay field in section 6.2 is set to zero, where k_1 is given in section 6.1.1. The UE shall postpone aperiodic CSI reporting to the next available UL subframe if the UL delay field is set to 1.

The minimum reporting interval for aperiodic reporting of CQI and PMI and RI is 1 subframe. The subband size for CQI shall be the same for transmitter-receiver configurations with and without precoding.

If a UE is not configured for simultaneous PUSCH and PUCCH transmission, when aperiodic CSI report with no transport block associated as defined in section 8.6.2 and positive SR is transmitted in the same subframe, the UE shall transmit SR, and, if applicable, HARQ-ACK, on PUCCH resources as described in Section 10.1

A UE is semi-statically configured by higher layers to feed back CQI and PMI and corresponding RI on the same PUSCH using one of the following CSI reporting modes given in Table 7.2.1-1 and described below.

Table 7.2.1-1: CQI and PMI Feedback Types for PUSCH CSI reporting Modes

		PMI Feedback Type		
		No PMI	Single PMI	Multiple PMI
PUSCH CQI Feedback Type	Wideband (wideband CQI)			Mode 1-2
	UE Selected (subband CQI)	Mode 2-0		Mode 2-2
	Higher Layer-configured (subband CQI)	Mode 3-0	Mode 3-1	

For each of the transmission modes defined in Section 7.1, the following reporting modes are supported on PUSCH:

- Transmission mode 1 : Modes 2-0, 3-0
- Transmission mode 2 : Modes 2-0, 3-0
- Transmission mode 3 : Modes 2-0, 3-0
- Transmission mode 4 : Modes 1-2, 2-2, 3-1
- Transmission mode 5 : Mode 3-1
- Transmission mode 6 : Modes 1-2, 2-2, 3-1
- Transmission mode 7 : Modes 2-0, 3-0
- Transmission mode 8 : Modes 1-2, 2-2, 3-1 if the UE is configured with PMI/RI reporting; modes 2-0, 3-0 if the UE is configured without PMI/RI reporting
- Transmission mode 9 : Modes 1-2, 2-2, 3-1 if the UE is configured with PMI/RI reporting and number of CSI-RS ports > 1; modes 2-0, 3-0 if the UE is configured without PMI/RI reporting or number of CSI-RS ports=1

The aperiodic CSI reporting mode is given by the parameter *cqi-ReportModeAperiodic* which is configured by higher-layer signalling.

For a serving cell with $N_{RB}^{DL} \leq 7$, PUSCH reporting modes are not supported for that serving cell.

RI is only reported for transmission modes 3 and 4, as well as transmission modes 8 and 9 with PMI/RI reporting.

A RI report for a serving cell on an aperiodic reporting mode is valid only for CQI/PMI report for that serving cell on that aperiodic reporting mode

- Wideband feedback
 - Mode 1-2 description:
 - For each subband a preferred precoding matrix is selected from the codebook subset assuming transmission only in the subband
 - A UE shall report one wideband CQI value per codeword which is calculated assuming the use of the corresponding selected precoding matrix in each subband and transmission on set S subbands.
 - The UE shall report the selected precoding matrix indicator for each set S subband except for transmission mode 9 with 8 CSI-RS ports configured in which case a first precoding matrix indicator i_1 is reported for the set S subbands and a second precoding matrix indicator i_2 is reported for each set S subband.
 - Subband size is given by Table 7.2.1-3.
 - For transmission modes 4, 8 and 9, the reported PMI and CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.
- Higher Layer-configured subband feedback
 - Mode 3-0 description:
 - A UE shall report a wideband CQI value which is calculated assuming transmission on set S subbands
 - The UE shall also report one subband CQI value for each set S subband. The subband CQI value is calculated assuming transmission only in the subband
 - Both the wideband and subband CQI represent channel quality for the first codeword, even when $RI > 1$.
 - For transmission mode 3 the reported CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.
 - Mode 3-1 description:
 - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands
 - A UE shall report one subband CQI value per codeword for each set S subband which are calculated assuming the use of the single precoding matrix in all subbands and assuming transmission in the corresponding subband.
 - A UE shall report a wideband CQI value per codeword which is calculated assuming the use of the single precoding matrix in all subbands and transmission on set S subbands
 - The UE shall report the selected single precoding matrix indicator except for transmission mode 9 with 8 CSI-RS ports configured in which case a first and second precoding matrix indicator are reported corresponding to the selected single precoding matrix.
 - For transmission modes 4, 8 and 9, the reported PMI and CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.
 - Subband CQI value for each codeword are encoded differentially with respect to their respective wideband CQI using 2-bits as defined by

- Subband differential CQI offset level = subband CQI index – wideband CQI index. The mapping from the 2-bit subband differential CQI value to the offset level is shown in Table 7.2.1-2.

Table 7.2.1-2: Mapping subband differential CQI value to offset level

Subband differential CQI value	Offset level
0	0
1	1
2	≥ 2
3	≤ -1

- Supported subband size (k) is given in Table 7.2.1-3.

Table 7.2.1-3: Subband Size (k) vs. System Bandwidth

System Bandwidth N_{RB}^{DL}	Subband Size (k)
6 - 7	NA
8 - 10	4
11 - 26	4
27 - 63	6
64 - 110	8

- UE-selected subband feedback
 - Mode 2-0 description:
 - The UE shall select a set of M preferred subbands of size k (where k and M are given in Table 7.2.1-5 for each system bandwidth range) within the set of subbands S .
 - The UE shall also report one CQI value reflecting transmission only over the M selected subbands determined in the previous step. The CQI represents channel quality for the first codeword, even when RI>1.
 - Additionally, the UE shall also report one wideband CQI value which is calculated assuming transmission on set S subbands. The wideband CQI represents channel quality for the first codeword, even when RI>1.
 - For transmission mode 3 the reported CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.
 - Mode 2-2 description:
 - The UE shall perform joint selection of the set of M preferred subbands of size k within the set of subbands S and a preferred single precoding matrix selected from the codebook subset that is preferred to be used for transmission over the M selected subbands.
 - The UE shall report one CQI value per codeword reflecting transmission only over the selected M preferred subbands and using the same selected single precoding matrix in each of the M subbands.
 - Except for transmission mode 9 with 8 CSI-RS ports configured, the UE shall also report the selected single precoding matrix indicator preferred for the M selected subbands. A UE shall also report the selected single precoding matrix indicator for all set S subbands.

- For transmission mode 9 with 8 CSI-RS ports configured, a UE shall report a first precoding matrix indicator for all set S subbands. A UE shall also report a second precoding matrix indicator for all set S subbands and another second precoding matrix indicator for the M selected subbands.
 - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands
 - A UE shall report a wideband CQI value per codeword which is calculated assuming the use of the single precoding matrix in all subbands and transmission on set S subbands
 - For transmission modes 4, 8 and 9, the reported PMI and CQI values are calculated conditioned on the reported RI. For other transmission modes they are reported conditioned on rank 1.
- For all UE-selected subband feedback modes the UE shall report the positions of the M selected subbands using a combinatorial index r defined as
- $$r = \sum_{i=0}^{M-1} \left\langle \begin{matrix} N - s_i \\ M - i \end{matrix} \right\rangle$$
 - where the set $\{s_i\}_{i=0}^{M-1}$, $(1 \leq s_i \leq N, s_i < s_{i+1})$ contains the M sorted subband indices
- and $\left\langle \begin{matrix} x \\ y \end{matrix} \right\rangle = \begin{cases} \binom{x}{y} & x \geq y \\ 0 & x < y \end{cases}$ is the extended binomial coefficient, resulting in unique label
- $$r \in \left\{ 0, \dots, \binom{N}{M} - 1 \right\}.$$
- The CQI value for the M selected subbands for each codeword is encoded differentially using 2-bits relative to its respective wideband CQI as defined by
- Differential CQI offset level = M selected subbands CQI index – wideband CQI index
 - The mapping from the 2-bit differential CQI value to the offset level is shown in Table 7.2.1-4.

Table 7.2.1-4: Mapping differential CQI value to offset level

Differential CQI value	Offset level
0	≤ 1
1	2
2	3
3	≥ 4

- Supported subband size k and M values include those shown in Table 7.2.1-5. In Table 7.2.1-5 the k and M values are a function of system bandwidth.
- The number of bits to denote the position of the M selected subbands is $L = \left\lceil \log_2 \binom{N}{M} \right\rceil$.

Table 7.2.1-5: Subband Size (k) and Number of Subbands (M) in S vs. Downlink System Bandwidth

System Bandwidth N_{RB}^{DL}	Subband Size k (RBs)	M
6 – 7	NA	NA
8 – 10	2	1
11 – 26	2	3
27 – 63	3	5
64 – 110	4	6

7.2.2 Periodic CSI Reporting using PUCCH

A UE is semi-statically configured by higher layers to periodically feed back different CSI (CQI, PMI, PTI, and/or RI) on the PUCCH using the reporting modes given in Table 7.2.2-1 and described below.

Table 7.2.2-1: CQI and PMI Feedback Types for PUCCH CSI reporting Modes

		PMI Feedback Type	
		No PMI	Single PMI
PUCCH CQI Feedback Type	Wideband (wideband CQI)	Mode 1-0	Mode 1-1
	UE Selected (subband CQI)	Mode 2-0	Mode 2-1

For each of the transmission modes defined in Section 7.1, the following periodic CSI reporting modes are supported on PUCCH:

- Transmission mode 1 : Modes 1-0, 2-0
- Transmission mode 2 : Modes 1-0, 2-0
- Transmission mode 3 : Modes 1-0, 2-0
- Transmission mode 4 : Modes 1-1, 2-1
- Transmission mode 5 : Modes 1-1, 2-1
- Transmission mode 6 : Modes 1-1, 2-1
- Transmission mode 7 : Modes 1-0, 2-0
- Transmission mode 8 : Modes 1-1, 2-1 if the UE is configured with PMI/RI reporting; modes 1-0, 2-0 if the UE is configured without PMI/RI reporting
- Transmission mode 9 : Modes 1-1, 2-1 if the UE is configured with PMI/RI reporting and number of CSI-RS ports>1; modes 1-0, 2-0 if the UE is configured without PMI/RI reporting or number of CSI-RS ports=1.

The periodic CSI reporting mode for each serving cell is configured by higher-layer signalling. For a UE configured with transmission mode 9 and with 8 CSI-RS ports, mode 1-1 is configured to be either submode 1 or submode 2 via higher-layer signaling using the parameter *PUCCH_format1-1_CSI_reporting_mode*.

For the UE-selected subband CQI, a CQI report in a certain subframe of a certain serving cell describes the channel quality in a particular part or in particular parts of the bandwidth of that serving cell described subsequently as bandwidth part (BP) or parts. The bandwidth parts shall be indexed in the order of increasing frequency and non-increasing sizes starting at the lowest frequency.

For each serving cell

- There are a total of N subbands for a serving cell system bandwidth given by N_{RB}^{DL} where $\lfloor N_{RB}^{DL} / k \rfloor$ subbands are of size k . If $\lceil N_{RB}^{DL} / k \rceil - \lfloor N_{RB}^{DL} / k \rfloor > 0$ then one of the subbands is of size $N_{RB}^{DL} - k \cdot \lfloor N_{RB}^{DL} / k \rfloor$.
- A bandwidth part j is frequency-consecutive and consists of N_j subbands where J bandwidth parts span S or N_{RB}^{DL} as given in Table 7.2.2-2. If $J = 1$ then N_j is $\lceil N_{RB}^{DL} / k / J \rceil$. If $J > 1$ then N_j is either $\lceil N_{RB}^{DL} / k / J \rceil$ or $\lceil N_{RB}^{DL} / k / J \rceil - 1$, depending on N_{RB}^{DL} , k and J .
- Each bandwidth part j , where $0 \leq j \leq J-1$, is scanned in sequential order according to increasing frequency.
- For UE selected subband feedback a single subband out of N_j subbands of a bandwidth part is selected along with a corresponding L -bit label indexed in the order of increasing frequency, where $L = \lceil \log_2 \lceil N_{RB}^{DL} / k / J \rceil \rceil$.

The CQI and PMI payload sizes of each PUCCH CSI reporting mode are given in Table 7.2.2-3.

The following CQI/PMI and RI reporting types with distinct periods and offsets are supported for the PUCCH CSI reporting modes given in Table 7.2.2-3:

- Type 1 report supports CQI feedback for the UE selected sub-bands
- Type 1a report supports subband CQI and second PMI feedback
- Type 2, Type 2b, and Type 2c report supports wideband CQI and PMI feedback
- Type 2a report supports wideband PMI feedback
- Type 3 report supports RI feedback
- Type 4 report supports wideband CQI
- Type 5 report supports RI and wideband PMI feedback
- Type 6 report supports RI and PTI feedback

For each serving cell, the periodicity N_{pd} (in subframes) and offset $N_{OFFSET,CQI}$ (in subframes) for CQI/PMI reporting are determined based on the parameter $cqi-pmi-ConfigIndex$ ($I_{CQI/PMI}$) given in Table 7.2.2-1A for FDD and Table 7.2.2-1C for TDD. The periodicity M_{RI} and relative offset $N_{OFFSET,RI}$ for RI reporting are determined based on the parameter $ri-ConfigIndex$ (I_{RI}) given in Table 7.2.2-1B. Both $cqi-pmi-ConfigIndex$ and $ri-ConfigIndex$ are configured by higher layer signalling. The relative reporting offset for RI $N_{OFFSET,RI}$ takes values from the set $\{0, -1, \dots, -(N_{pd} - 1)\}$. If a UE is configured to report for more than one CSI subframe set then parameter $cqi-pmi-ConfigIndex$ and $ri-ConfigIndex$ respectively correspond to the CQI/PMI and RI periodicity and relative reporting offset for subframe set 1 and $cqi-pmi-ConfigIndex2$ and $ri-ConfigIndex2$ respectively correspond to the CQI/PMI and RI periodicity and relative reporting offset for subframe set 2.

In the case where wideband CQI/PMI reporting is configured:

- The reporting instances for wideband CQI/PMI are subframes satisfying $(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}) \bmod (N_{pd}) = 0$.
- In case RI reporting is configured, the reporting interval of the RI reporting is an integer multiple M_{RI} of period N_{pd} (in subframes).
 - The reporting instances for RI are subframes satisfying $(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI} - N_{OFFSET,RI}) \bmod (N_{pd} \cdot M_{RI}) = 0$.

In the case where both wideband CQI/PMI and subband CQI reporting are configured:

- The reporting instances for wideband CQI/PMI and subband CQI are subframes satisfying $(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}) \bmod N_{pd} = 0$.
 - When PTI is not transmitted (due to not being configured) or the most recently transmitted PTI was equal to 1:

- The wideband CQI/ wideband PMI (or wideband CQI/wideband second PMI for transmission mode 9) report has period $H \cdot N_{pd}$, and is reported on the subframes satisfying $(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}) \bmod (H \cdot N_{pd}) = 0$. The integer H is defined as $H = J \cdot K + 1$, where J is the number of bandwidth parts.
- Between every two consecutive wideband CQI/ wideband PMI (or wideband CQI/wideband second PMI for transmission mode 9) reports, the remaining $J \cdot K$ reporting instances are used in sequence for subband CQI reports on K full cycles of bandwidth parts except when the gap between two consecutive wideband CQI/PMI reports contains less than $J \cdot K$ reporting instances due to a system frame number transition to 0, in which case the UE shall not transmit the remainder of the subband CQI reports which have not been transmitted before the second of the two wideband CQI/ wideband PMI (or wideband CQI/wideband second PMI for transmission mode 9) reports. Each full cycle of bandwidth parts shall be in increasing order starting from bandwidth part 0 to bandwidth part $J - 1$. The parameter K is configured by higher-layer signalling.
- When the most recently transmitted PTI is 0:
 - The wideband first precoding matrix indicator report has period $H' \cdot N_{pd}$, and is reported on the subframes satisfying $(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI}) \bmod (H' \cdot N_{pd}) = 0$, where H' is signalled by higher layers.
 - Between every two consecutive wideband first precoding matrix indicator reports, the remaining reporting instances are used for a wideband second precoding matrix indicator with wideband CQI as described below
- In case RI reporting is configured, the reporting interval of RI is M_{RI} times the wideband CQI/PMI period $H \cdot N_{pd}$, and RI is reported on the same PUCCH cyclic shift resource as both the wideband CQI/PMI and subband CQI reports.
 - The reporting instances for RI are subframes satisfying $(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{OFFSET,CQI} - N_{OFFSET,RI}) \bmod (H \cdot N_{pd} \cdot M_{RI}) = 0$

In case of collision of a CSI report with PUCCH reporting type 3, 5, or 6 of one serving cell with a CSI report with PUCCH reporting type 1, 1a, 2, 2a, 2b, 2c, or 4 of the same serving cell the latter CSI report with PUCCH reporting type (1, 1a, 2, 2a, 2b, 2c, or 4) has lower priority and is dropped.

If the UE is configured with more than one serving cell, the UE transmits a CSI report of only one serving cell in any given subframe. For a given subframe, in case of collision of a CSI report with PUCCH reporting type 3, 5, 6, or 2a of one serving cell with a CSI report with PUCCH reporting type 1, 1a, 2, 2b, 2c, or 4 of another serving cell, the latter CSI with PUCCH reporting type (1, 1a, 2, 2b, 2c, or 4) has lower priority and is dropped. For a given subframe, in case of collision of CSI report with PUCCH reporting type 2, 2b, 2c, or 4 of one serving cell with CSI report with PUCCH reporting type 1 or 1a of another serving cell, the latter CSI report with PUCCH reporting type 1, or 1a has lower priority and is dropped.

For a given subframe, in case of collision between CSI reports of different serving cells with PUCCH reporting type of the same priority, the CSI of the serving cell with lowest *ServCellIndex* is reported, and CSI of all other serving cells are dropped.

See section 10.1 regarding UE behaviour for collision between CSI and HARQ-ACK and the corresponding PUCCH format assignment.

The CSI report of a given PUCCH reporting type shall be transmitted on the PUCCH resource $n_{PUCCH}^{(2,\tilde{p})}$ as defined in [3], where $n_{PUCCH}^{(2,\tilde{p})}$ is UE specific and configured by higher layers for each serving cell.

If the UE is not configured for simultaneous PUSCH and PUCCH transmission or, if the UE is configured for simultaneous PUSCH and PUCCH transmission and not transmitting PUSCH, in case of collision between CSI and positive SR in a same subframe, CSI is dropped.

Table 7.2.2-1A: Mapping of $I_{CQI/PMI}$ to N_{pd} and $N_{OFFSET,CQI}$ for FDD.

$I_{CQI/PMI}$	Value of N_{pd}	Value of $N_{OFFSET,CQI}$
$0 \leq I_{CQI/PMI} \leq 1$	2	$I_{CQI/PMI}$
$2 \leq I_{CQI/PMI} \leq 6$	5	$I_{CQI/PMI} - 2$
$7 \leq I_{CQI/PMI} \leq 16$	10	$I_{CQI/PMI} - 7$
$17 \leq I_{CQI/PMI} \leq 36$	20	$I_{CQI/PMI} - 17$
$37 \leq I_{CQI/PMI} \leq 76$	40	$I_{CQI/PMI} - 37$
$77 \leq I_{CQI/PMI} \leq 156$	80	$I_{CQI/PMI} - 77$
$157 \leq I_{CQI/PMI} \leq 316$	160	$I_{CQI/PMI} - 157$
$I_{CQI/PMI} = 317$	Reserved	
$318 \leq I_{CQI/PMI} \leq 349$	32	$I_{CQI/PMI} - 318$
$350 \leq I_{CQI/PMI} \leq 413$	64	$I_{CQI/PMI} - 350$
$414 \leq I_{CQI/PMI} \leq 541$	128	$I_{CQI/PMI} - 414$
$542 \leq I_{CQI/PMI} \leq 1023$	Reserved	

Table 7.2.2-1B: Mapping of I_{RI} to M_{RI} and $N_{OFFSET,RI}$.

I_{RI}	Value of M_{RI}	Value of $N_{OFFSET,RI}$
$0 \leq I_{RI} \leq 160$	1	$-I_{RI}$
$161 \leq I_{RI} \leq 321$	2	$-(I_{RI} - 161)$
$322 \leq I_{RI} \leq 482$	4	$-(I_{RI} - 322)$
$483 \leq I_{RI} \leq 643$	8	$-(I_{RI} - 483)$
$644 \leq I_{RI} \leq 804$	16	$-(I_{RI} - 644)$
$805 \leq I_{RI} \leq 965$	32	$-(I_{RI} - 805)$
$966 \leq I_{RI} \leq 1023$	Reserved	

Table 7.2.2-1C: Mapping of $I_{CQI/PMI}$ to N_{pd} and $N_{OFFSET,CQI}$ for TDD.

$I_{CQI/PMI}$	Value of N_{pd}	Value of $N_{OFFSET,CQI}$
$I_{CQI/PMI} = 0$	1	$I_{CQI/PMI}$
$1 \leq I_{CQI/PMI} \leq 5$	5	$I_{CQI/PMI} - 1$
$6 \leq I_{CQI/PMI} \leq 15$	10	$I_{CQI/PMI} - 6$
$16 \leq I_{CQI/PMI} \leq 35$	20	$I_{CQI/PMI} - 16$
$36 \leq I_{CQI/PMI} \leq 75$	40	$I_{CQI/PMI} - 36$
$76 \leq I_{CQI/PMI} \leq 155$	80	$I_{CQI/PMI} - 76$
$156 \leq I_{CQI/PMI} \leq 315$	160	$I_{CQI/PMI} - 156$
$316 \leq I_{CQI/PMI} \leq 1023$	Reserved	

For TDD periodic CQI/PMI reporting, the following periodicity values apply depending on the TDD UL/DL configuration [3]:

- The reporting period of $N_{pd} = 1$ is only applicable to TDD UL/DL configurations 0, 1, 3, 4, and 6, where all UL subframes in a radio frame are used for CQI/PMI reporting.
- The reporting period of $N_{pd} = 5$ is only applicable to TDD UL/DL configurations 0, 1, 2, and 6.
- The reporting periods of $N_{pd} = \{10, 20, 40, 80, 160\}$ are applicable to all TDD UL/DL configurations.

For a serving cell with $N_{RB}^{DL} \leq 7$, Mode 2-0 and Mode 2-1 are not supported for that serving cell.

The sub-sampled codebook for PUCCH mode 1-1 submode 2 is defined in Table 7.2.2-1D for first and second precoding matrix indicator i_1 and i_2 . Joint encoding of rank and first precoding matrix indicator i_1 for PUCCH mode 1-1 submode 1 is defined in Table 7.2.2-1E. The sub-sampled codebook for PUCCH mode 2-1 is defined in Table 7.2.2-1F for the second precoding matrix indicator i_2 .

Table 7.2.2-1D: PUCCH mode 1-1 submode 2 codebook subsampling.

RI	Relationship between the first PMI value and codebook index i_1		Relationship between the second PMI value and codebook index i_2		total
	Value of the first PMI I_{PMI1}	Codebook index i_1	Value of the second PMI I_{PMI2}	Codebook index i_2	#bits
1	0-7	$2I_{PMI1}$	0-1	$2I_{PMI2}$	4
2	0-7	$2I_{PMI1}$	0-1	I_{PMI2}	4
3	0-1	$2I_{PMI1}$	0-7	$4\lfloor I_{PMI2}/4 \rfloor + I_{PMI2}$	4
4	0-1	$2I_{PMI1}$	0-7	I_{PMI2}	4
5	0-3	I_{PMI1}	0	0	2
6	0-3	I_{PMI1}	0	0	2
7	0-3	I_{PMI1}	0	0	2
8	0	0	0	0	0

Table 7.2.2-1E: Joint encoding of RI and i_1 for PUCCH mode 1-1 submode 1.

Value of joint encoding of RI and the first PMI $I_{RI/PMI1}$	RI	Codebook index i_1
0-7	1	$2I_{RI/PMI1}$
8-15	2	$2(I_{RI/PMI1}-8)$
16-17	3	$2(I_{RI/PMI1}-16)$
18-19	4	$2(I_{RI/PMI1}-18)$
20-21	5	$2(I_{RI/PMI1}-20)$
22-23	6	$2(I_{RI/PMI1}-22)$
24-25	7	$2(I_{RI/PMI1}-24)$
26	8	0
27-31	reserved	NA

Table 7.2.2-1F: PUCCH mode 2-1 codebook subsampling.

RI	Relationship between the second PMI value and codebook index i_2	
	Value of the second PMI I_{PMI2}	Codebook index i_2

1	0-15	I_{PMI2}
2	0-3	$2I_{PMI2}$
3	0-3	$8 \cdot \lfloor I_{PMI2} / 2 \rfloor + (I_{PMI2} \bmod 2) + 2$
4	0-3	$2I_{PMI2}$
5	0	0
6	0	0
7	0	0
8	0	0

An RI or PTI or any precoding matrix indicator reported for a serving cell in a periodic reporting mode is valid only for CSI reports for that serving cell on that periodic CSI reporting mode.

For the calculation of CQI/PMI conditioned on the last reported RI, in the absence of a last reported RI the UE shall conduct the CQI/PMI calculation conditioned on the lowest possible RI as given by the bitmap parameter *codebookSubsetRestriction*. If reporting for more than one CSI subframe set is configured, CQI/PMI is conditioned on the last reported RI linked to the same subframe set as the CSI report.

- Wideband feedback
 - Mode 1-0 description:
 - In the subframe where RI is reported (only for transmission mode 3):
 - A UE shall determine a RI assuming transmission on set S subbands.
 - The UE shall report a type 3 report consisting of one RI.
 - In the subframe where CQI is reported:
 - A UE shall report a type 4 report consisting of one wideband CQI value which is calculated assuming transmission on set S subbands. The wideband CQI represents channel quality for the first codeword, even when $RI > 1$.
 - For transmission mode 3 the CQI is calculated conditioned on the last reported periodic RI. For other transmission modes it is calculated conditioned on transmission rank 1.
 - Mode 1-1 description:
 - In the subframe where RI is reported (only for transmission mode 4 and transmission mode 8 and transmission mode 9):
 - A UE shall determine a RI assuming transmission on set S subbands.
 - The UE shall report a type 3 report consisting of one RI.
 - In the subframe where RI and a first PMI are reported (only for transmission mode 9 with submode 1 and when 8 CSI-RS ports are configured)
 - A UE shall determine a RI assuming transmission on set S subbands.
 - The UE shall report a type 5 report consisting of jointly coded RI and a first PMI corresponding to a set of precoding matrices selected from the codebook subset assuming transmission on set S subbands.
 - The wideband first PMI value is calculated conditioned on the reported periodic RI.
 - In the subframe where CQI/PMI is reported for all transmission modes except transmission mode 9 with 8 CSI-RS ports configured:
 - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands.
 - A UE shall report a type 2 report consisting of

- A single wideband CQI value which is calculated assuming the use of a single precoding matrix in all subbands and transmission on set S subbands.
 - The selected single PMI (wideband PMI).
 - When $RI > 1$, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
- For transmission mode 4, 8 and 9, the PMI and CQI are calculated conditioned on the last reported periodic RI. For other transmission modes they are calculated conditioned on transmission rank 1.
- In the subframe where wideband CQI/second PMI is reported for transmission mode 9 with 8 CSI-RS ports configured to submode 1 only:
 - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands.
 - A UE shall report a type 2b report consisting of
 - A single wideband CQI value which is calculated assuming the use of the single precoding matrix in all subbands and transmission on set S subbands.
 - The wideband second PMI corresponding to the selected single precoding matrix.
 - When $RI > 1$, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
 - The wideband second PMI value is calculated conditioned on the last reported periodic RI and the wideband first PMI. The wideband CQI value is calculated conditioned on the selected precoding matrix and the last reported periodic RI.
- In the subframe where wideband CQI/first PMI/second PMI is reported for transmission mode 9 with 8 CSI-RS ports configured to submode 2 only:
 - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands.
 - A UE shall report a type 2c report consisting of
 - A single wideband CQI value which is calculated assuming the use of a single precoding matrix in all subbands and transmission on set S subbands.
 - The wideband first PMI and the wideband second PMI corresponding to the selected single precoding matrix as defined in Section 7.2.4.
 - When $RI > 1$, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
 - The wideband first PMI, the wideband second PMI and the wideband CQI are calculated conditioned on the last reported periodic RI.
- UE Selected subband feedback
 - Mode 2-0 description:
 - In the subframe where RI is reported (only for transmission mode 3):
 - A UE shall determine a RI assuming transmission on set S subbands.
 - The UE shall report a type 3 report consisting of one RI.
 - In the subframe where wideband CQI is reported:
 - The UE shall report a type 4 report on each respective successive reporting opportunity consisting of one wideband CQI value which is calculated

assuming transmission on set S subbands. The wideband CQI represents channel quality for the first codeword, even when $RI > 1$.

- For transmission mode 3 the CQI is calculated conditioned on the last reported periodic RI. For other transmission modes it is calculated conditioned on transmission rank 1.
- In the subframe where CQI for the selected subbands is reported:
 - The UE shall select the preferred subband within the set of N_j subbands in each of the J bandwidth parts where J is given in Table 7.2.2-2.
 - The UE shall report a type 1 report consisting of one CQI value reflecting transmission only over the selected subband of a bandwidth part determined in the previous step along with the corresponding preferred subband L -bit label. A type 1 report for each bandwidth part will in turn be reported in respective successive reporting opportunities. The CQI represents channel quality for the first codeword, even when $RI > 1$.
 - For transmission mode 3 the preferred subband selection and CQI values are calculated conditioned on the last reported periodic RI. For other transmission modes they are calculated conditioned on transmission rank 1.
- Mode 2-1 description:
 - In the subframe where RI is reported (only for transmission mode 4, 8 and 9 if the number of configured CSI-RS ports is 2 or 4):
 - A UE shall determine a RI assuming transmission on set S subbands.
 - The UE shall report a type 3 report consisting of one RI.
 - In the subframe where RI is reported for transmission mode 9 with 8 CSI-RS ports configured then:
 - A UE shall determine a RI assuming transmission on set S subbands.
 - A UE shall determine a precoder type indication (PTI).
 - The UE shall report a type 6 report consisting of one RI and the PTI.
 - In the subframe where wideband CQI/PMI is reported for all transmission modes except transmission mode 9 with 8 CSI-RS ports configured:
 - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands.
 - A UE shall report a type 2 report on each respective successive reporting opportunity consisting of:
 - A wideband CQI value which is calculated assuming the use of a single precoding matrix in all subbands and transmission on set S subbands.
 - The selected single PMI (wideband PMI).
 - When $RI > 1$, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
 - For transmission modes 4, 8 and 9, the PMI and CQI values are calculated conditioned on the last reported periodic RI. For other transmission modes they are calculated conditioned on transmission rank 1.
 - In the subframe where the wideband first PMI is reported for transmission mode 9 with 8 CSI-RS ports configured and the last reported PTI=0:
 - A set of precoding matrices corresponding to the wideband first PMI is selected from the codebook subset assuming transmission on set S subbands.

- A UE shall report a type 2a report on each respective successive reporting opportunity consisting of the wideband first PMI corresponding to the selected set of precoding matrices.
- The wideband first PMI value is calculated conditioned on the last reported periodic RI.
- In the subframe where wideband CQI/second PMI is reported for transmission mode 9 with 8 CSI-RS ports configured and the last reported PTI=1:
 - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands.
 - A UE shall report a type 2b report on each respective successive reporting opportunity consisting of:
 - A wideband CQI value which is calculated assuming the use of the selected single precoding matrix in all subbands and transmission on set S subbands.
 - The wideband second PMI corresponding to the selected single precoding matrix.
 - When $RI > 1$, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
 - The wideband second PMI value is calculated conditioned on the last reported periodic RI and the wideband first PMI. The wideband CQI value is calculated conditioned on the selected precoding matrix and the last reported periodic RI.
 - If the last reported first PMI was computed under an RI assumption that differs from the last reported periodic RI, or in the absence of a last reported first PMI, the conditioning of the second PMI value is not specified.
- In the subframe where CQI for the selected subband is reported for all transmission modes except for transmission mode 9 with 8 CSI-RS ports configured:
 - The UE shall select the preferred subband within the set of N_j subbands in each of the J bandwidth parts where J is given in Table 7.2.2-2.
 - The UE shall report a type 1 report per bandwidth part on each respective successive reporting opportunity consisting of:
 - CQI value for codeword 0 reflecting transmission only over the selected subband of a bandwidth part determined in the previous step along with the corresponding preferred subband L -bit label.
 - When $RI > 1$, an additional 3-bit subband spatial differential CQI value for codeword 1 offset level
 - Codeword 1 offset level = subband CQI index for codeword 0 – subband CQI index for codeword 1.
 - Assuming the use of the most recently reported single precoding matrix in all subbands and transmission on the selected subband within the applicable bandwidth part.
 - The mapping from the 3-bit subband spatial differential CQI value to the offset level is shown in Table 7.2-2.
 - For transmission modes 4, 8 and 9, the subband selection and CQI values are calculated conditioned on the last reported periodic wideband PMI and RI. For other transmission modes they are calculated conditioned on the last reported PMI and transmission rank 1.

- In the subframe where wideband CQI/second PMI is reported for transmission mode 9 with 8 CSI-RS ports configured and the last reported PTI=0:
 - A single precoding matrix is selected from the codebook subset assuming transmission on set S subbands.
 - The UE shall report a type 2b report on each respective successive reporting opportunity consisting of:
 - A wideband CQI value which is calculated assuming the use of the selected single precoding matrix in all subbands and transmission on set S subbands.
 - The wideband second PMI corresponding to the selected single precoding matrix.
 - When $RI > 1$, an additional 3-bit wideband spatial differential CQI, which is shown in Table 7.2-2.
 - The wideband second PMI value is calculated conditioned on the last reported periodic RI and the wideband first PMI. The wideband CQI value is calculated conditioned on the selected precoding matrix and the last reported periodic RI.
 - If the last reported first PMI was computed under an RI assumption that differs from the last reported periodic RI, or in the absence of a last reported first PMI, the conditioning of the second PMI value is not specified.
- In the subframe where subband CQI/second PMI for the selected subband is reported for transmission mode 9 with 8 CSI-RS ports configured and the last reported PTI=1:
 - The UE shall select the preferred subband within the set of N_j subbands in each of the J bandwidth parts where J is given in Table 7.2.2-2.
 - The UE shall report a type 1a report per bandwidth part on each respective successive reporting opportunity consisting of:
 - CQI value for codeword 0 reflecting transmission only over the selected subband of a bandwidth part determined in the previous step along with the corresponding preferred subband L -bit label.
 - When $RI > 1$, an additional 3-bit subband spatial differential CQI value for codeword 1 offset level
 - Codeword 1 offset level = subband CQI index for codeword 0 – subband CQI index for codeword 1.
 - Assuming the use of the precoding matrix corresponding to the selected second PMI and the most recently reported first PMI and transmission on the selected subband within the applicable bandwidth part.
 - The mapping from the 3-bit subband spatial differential CQI value to the offset level is shown in Table 7.2-2.
 - A second PMI of the preferred precoding matrix selected from the codebook subset assuming transmission only over the selected subband within the applicable bandwidth part determined in the previous step.
 - The subband second PMI values are calculated conditioned on the last reported periodic RI and the wideband first PMI. The subband selection and CQI values are calculated conditioned on the selected precoding matrix and the last reported periodic RI.

- If the last reported first PMI was computed under an RI assumption that differs from the last reported periodic RI, or in the absence of a last reported first PMI, the conditioning of the second PMI value is not specified.

Table 7.2.2-2: Subband Size (k) and Bandwidth Parts (J) vs. Downlink System Bandwidth

System Bandwidth N_{RB}^{DL}	Subband Size k (RBs)	Bandwidth Parts (J)
6 – 7	NA	NA
8 – 10	4	1
11 – 26	4	2
27 – 63	6	3
64 – 110	8	4

If parameter *ttiBundling* provided by higher layers is set to *TRUE* and if an UL-SCH in subframe bundling operation collides with a periodic CSI reporting instance, then the UE shall drop the periodic CSI report of a given PUCCH reporting type in that subframe and shall not multiplex the periodic CSI report payload in the PUSCH transmission in that subframe. A UE is not expected to be configured with simultaneous PUCCH and PUSCH transmission when UL-SCH subframe bundling is configured.

Table 7.2.2-3: PUCCH Reporting Type Payload size per PUCCH Reporting Mode and Mode State

PUCCH Reporting Type	Reported	Mode State	PUCCH Reporting Modes			
			Mode 1-1 (bits/BP)	Mode 2-1 (bits/BP)	Mode 1-0 (bits/BP)	Mode 2-0 (bits/BP)
1	Sub-band CQI	RI = 1	NA	4+L	NA	4+L
		RI > 1	NA	7+L	NA	4+L
1a	Sub-band CQI / second PMI	8 antenna ports RI = 1	NA	8+L	NA	NA
		8 antenna ports 1 < RI < 5	NA	9+L	NA	NA
		8 antenna ports RI > 4	NA	7+L	NA	NA
2	Wideband CQI/PMI	2 antenna ports RI = 1	6	6	NA	NA
		4 antenna ports RI = 1	8	8	NA	NA
		2 antenna ports RI > 1	8	8	NA	NA
		4 antenna ports RI > 1	11	11	NA	NA
2a	Wideband first PMI	8 antenna ports RI < 3	NA	4	NA	NA
		8 antenna ports 2 < RI < 8	NA	2	NA	NA
		8 antenna ports RI = 8	NA	0	NA	NA
2b	Wideband CQI / second PMI	8 antenna ports RI = 1	8	8	NA	NA
		8 antenna ports 1 < RI < 4	11	11	NA	NA
		8 antenna ports RI = 4	10	10	NA	NA
		8 antenna ports RI > 4	7	7	NA	NA
2c	Wideband CQI / first PMI / second PMI	8 antenna ports RI = 1	8	NA	NA	NA
		8 antenna ports 1 < RI ≤ 4	11	NA	NA	NA
		8 antenna ports 4 < RI ≤ 7	9	NA	NA	NA
		8 antenna ports RI = 8	7	NA	NA	NA
3	RI	2/4 antenna ports, 2-layer spatial multiplexing	1	1	1	1
		8 antenna ports, 2-layer spatial multiplexing	1	NA	NA	NA
		4 antenna ports, 4-layer spatial multiplexing	2	2	2	2
		8 antenna ports, 4-layer spatial multiplexing	2	NA	NA	NA
		8-layer spatial multiplexing	3	NA	NA	NA

4	Wideband CQI	RI = 1 or RI>1	NA	NA	4	4
5	RI/ first PMI	8 antenna ports, 2-layer spatial multiplexing	4	NA	NA	NA
		8 antenna ports, 4 and 8-layer spatial multiplexing	5			
6	RI/PTI	8 antenna ports, 2-layer spatial multiplexing	NA	2	NA	NA
		8 antenna ports, 4-layer spatial multiplexing	NA	3	NA	NA
		8 antenna ports, 8-layer spatial multiplexing	NA	4	NA	NA

7.2.3 Channel quality indicator (CQI) definition

The CQI indices and their interpretations are given in Table 7.2.3-1.

Based on an unrestricted observation interval in time and frequency, the UE shall derive for each CQI value reported in uplink subframe n the highest CQI index between 1 and 15 in Table 7.2.3-1 which satisfies the following condition, or CQI index 0 if CQI index 1 does not satisfy the condition:

- A single PDSCH transport block with a combination of modulation scheme and transport block size corresponding to the CQI index, and occupying a group of downlink physical resource blocks termed the CSI reference resource, could be received with a transport block error probability not exceeding 0.1.

If CSI subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ are configured by higher layers, each CSI reference resource belongs to either $C_{CSI,0}$ or $C_{CSI,1}$ but not to both. When CSI subframe sets $C_{CSI,0}$ and $C_{CSI,1}$ are configured by higher layers a UE is not expected to receive a trigger for which the CSI reference resource is in subframe that does not belong to either subframe set.

For a UE in transmission mode 9 when parameter *pmi-RI-Report* is configured by higher layers, the UE shall derive the channel measurements for computing the CQI value reported in uplink subframe n based on only the Channel-State Information (CSI) reference signals defined in [3] for which the UE is configured to assume non-zero power. For a UE in transmission mode 9 when the parameter *pmi-RI-Report* is not configured by higher layers or in other transmission modes the UE shall derive the channel measurements for computing CQI based on CRS.

A combination of modulation scheme and transport block size corresponds to a CQI index if:

- the combination could be signalled for transmission on the PDSCH in the CSI reference resource according to the relevant Transport Block Size table, and
- the modulation scheme is indicated by the CQI index, and
- the combination of transport block size and modulation scheme when applied to the reference resource results in the effective channel code rate which is the closest possible to the code rate indicated by the CQI index. If more than one combination of transport block size and modulation scheme results in an effective channel code rate equally close to the code rate indicated by the CQI index, only the combination with the smallest of such transport block sizes is relevant.

The CSI reference resource is defined as follows:

- In the frequency domain, the CSI reference resource is defined by the group of downlink physical resource blocks corresponding to the band to which the derived CQI value relates.
- In the time domain, the CSI reference resource is defined by a single downlink subframe $n - n_{CQI_ref}$,
 - o where for periodic CSI reporting n_{CQI_ref} is the smallest value greater than or equal to 4, such that it corresponds to a valid downlink subframe;

- where for aperiodic CSI reporting n_{CQI_ref} is such that the reference resource is in the same valid downlink subframe as the corresponding CSI request in an uplink DCI format.
- where for aperiodic CSI reporting n_{CQI_ref} is equal to 4 and downlink subframe $n - n_{CQI_ref}$ corresponds to a valid downlink subframe, where downlink subframe $n - n_{CQI_ref}$ is received after the subframe with the corresponding CSI request in a Random Access Response Grant.

A downlink subframe in a serving cell shall be considered to be valid if:

- it is configured as a downlink subframe for that UE, and
- except for transmission mode 9, it is not an MBSFN subframe, and
- it does not contain a DwPTS field in case the length of DwPTS is $7680 \cdot T_s$ and less, and
- it does not fall within a configured measurement gap for that UE, and
- for periodic CSI reporting, it is an element of the CSI subframe set linked to the periodic CSI report when that UE is configured with CSI subframe sets.

If there is no valid downlink subframe for the CSI reference resource in a serving cell, CSI reporting is omitted for the serving cell in uplink subframe n .

- In the layer domain, the CSI reference resource is defined by any RI and PMI on which the CQI is conditioned.

In the CSI reference resource, the UE shall assume the following for the purpose of deriving the CQI index, and if also configured, PMI and RI:

- The first 3 OFDM symbols are occupied by control signalling
- No resource elements used by primary or secondary synchronisation signals or PBCH
- CP length of the non-MBSFN subframes
- Redundancy Version 0
- If CSI-RS is used for channel measurements, the ratio of PDSCH EPRE to CSI-RS EPRE is as given in Section 7.2.5
- For transmission mode 9 CSI reporting:
 - CRS REs are as in non-MBSFN subframes;
 - If the UE is configured for PMI/RI reporting, the UE-specific reference signal overhead is consistent with the most recent reported rank; and PDSCH signals on antenna ports $\{7 \dots 6 + \nu\}$ for ν layers would result in signals equivalent to corresponding symbols transmitted on antenna ports

$$\{15 \dots 14 + P\}, \text{ as given by } \begin{bmatrix} y^{(15)}(i) \\ \vdots \\ y^{(14+P)}(i) \end{bmatrix} = W(i) \begin{bmatrix} x^{(0)}(i) \\ \vdots \\ x^{(\nu-1)}(i) \end{bmatrix}, \text{ where}$$

$x(i) = [x^{(0)}(i) \dots x^{(\nu-1)}(i)]^T$ is a vector of symbols from the layer mapping in section 6.3.3.2 of [3], $P \in \{1, 2, 4, 8\}$ is the number of CSI-RS ports configured, and if only one CSI-RS port is configured, $W(i)$ is 1, otherwise $W(i)$ is the precoding matrix corresponding to the reported PMI applicable to $x(i)$. The corresponding PDSCH signals transmitted on antenna ports $\{15 \dots 14 + P\}$ would have a ratio of EPRE to CSI-RS EPRE equal to the ratio given in section 7.2.5

- Assume no REs allocated for CSI-RS and zero-power CSI-RS
- Assume no REs allocated for PRS
- The PDSCH transmission scheme given by Table 7.2.3-0 depending on the transmission mode currently configured for the UE (which may be the default mode).
- If CRS is used for channel measurements, the ratio of PDSCH EPRE to cell-specific RS EPRE is as given in Section 5.2 with the exception of ρ_A which shall be assumed to be
 - $\rho_A = P_A + \Delta_{offset} + 10 \log_{10}(2)$ [dB] for any modulation scheme, if the UE is configured with transmission mode 2 with 4 cell-specific antenna ports, or transmission mode 3 with 4 cell-specific antenna ports and the associated RI is equal to one;
 - $\rho_A = P_A + \Delta_{offset}$ [dB] for any modulation scheme and any number of layers, otherwise.

The shift Δ_{offset} is given by the parameter *nomPDSCH-RS-EPRE-Offset* which is configured by higher-layer signalling.

Table 7.2.3-0: PDSCH transmission scheme assumed for CSI reference resource

Transmission mode	Transmission scheme of PDSCH
1	Single-antenna port, port 0
2	Transmit diversity
3	Transmit diversity if the associated rank indicator is 1, otherwise large delay CDD
4	Closed-loop spatial multiplexing
5	Multi-user MIMO
6	Closed-loop spatial multiplexing with a single transmission layer
7	If the number of PBCH antenna ports is one, Single-antenna port, port 0; otherwise Transmit diversity
8	If the UE is configured without PMI/RI reporting: if the number of PBCH antenna ports is one, single-antenna port, port 0; otherwise transmit diversity If the UE is configured with PMI/RI reporting: closed-loop spatial multiplexing
9	If the UE is configured without PMI/RI reporting: if the number of PBCH antenna ports is one, single-antenna port, port 0; otherwise transmit diversity If the UE is configured with PMI/RI reporting: if the number of CSI-RS ports is one, single-antenna port, port 7; otherwise up to 8 layer transmission, ports 7-14 (see subclause 7.1.5B)

Table 7.2.3-1: 4-bit CQI Table

CQI index	modulation	code rate x 1024	efficiency
0	out of range		
1	QPSK	78	0.1523
2	QPSK	120	0.2344
3	QPSK	193	0.3770
4	QPSK	308	0.6016
5	QPSK	449	0.8770
6	QPSK	602	1.1758
7	16QAM	378	1.4766
8	16QAM	490	1.9141
9	16QAM	616	2.4063
10	64QAM	466	2.7305
11	64QAM	567	3.3223
12	64QAM	666	3.9023
13	64QAM	772	4.5234
14	64QAM	873	5.1152
15	64QAM	948	5.5547

7.2.4 Precoding Matrix Indicator (PMI) definition

For transmission modes 4, 5 and 6, precoding feedback is used for channel dependent codebook based precoding and relies on UEs reporting precoding matrix indicator (PMI). For transmission mode 8, the UE shall report PMI if configured with PMI/RI reporting. For transmission mode 9, the UE shall report PMI if configured with PMI/RI reporting and the number of CSI-RS ports is larger than 1. A UE shall report PMI based on the feedback modes described in 7.2.1 and 7.2.2. For other transmission modes, PMI reporting is not supported.

For 2 and 4 antenna ports, each PMI value corresponds to a codebook index given in Table 6.3.4.2.3-1 or Table 6.3.4.2.3-2 of [3] as follows:

- For 2 antenna ports $\{0,1\}$ or $\{15,16\}$ and an associated RI value of 1, a PMI value of $n \in \{0,1,2,3\}$ corresponds to the codebook index n given in Table 6.3.4.2.3-1 of [3] with $\nu = 1$.
- For 2 antenna ports $\{0,1\}$ or $\{15,16\}$ and an associated RI value of 2, a PMI value of $n \in \{0,1\}$ corresponds to the codebook index $n + 1$ given in Table 6.3.4.2.3-1 of [3] with $\nu = 2$.
- For 4 antenna ports $\{0,1,2,3\}$ or $\{15,16,17,18\}$, a PMI value of $n \in \{0,1,\dots,15\}$ corresponds to the codebook index n given in Table 6.3.4.2.3-2 of [3] with ν equal to the associated RI value.

For 8 antenna ports, each PMI value corresponds to a pair of codebook indices given in Table 7.2.4-1, 7.2.4-2, 7.2.4-3, 7.2.4-4, 7.2.4-5, 7.2.4-6, 7.2.4-7, or 7.2.4-8, where the quantities φ_n and $\mathbf{v}_m$ are given by

$$\varphi_n = e^{j\pi n/2}$$

$$\mathbf{v}_m = \begin{bmatrix} 1 & e^{j2\pi m/32} & e^{j4\pi m/32} & e^{j6\pi m/32} \end{bmatrix}^T$$

- as follows: For 8 antenna ports $\{15,16,17,18,19,20,21,22\}$, a first PMI value of $n_1 \in \{0,1,\dots,f(\nu)-1\}$ and a second PMI value of $n_2 \in \{0,1,\dots,g(\nu)-1\}$ corresponds to the codebook indices n_1 and n_2 given in Table 7.2.4- j with ν equal to the associated RI value and where $j = \nu$, $f(\nu) = \{16,16,4,4,4,4,1\}$ and $g(\nu) = \{16,16,16,8,1,1,1\}$.
- In some cases codebook subsampling is supported. The sub-sampled codebook for PUCCH mode 1-1 submode 2 is defined in Table 7.2.2-1D for first and second precoding matrix indicator i_1 and i_2 . Joint encoding of rank and first precoding matrix indicator i_1 for PUCCH mode 1-1 submode 1 is defined in Table 7.2.2-1E. The sub-sampled codebook for PUCCH mode 2-1 is defined in Table 7.2.2-1F for the second precoding matrix indicator i_2 .

Table 7.2.4-1: Codebook for 1-layer CSI reporting using antenna ports 15 to 22.

i_1	i_2							
	0	1	2	3	4	5	6	7
0 – 15	$W_{2i_1,0}^{(1)}$	$W_{2i_1,1}^{(1)}$	$W_{2i_1,2}^{(1)}$	$W_{2i_1,3}^{(1)}$	$W_{2i_1+1,0}^{(1)}$	$W_{2i_1+1,1}^{(1)}$	$W_{2i_1+1,2}^{(1)}$	$W_{2i_1+1,3}^{(1)}$
i_1	i_2							
	8	9	10	11	12	13	14	15
0 – 15	$W_{2i_1+2,0}^{(1)}$	$W_{2i_1+2,1}^{(1)}$	$W_{2i_1+2,2}^{(1)}$	$W_{2i_1+2,3}^{(1)}$	$W_{2i_1+3,0}^{(1)}$	$W_{2i_1+3,1}^{(1)}$	$W_{2i_1+3,2}^{(1)}$	$W_{2i_1+3,3}^{(1)}$
where $W_{m,n}^{(1)} = \frac{1}{\sqrt{8}} \begin{bmatrix} \mathbf{v}_m \\ \varphi_n \mathbf{v}_m \end{bmatrix}$								

Table 7.2.4-2: Codebook for 2-layer CSI reporting using antenna ports 15 to 22.

i_1	i_2			
	0	1	2	3
0 – 15	$W_{2i_1,2i_1,0}^{(2)}$	$W_{2i_1,2i_1,1}^{(2)}$	$W_{2i_1+1,2i_1+1,0}^{(2)}$	$W_{2i_1+1,2i_1+1,1}^{(2)}$
i_1	i_2			
	4	5	6	7

0 – 15	$W_{2i_1+2,2i_1+2,0}^{(2)}$	$W_{2i_1+2,2i_1+2,1}^{(2)}$	$W_{2i_1+3,2i_1+3,0}^{(2)}$	$W_{2i_1+3,2i_1+3,1}^{(2)}$
i_1	i_2			
	8	9	10	11
0 – 15	$W_{2i_1,2i_1+1,0}^{(2)}$	$W_{2i_1,2i_1+1,1}^{(2)}$	$W_{2i_1+1,2i_1+2,0}^{(2)}$	$W_{2i_1+1,2i_1+2,1}^{(2)}$
i_1	i_2			
	12	13	14	15
0 – 15	$W_{2i_1,2i_1+3,0}^{(2)}$	$W_{2i_1,2i_1+3,1}^{(2)}$	$W_{2i_1+1,2i_1+3,0}^{(2)}$	$W_{2i_1+1,2i_1+3,1}^{(2)}$
where $W_{m,m',n}^{(2)} = \frac{1}{4} \begin{bmatrix} v_m & v_{m'} \\ \varphi_n v_m & -\varphi_n v_{m'} \end{bmatrix}$				

Table 7.2.4-3: Codebook for 3-layer CSI reporting using antenna ports 15 to 22.

i_1	i_2			
	0	1	2	3
0 - 3	$W_{8i_1,8i_1,8i_1+8}^{(3)}$	$W_{8i_1+8,8i_1,8i_1+8}^{(3)}$	$\tilde{W}_{8i_1,8i_1+8,8i_1+8}^{(3)}$	$\tilde{W}_{8i_1+8,8i_1,8i_1}^{(3)}$
i_1	i_2			
	4	5	6	7
0 - 3	$W_{8i_1+2,8i_1+2,8i_1+10}^{(3)}$	$W_{8i_1+10,8i_1+2,8i_1+10}^{(3)}$	$\tilde{W}_{8i_1+2,8i_1+10,8i_1+10}^{(3)}$	$\tilde{W}_{8i_1+10,8i_1+2,8i_1+2}^{(3)}$
i_1	i_2			
	8	9	10	11
0 - 3	$W_{8i_1+4,8i_1+4,8i_1+12}^{(3)}$	$W_{8i_1+12,8i_1+4,8i_1+12}^{(3)}$	$\tilde{W}_{8i_1+4,8i_1+12,8i_1+12}^{(3)}$	$\tilde{W}_{8i_1+12,8i_1+4,8i_1+4}^{(3)}$
i_1	i_2			
	12	13	14	15
0 - 3	$W_{8i_1+6,8i_1+6,8i_1+14}^{(3)}$	$W_{8i_1+14,8i_1+6,8i_1+14}^{(3)}$	$\tilde{W}_{8i_1+6,8i_1+14,8i_1+14}^{(3)}$	$\tilde{W}_{8i_1+14,8i_1+6,8i_1+6}^{(3)}$
where $W_{m,m',m''}^{(3)} = \frac{1}{\sqrt{24}} \begin{bmatrix} v_m & v_{m'} & v_{m''} \\ v_m & -v_{m'} & -v_{m''} \end{bmatrix}$, $\tilde{W}_{m,m',m''}^{(3)} = \frac{1}{\sqrt{24}} \begin{bmatrix} v_m & v_{m'} & v_{m''} \\ v_m & v_{m'} & -v_{m''} \end{bmatrix}$				

Table 7.2.4-4: Codebook for 4-layer CSI reporting using antenna ports 15 to 22.

i_1	i_2			
	0	1	2	3
0 - 3	$W_{8i_1,8i_1+8,0}^{(4)}$	$W_{8i_1,8i_1+8,1}^{(4)}$	$W_{8i_1+2,8i_1+10,0}^{(4)}$	$W_{8i_1+2,8i_1+10,1}^{(4)}$
i_1	i_2			
	4	5	6	7
0 - 3	$W_{8i_1+4,8i_1+12,0}^{(4)}$	$W_{8i_1+4,8i_1+12,1}^{(4)}$	$W_{8i_1+6,8i_1+14,0}^{(4)}$	$W_{8i_1+6,8i_1+14,1}^{(4)}$
where $W_{m,m',n}^{(4)} = \frac{1}{\sqrt{32}} \begin{bmatrix} v_m & v_{m'} & v_m & v_{m'} \\ \varphi_n v_m & \varphi_n v_{m'} & -\varphi_n v_m & -\varphi_n v_{m'} \end{bmatrix}$				

Table 7.2.4-5: Codebook for 5-layer CSI reporting using antenna ports 15 to 22.

i_1	i_2				
	0				
0 - 3	$W_{i_1}^{(5)} = \frac{1}{\sqrt{40}} \begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} \end{bmatrix}$				

Table 7.2.4-6: Codebook for 6-layer CSI reporting using antenna ports 15 to 22.

i_1	i_2
	0
0 - 3	$W_{i_1}^{(6)} = \frac{1}{\sqrt{48}} \begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} & v_{2i_1+16} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} & -v_{2i_1+16} \end{bmatrix}$

Table 7.2.4-7: Codebook for 7-layer CSI reporting using antenna ports 15 to 22.

i_1	i_2
	0
0 - 3	$W_{i_1}^{(7)} = \frac{1}{\sqrt{56}} \begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} & v_{2i_1+16} & v_{2i_1+24} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} & -v_{2i_1+16} & v_{2i_1+24} \end{bmatrix}$

Table 7.2.4-8: Codebook for 8-layer CSI reporting using antenna ports 15 to 22.

i_1	i_2
	0
0	$W_{i_1}^{(8)} = \frac{1}{8} \begin{bmatrix} v_{2i_1} & v_{2i_1} & v_{2i_1+8} & v_{2i_1+8} & v_{2i_1+16} & v_{2i_1+16} & v_{2i_1+24} & v_{2i_1+24} \\ v_{2i_1} & -v_{2i_1} & v_{2i_1+8} & -v_{2i_1+8} & v_{2i_1+16} & -v_{2i_1+16} & v_{2i_1+24} & -v_{2i_1+24} \end{bmatrix}$

7.2.5 Channel-State Information – Reference Signal (CSI-RS) definition

The following parameters for CSI-RS are configured via higher layer signaling:

- Number of CSI-RS ports. The allowable values and port mapping are given in Section 6.10.5 of [3].
- CSI RS Configuration (see Table 6.10.5.2-1 and Table 6.10.5.2-2 in [3])
- CSI RS subframe configuration $I_{\text{CSI-RS}}$. The allowable values are given in Section 6.10.5.3 of [3].
- Subframe configuration period $T_{\text{CSI-RS}}$. The allowable values are given in Section 6.10.5.3 of [3].
- Subframe offset $\Delta_{\text{CSI-RS}}$. The allowable values are given in Section 6.10.5.3 of [3].
- UE assumption on reference PDSCH transmitted power for CSI feedback P_c . P_c is the assumed ratio of PDSCH EPRE to CSI-RS EPRE when UE derives CSI feedback and takes values in the range of [-8, 15] dB with 1 dB step size, where the PDSCH EPRE corresponds to the symbols for which the ratio of the PDSCH EPRE to the cell-specific RS EPRE is denoted by ρ_A , as specified in Table 5.2-2 and Table 5.2-3.

A UE should not expect the configuration of CSI-RS and/or zero-power CSI-RS and PMCH in the same subframe of a serving cell.

7.3 UE procedure for reporting HARQ-ACK

For FDD with PUCCH format 1a/1b transmission, when both HARQ-ACK and SR are transmitted in the same sub-frame, a UE shall transmit the HARQ-ACK on its assigned HARQ-ACK PUCCH format 1a/1b resource for a negative SR transmission and transmit the HARQ-ACK on its assigned SR PUCCH resource for a positive SR transmission.

For FDD with PUCCH format 1b with channel selection, when both HARQ-ACK and SR are transmitted in the same sub-frame a UE shall transmit the HARQ-ACK on its assigned HARQ-ACK PUCCH resource with channel selection as defined in section 10.1.2.1.1 for a negative SR transmission and transmit the per serving cell spatially-bundled HARQ-ACK on its assigned SR PUCCH resource for a positive SR transmission.

For FDD, when a PUCCH format 3 transmission of HARQ-ACK coincides with a sub-frame configured to the UE by higher layers for transmission of a scheduling request, the UE shall multiplex HARQ-ACK and SR bits on HARQ-ACK PUCCH resource as defined in section 5.2.3.1 in [4], unless the HARQ-ACK corresponds to a PDSCH transmission on

the primary cell only or a PDCCH indicating downlink SPS release on the primary cell only, in which case the SR shall be transmitted as for FDD with PUCCH format 1a/1b.

For TDD, the UE shall upon detection of a PDSCH transmission or a PDCCH indicating downlink SPS release (defined in section 9.2) within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1 intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in UL subframe n .

For TDD, when PUCCH format 3 is configured for transmission of HARQ-ACK, for special subframe configurations 0 and 5 with normal downlink CP or configurations 0 and 4 with extended downlink CP in a serving cell, shown in table 4.2-1 [3], the special subframe of the serving cell is excluded from the HARQ-ACK codebook size determination. In this case, if the serving cell is the primary cell, there is no PDCCH indicating downlink SPS release in the special subframe.

For TDD UL-DL configurations 1-6 and one configured serving cell, if the UE is not configured with PUCCH format 3, the value of the Downlink Assignment Index (DAI) in DCI format 0/4, V_{DAI}^{UL} , detected by the UE according to Table 7.3-X in subframe $n-k'$, where k' is defined in Table 7.3-Y, represents the total number of subframes with PDSCH transmissions and with PDCCH indicating downlink SPS release to the corresponding UE within all the subframe(s) $n-k$, where $k \in K$. The value V_{DAI}^{UL} includes all PDSCH transmission with and without corresponding PDCCH within all the subframe(s) $n-k$. In case neither PDSCH transmission, nor PDCCH indicating the downlink SPS resource release is intended to the UE, the UE can expect that the value of the DAI in DCI format 0/4, V_{DAI}^{UL} , if transmitted, is set to 4.

For TDD UL-DL configuration 1-6 and a UE configured with more than one serving cell, or for TDD UL-DL configuration 1-6 and a UE configured with one serving cell and PUCCH format 3, a value W_{DAI}^{UL} is determined by the Downlink Assignment Index (DAI) in DCI format 0/4 according to Table 7.3-Z in subframe $n-k'$, where k' is defined in Table 7.3-Y. In case neither PDSCH transmission, nor PDCCH indicating the downlink SPS resource release is intended to the UE, the UE can expect that the value of W_{DAI}^{UL} is set to 4 by the DAI in DCI format 0/4 if transmitted.

For TDD UL-DL configurations 1-6, the value of the DAI in DCI format 1/1A/1B/1D/2/2A/2B/2C denotes the accumulative number of PDCCH(s) with assigned PDSCH transmission(s) and PDCCH indicating downlink SPS release up to the present subframe within subframe(s) $n-k$ of each configured serving cell, where $k \in K$, and shall be updated from subframe to subframe. Denote $V_{DAI,c}^{DL}$ as the value of the DAI in PDCCH with DCI format 1/1A/1B/1D/2/2A/2B/2C detected by the UE according to Table 7.3-X in subframe $n-k_m$ in serving cell c , where k_m is the smallest value in the set K (defined in Table 10.1.3.1-1) such that the UE detects a DCI format 1/1A/1B/1D/2/2A/2B/2C. When configured with one serving cell, the subscript of c in $V_{DAI,c}^{DL}$ can be omitted.

For all TDD UL-DL configurations, denote $U_{DAI,c}$ as the total number of PDCCH(s) with assigned PDSCH transmission(s) and PDCCH indicating downlink SPS release detected by the UE within the subframe(s) $n-k$ in serving cell c , where $k \in K$. When configured with one serving cell, the subscript of c in $U_{DAI,c}$ can be omitted.

Denote N_{SPS} , which can be zero or one, as the number of PDSCH transmissions without a corresponding PDCCH within the subframe(s) $n-k$, where $k \in K$.

For TDD HARQ-ACK bundling or HARQ-ACK multiplexing and a subframe n with $M=1$, the UE shall generate one or two HARQ-ACK bits by performing a logical AND operation per codeword across M DL subframes associated with a single UL subframe, of all the corresponding $U_{DAI} + N_{SPS}$ individual PDSCH transmission HARQ-ACKs and individual ACK in response to received PDCCH indicating downlink SPS release, where M is the number of elements in the set K defined in Table 10.1.3.1-1. The UE shall detect if at least one downlink assignment has been missed, and for the case that the UE is transmitting on PUSCH the UE shall also determine the parameter N_{bundled} . For TDD UL-DL configuration 0, N_{bundled} shall be 1 if the UE detects the PDSCH transmission with or without corresponding PDCCH within the subframe $n-k$, where $k \in K$.

- For the case that the UE is not transmitting on PUSCH in subframe n and TDD UL-DL configurations 1-6, if $U_{DAI} > 0$ and $V_{DAI}^{DL} \neq (U_{DAI} - 1) \bmod 4 + 1$, the UE detects that at least one downlink assignment has been missed.
- For the case that the UE is transmitting on PUSCH and the PUSCH transmission is adjusted based on a detected PDCCH with DCI format 0/4 intended for the UE and TDD UL-DL configurations 1-6, if $V_{DAI}^{UL} \neq (U_{DAI} + N_{SPS} - 1) \bmod 4 + 1$ the UE detects that at least one downlink assignment has been missed and the UE shall generate NACK for all codewords where N_{bundled} is determined by the UE as $N_{\text{bundled}} = V_{DAI}^{UL} + 2$. If the UE does not detect any downlink assignment missing, N_{bundled} is determined by the UE as $N_{\text{bundled}} = V_{DAI}^{UL}$. UE shall not transmit HARQ-ACK if $U_{DAI} + N_{SPS} = 0$ and $V_{DAI}^{UL} = 4$.
- For the case that the UE is transmitting on PUSCH, and the PUSCH transmission is not based on a detected PDCCH with DCI format 0/4 intended for the UE and TDD UL-DL configurations 1-6, if $U_{DAI} > 0$ and $V_{DAI}^{DL} \neq (U_{DAI} - 1) \bmod 4 + 1$, the UE detects that at least one downlink assignment has been missed and the UE shall generate NACK for all codewords. The UE determines $N_{\text{bundled}} = (U_{DAI} + N_{SPS})$ as the number of assigned subframes. The UE shall not transmit HARQ-ACK if $U_{DAI} + N_{SPS} = 0$.

For TDD, when PUCCH format 3 is configured for transmission of HARQ-ACK, the HARQ-ACK feedback bits $o_{c,0}^{ACK}, o_{c,1}^{ACK}, \dots, o_{c,O_c^{ACK}-1}^{ACK}$ for the c -th serving cell configured by RRC are constructed as follows, where $c \geq 0$,

$O_c^{ACK} = B_c^{DL}$ if transmission mode configured in the c -th serving cell supports one transport block or spatial HARQ-ACK bundling is applied and $O_c^{ACK} = 2B_c^{DL}$ otherwise, where B_c^{DL} is the number of downlink subframes for which the UE needs to feedback HARQ-ACK bits for the c -th serving cell.

- For the case that the UE is transmitting on PUCCH, $B_c^{DL} = M$ where M is the number of elements in the set K defined in Table 10.1.3.1-1 associated with subframe n and the set K does not include a special subframe of configurations 0 and 5 with normal downlink CP or of configurations 0 and 4 with extended downlink CP; otherwise $B_c^{DL} = M - 1$.
- For TDD UL-DL configuration 0 or for a PUSCH transmission not adjusted based on a detected PDCCH with DCI format 0/4, the UE shall assume $B_c^{DL} = M$ where M is the number of elements in the set K defined in Table 10.1.3.1-1 associated with subframe n and the set K does not include a special subframe of configurations 0 and 5 with normal downlink CP or of configurations 0 and 4 with extended downlink CP; otherwise $B_c^{DL} = M - 1$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH indicating downlink SPS release in subframe(s) $n - k$, where $k \in K$.
- For TDD UL-DL configurations $\{1, 2, 3, 4, 6\}$ and a PUSCH transmission adjusted based on a detected PDCCH with DCI format 0/4, the UE shall assume $B_c^{DL} = W_{DAI}^{UL}$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH indicating downlink SPS release in subframe(s) $n - k$ where $k \in K$ and $W_{DAI}^{UL} = 4$.
- For TDD UL-DL configurations 5 and a PUSCH transmission adjusted based on a detected PDCCH with DCI format 0/4, the UE shall assume $B_c^{DL} = W_{DAI}^{UL} + 4 \left\lceil \frac{U - W_{DAI}^{UL}}{4} \right\rceil$, where U denotes the maximum value of U_c among all the configured serving cells, U_c is the total number of received PDSCHs and PDCCH indicating downlink SPS release in subframe(s) $n - k$ on the c -th serving cell, $k \in K$. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH indicating downlink SPS release in subframe(s) $n - k$ where $k \in K$ and $W_{DAI}^{UL} = 4$.

The HARQ-ACK for a PDSCH transmission with a corresponding PDCCH or for a PDCCH indicating downlink SPS release in subframe $n - k$ is associated with $o_{c,DAI(k)-1}^{ACK}$ if transmission mode configured in the c -th serving cell

supports one transport block or spatial HARQ-ACK bundling is applied, or associated with $o_{c,2DAI(k)-2}^{ACK}$ and $o_{c,2DAI(k)-1}^{ACK}$ otherwise, where $DAI(k)$ is the value of DAI in DCI format 1A/1B/1D/1/2/2A/2B/2C detected in subframe $n-k$, $o_{c,2DAI(k)-2}^{ACK}$ and $o_{c,2DAI(k)-1}^{ACK}$ are the HARQ-ACK feedback for codeword 0 and codeword 1, respectively. For the case with $N_{SPS} > 0$, the HARQ-ACK associated with a PDSCH transmission without a corresponding PDCCH is mapped to $o_{c,O_c^{ACK}-1}^{ACK}$. The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH indicating downlink SPS release are set to NACK.

For TDD when format 1b with channel selection is configured for transmission of HARQ-ACK and for 2 configured serving cells, the HARQ-ACK feedback bits $o_0^{ACK}, o_1^{ACK}, \dots, o_{O_c^{ACK}-1}^{ACK}$ on PUSCH are constructed as follows.

- For TDD UL-DL configuration 0, $o_j^{ACK} = \text{HARQ-ACK}(j)$, $0 \leq j \leq A-1$ as defined in section 10.1.3.2.1. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$.
- For TDD UL-DL configurations $\{1, 2, 3, 4, 6\}$ and a PUSCH transmission adjusted based on a detected PDCCH with DCI format 0/4 with $W_{DAI}^{UL}=1$ or 2, o_j^{ACK} is determined as if PUCCH format 3 is configured for transmission of HARQ-ACK, except that spatial HARQ-ACK bundling across multiple codewords within a DL subframe is performed for all serving cells configured with a downlink transmission mode that supports up to two transport blocks in case $W_{DAI}^{UL}=2$.
- For TDD UL-DL configurations $\{1, 2, 3, 4, 6\}$ and a PUSCH transmission adjusted based on a detected PDCCH with DCI format 0/4 with $W_{DAI}^{UL}=3$ or 4, $o_j^{ACK} = o(j)$, $0 \leq j \leq 3$ as defined in Table 10.1.3.2-5 or in Table 10.1.3.2-6 respectively, where the value of M is replaced by W_{DAI}^{UL} . The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$ and $W_{DAI}^{UL} = 4$.
- For TDD UL-DL configurations $\{1, 2, 3, 4, 6\}$ and a PUSCH transmission not adjusted based on a detected PDCCH with DCI format 0/4 and a subframe n with $M=1$ or 2, $o_j^{ACK} = \text{HARQ-ACK}(j)$, $0 \leq j \leq A-1$ as defined in section 10.1.3.2.1. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$.
- For TDD UL-DL configurations $\{1, 2, 3, 4, 6\}$ and a PUSCH transmission not adjusted based on a detected PDCCH with DCI format 0/4 and a subframe n with $M=3$ or 4, $o_j^{ACK} = o(j)$, $0 \leq j \leq 3$ as defined in Table 10.1.3.2-5 or in Table 10.1.3.2-6 respectively. The UE shall not transmit HARQ-ACK on PUSCH if the UE does not receive PDSCH or PDCCH indicating downlink SPS release in subframe(s) $n-k$ where $k \in K$.

For TDD HARQ-ACK bundling, when the UE is configured by transmission mode 3, 4, 8 or 9 defined in Section 7.1 and HARQ-ACK bits are transmitted on PUSCH, the UE shall always generate 2 HARQ-ACK bits assuming both codeword 0 and 1 are enabled. For the case that the UE detects only the PDSCH transmission associated with codeword 0 within the bundled subframes, the UE shall generate NACK for codeword 1.

Table 7.3-X: Value of Downlink Assignment Index

DAI MSB, LSB	V_{DAI}^{UL} or V_{DAI}^{DL}	Number of subframes with PDSCH transmission and with PDCCH indicating DL SPS release
0,0	1	1 or 5 or 9
0,1	2	2 or 6
1,0	3	3 or 7
1,1	4	0 or 4 or 8

Table 7.3-Y: Uplink association index k' for TDD

TDD UL/DL Configuration	subframe number n									
	0	1	2	3	4	5	6	7	8	9
1			6	4				6	4	
2			4					4		
3			4	4	4					
4			4	4						
5			4							
6			7	7	5			7	7	

Table 7.3-Z: Value of W_{DAI}^{UL} determined by the DAI field in DCI format 0/4

DAI MSB, LSB	W_{DAI}^{UL}
0,0	1
0,1	2
1,0	3
1,1	4

For TDD HARQ-ACK multiplexing and a subframe n with $M > 1$, spatial HARQ-ACK bundling across multiple codewords within a DL subframe is performed by a logical AND operation of all the corresponding individual HARQ-ACKs. In case the UE is transmitting on PUSCH, the UE shall determine the number of HARQ-ACK feedback bits O^{ACK} and the HARQ-ACK feedback bits o_n^{ACK} , $n = 0, \dots, O^{ACK} - 1$ to be transmitted in subframe n .

- If the PUSCH transmission is adjusted based on a detected PDCCH with DCI format 0/4 intended for the UE, then $O^{ACK} = V_{DAI}^{UL}$ unless $V_{DAI}^{UL} = 4$ and $U_{DAI} + N_{SPS} = 0$ in which case the UE shall not transmit HARQ-ACK. The spatially bundled HARQ-ACK for a PDSCH transmission with a corresponding PDCCH or for a PDCCH indicating downlink SPS release in subframe $n - k$ is associated with $o_{DAI(k)-1}^{ACK}$ where $DAI(k)$ is the value of DAI in DCI format 1A/1B/1D/1/2/2A/2B/2C detected in subframe $n - k$. For the case with $N_{SPS} > 0$, the HARQ-ACK associated with a PDSCH transmission without a corresponding PDCCH is mapped to $o_{O^{ACK}-1}^{ACK}$. The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH indicating downlink SPS release are set to NACK.
- If the PUSCH transmission is not adjusted based on a detected PDCCH with DCI format 0/4 intended for the UE, $O^{ACK} = M$, and o_i^{ACK} is associated with the spatially bundled HARQ-ACK for DL subframe $n - k_i$, where $k_i \in K$. The HARQ-ACK feedback bits without any detected PDSCH transmission or without detected PDCCH indicating downlink SPS release are set to NACK. The UE shall not transmit HARQ-ACK if $U_{DAI} + N_{SPS} = 0$.

For TDD when a PUCCH format 3 transmission of HARQ-ACK coincides with a sub-frame configured to the UE by higher layers for transmission of a scheduling request, the UE shall multiplex HARQ-ACK and SR bits on HARQ-ACK PUCCH resource as defined in section 5.2.3.1 in [4], unless the HARQ-ACK corresponds to one of the following cases

- a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n - k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X), or a PDCCH indicating downlink SPS release (defined in section 9.2) in subframe $n - k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1', or

- a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH indicating downlink SPS release (defined in section 9.2) within subframe(s) $n-k$, where $k \in K$, or
- a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH detected within subframe(s) $n-k$, where $k \in K$ and an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X) or a PDCCH indicating downlink SPS release (defined in section 9.2) in the subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1',

in which case the UE shall transmit the HARQ-ACK and scheduling request according to the procedure for PUCCH format 1b with channel selection in TDD.

For TDD when the UE is configured with HARQ-ACK bundling, HARQ-ACK multiplexing or PUCCH format 1b with channel selection, and when both HARQ-ACK and SR are transmitted in the same sub-frame, a UE shall transmit the bundled HARQ-ACK or the multiple HARQ-ACK responses (according to section 10.1) on its assigned HARQ-ACK PUCCH resources for a negative SR transmission. For a positive SR, the UE shall transmit $b(0), b(1)$ on its assigned SR PUCCH resource using PUCCH format 1b according to section 5.4.1 in [3]. The value of $b(0), b(1)$ are generated

according to Table 7.3-1 from the $N_{SPS} + \sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c}$ HARQ-ACK responses including ACK in response to PDCCH indicating downlink SPS release by spatial HARQ-ACK bundling across multiple codewords within each PDSCH transmission for all serving cells N_{cells}^{DL} . For TDD UL-DL configurations 1-6, if $\sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c} > 0$ and $V_{DAI,c}^{DL} \neq (U_{DAI,c} - 1) \bmod 4 + 1$ for a serving cell c , the UE detects that at least one downlink assignment has been missed.

Table 7.3-1: Mapping between multiple HARQ-ACK responses and $b(0), b(1)$

Number of ACK among multiple ($N_{SPS} + \sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c}$) HARQ-ACK responses	$b(0), b(1)$
0 or None (UE detect at least one DL assignment is missed)	0, 0
1	1, 1
2	1, 0
3	0, 1
4	1, 1
5	1, 0
6	0, 1
7	1, 1
8	1, 0
9	0, 1

For TDD when both HARQ-ACK and CSI are configured to be transmitted in the same sub-frame on the PUCCH, if the UE is configured with HARQ-ACK bundling, HARQ-ACK multiplexing or PUCCH format 1b with channel selection, and if the UE receives PDSCH and/or PDCCH indicating downlink SPS only on the primary cell within subframe(s) $n-k$, where $k \in K$, a UE shall transmit the CSI and $b(0), b(1)$ using PUCCH format 2b for normal CP or PUCCH format 2 for extended CP, according to section 5.2.3.4 in [4] with a_0'', a_1'' replaced by $b(0), b(1)$. The value of

$b(0), b(1)$ are generated according to Table 7.3-1 from the $N_{SPS} + \sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c}$ HARQ-ACK responses including ACK in response to PDCCH indicating downlink SPS release by spatial HARQ-ACK bundling across multiple codewords within each PDSCH transmission for all serving cells N_{cells}^{DL} . For TDD UL-DL configurations 1-6, if

$\sum_{c=0}^{N_{cells}^{DL}-1} U_{DAI,c} > 0$ and $V_{DAI,c}^{DL} \neq (U_{DAI,c} - 1) \bmod 4 + 1$ for a serving cell c , the UE detects that at least one downlink assignment has been missed.

For TDD when both HARQ-ACK and CSI are configured to be transmitted in the same sub-frame and the UE is configured with PUCCH format 1b with channel selection and receives at least one PDSCH on the secondary cell within subframe(s) $n-k$, where $k \in K$, the UE shall drop the CSI and transmit HARQ-ACK according to section 10.1.3.

For TDD when both HARQ-ACK and CSI are configured to be transmitted in the same sub-frame and a UE configured with PUCCH format 3, if the UE receives

- a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X), or a PDCCH indicating downlink SPS release (defined in section 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1', or
- a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH detected within subframe(s) $n-k$, where $k \in K$ and no PDCCH indicating downlink SPS release (defined in section 9.2) within subframe(s) $n-k$, where $k \in K$,

the UE shall transmit the CSI and HARQ-ACK using PUCCH format 2/2a/2b according to section 5.2.3.4 in [4]; otherwise, the UE shall drop the CSI and transmit the HARQ-ACK according to section 10.1.3.

When only a positive SR is transmitted a UE shall use PUCCH Format 1 for the SR resource as defined in section 5.4.1 in [3].

8 Physical uplink shared channel related procedures

For FDD and transmission mode 1, there shall be 8 uplink HARQ processes per serving cell for non-subframe bundling operation, i.e. normal HARQ operation, and 4 uplink HARQ processes for subframe bundling operation. For FDD and transmission mode 2, there shall be 16 uplink HARQ processes per serving cell for non-subframe bundling operation and there are two HARQ processes associated with a given subframe as described in [8]. The subframe bundling operation is configured by the parameter *ttiBundling* provided by higher layers.

In case higher layers configure the use of subframe bundling for FDD and TDD, the subframe bundling operation is only applied to UL-SCH, such that four consecutive uplink subframes are used.

8.0 UE procedure for transmitting the physical uplink shared channel

For FDD and normal HARQ operation, the UE shall upon detection on a given serving cell of a PDCCH with DCI format 0/4 and/or a PHICH transmission in subframe n intended for the UE, adjust the corresponding PUSCH transmission in subframe $n+4$ according to the PDCCH and PHICH information.

For normal HARQ operation, if the UE detects a PHICH transmission and if the most recent PUSCH transmission for the same transport block was using spatial multiplexing according to section 8.0.2 and the UE does not detect a PDCCH with DCI format 4 in subframe n intended for the UE, the UE shall adjust the corresponding PUSCH retransmission in the associated subframe according to the PHICH information, and using the number of transmission layers and precoding matrix according to the most recent PDCCH, if the number of negatively acknowledged transport blocks is equal to the number of transport blocks indicated in the most recent PDCCH associated with the corresponding PUSCH.

For normal HARQ operation, if the UE detects a PHICH transmission and if the most recent PUSCH transmission for the same transport block was using spatial multiplexing according to section 8.0.2 and the UE does not detect a PDCCH with DCI format 4 in subframe n intended for the UE, and if the number of negatively acknowledged transport blocks is not equal to the number of transport blocks indicated in the most recent PDCCH associated with the corresponding PUSCH then the UE shall adjust the corresponding PUSCH retransmission in the associated subframe according to the

PHICH information, using the precoding matrix with codebook index 0 and the number of transmission layers equal to number of layers corresponding to the negatively acknowledged transport block from the most recent PDCCH. In this case, the UL DMRS resources are calculated according to the cyclic shift field for DMRS [3] in the most recent PDCCH with DCI format 4 associated with the corresponding PUSCH transmission and number of layers corresponding to the negatively acknowledged transport block.

If a UE is configured with the carrier indicator field for a given serving cell, the UE shall use the carrier indicator field value from the detected PDCCH with uplink DCI format to determine the serving cell for the corresponding PUSCH transmission.

For FDD and normal HARQ operation, if a PDCCH with CSI request field set to trigger an aperiodic CSI report, as described in section 7.2.1, is detected by a UE on subframe n , then on subframe $n+4$ UCI is mapped on the corresponding PUSCH transmission, when simultaneous PUSCH and PUCCH transmission is not configured for the UE.

For TDD and normal HARQ operation, if a PDCCH with CSI request field set to trigger an aperiodic CSI report, as described in section 7.2.1, is detected by a UE on subframe n , then on subframe $n+k$ UCI is mapped on the corresponding PUSCH transmission where k is given by Table 8-2, when simultaneous PUSCH and PUCCH transmission is not configured for the UE.

For FDD and subframe bundling operation, the UE shall upon detection of a PDCCH with DCI format 0 in subframe n intended for the UE, and/or a PHICH transmission in subframe $n-5$ intended for the UE, adjust the corresponding first PUSCH transmission in the bundle in subframe $n+4$ according to the PDCCH and PHICH information.

For FDD and TDD, the NDI as signalled on PDCCH, the RV as determined in section 8.6.1, and the TBS as determined in section 8.6.2, shall be delivered to higher layers.

For TDD and transmission mode 1, the number of HARQ processes per serving cell shall be determined by the DL/UL configuration (Table 4.2-2 of [3]), as indicated in Table 8-1. For TDD and transmission mode 2, the number of HARQ processes per serving cell for non-subframe bundling operation shall be twice the number determined by the DL/UL configuration (Table 4.2-2 of [3]) as indicated in Table 8-1 and there are two HARQ processes associated with a given subframe as described in [8].

Table 8-1: Number of synchronous UL HARQ processes for TDD

TDD UL/DL configuration	Number of HARQ processes for normal HARQ operation	Number of HARQ processes for subframe bundling operation
0	7	3
1	4	2
2	2	N/A
3	3	N/A
4	2	N/A
5	1	N/A
6	6	3

For TDD UL/DL configurations 1-6 and normal HARQ operation, the UE shall upon detection of a PDCCH with uplink DCI format and/or a PHICH transmission in subframe n intended for the UE, adjust the corresponding PUSCH transmission in subframe $n+k$, with k given in Table 8-2, according to the PDCCH and PHICH information.

For TDD UL/DL configuration 0 and normal HARQ operation the UE shall upon detection of a PDCCH with uplink DCI format and/or a PHICH transmission in subframe n intended for the UE, adjust the corresponding PUSCH transmission in subframe $n+k$ if the MSB of the UL index in the PDCCH with uplink DCI format is set to 1 or PHICH is received in subframe $n=0$ or 5 in the resource corresponding to $I_{PHICH} = 0$, as defined in Section 9.1.2, with k given in Table 8-2. If, for TDD UL/DL configuration 0 and normal HARQ operation, the LSB of the UL index in the DCI format 0/4 is set to 1 in subframe n or a PHICH is received in subframe $n=0$ or 5 in the resource corresponding to $I_{PHICH} = 1$, as defined in Section 9.1.2, or PHICH is received in subframe $n=1$ or 6, the UE shall adjust the corresponding PUSCH transmission in subframe $n+7$. If, for TDD UL/DL configuration 0, both the MSB and LSB of the UL index in the PDCCH with uplink DCI format are set in subframe n , the UE shall adjust the corresponding PUSCH transmission in both subframes $n+k$ and $n+7$, with k given in Table 8-2

For TDD UL/DL configurations 1 and 6 and subframe bundling operation, the UE shall upon detection of a PDCCH with DCI format 0 in subframe n intended for the UE, and/or a PHICH transmission intended for the UE in subframe $n-l$

with l given in Table 8-2a, adjust the corresponding first PUSCH transmission in the bundle in subframe $n+k$, with k given in Table 8-2, according to the PDCCH and PHICH information.

For TDD UL/DL configuration 0 and subframe bundling operation, the UE shall upon detection of a PDCCH with DCI format 0 in subframe n intended for the UE, and/or a PHICH transmission intended for the UE in subframe $n-l$ with l given in Table 8-2a, adjust the corresponding first PUSCH transmission in the bundle in subframe $n+k$, if the MSB of the UL index in the DCI format 0 is set to 1 or if $I_{PHICH} = 0$, as defined in Section 9.1.2, with k given in Table 8-2, according to the PDCCH and PHICH information. If, for TDD UL/DL configuration 0 and subframe bundling operation, the LSB of the UL index in the PDCCH with DCI format 0 is set to 1 in subframe n or if $I_{PHICH} = 1$, as defined in Section 9.1.2, the UE shall adjust the corresponding first PUSCH transmission in the bundle in subframe $n+7$, according to the PDCCH and PHICH information.

Table 8-2 k for TDD configurations 0-6

TDD UL/DL Configuration	subframe number n									
	0	1	2	3	4	5	6	7	8	9
0	4	6				4	6			
1		6			4		6			4
2				4					4	
3	4								4	4
4									4	4
5									4	
6	7	7				7	7			5

Table 8-2a l for TDD configurations 0, 1 and 6

TDD UL/DL Configuration	subframe number n									
	0	1	2	3	4	5	6	7	8	9
0	9	6				9	6			
1		2			3		2			3
6	5	5				6	6			8

A UE is semi-statically configured via higher layer signalling to transmit PUSCH transmissions signalled via PDCCH according to one of two uplink transmission modes, denoted mode 1 - 2 as defined in Table 8-3. If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the C-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 8-3 and transmit the corresponding PUSCH. The scrambling initialization of this PUSCH corresponding to these PDCCHs and the PUSCH retransmission for the same transport block is by C-RNTI. Transmission mode 1 is the default uplink transmission mode for a UE until the UE is assigned an uplink transmission mode by higher layer signalling.

When a UE configured in transmission mode 2 receives a DCI Format 0 uplink scheduling grant, it shall assume that the PUSCH transmission is associated with transport block 1 and that transport block 2 is disabled.

Table 8-3: PDCCH and PUSCH configured by C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PUSCH corresponding to PDCCH
Mode 1	DCI format 0	Common and UE specific by C-RNTI	Single-antenna port, port 10 (see subclause 8.0.1)
Mode 2	DCI format 0	Common and UE specific by C-RNTI	Single-antenna port, port 10 (see subclause 8.0.1)
	DCI format 4	UE specific by C-RNTI	Closed-loop spatial multiplexing (see subclause 8.0.2)

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the C-RNTI and is also configured to receive random access procedures initiated by PDCCH orders, the UE shall decode the PDCCH according to the combination defined in Table 8-4.

Table 8-4: PDCCH configured as PDCCH order to initiate random access procedure

DCI format	Search Space
DCI format 1A	Common and UE specific by C-RNTI

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the SPS C-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 8-5 and transmit the corresponding PUSCH. The scrambling initialization of this PUSCH corresponding to these PDCCHs and PUSCH retransmission for the same transport block is by SPS C-RNTI. The scrambling initialization of initial transmission of this PUSCH without a corresponding PDCCH and the PUSCH retransmission for the same transport block is by SPS C-RNTI.

Table 8-5: PDCCH and PUSCH configured by SPS C-RNTI

Transmission mode	DCI format	Search Space	Transmission scheme of PUSCH corresponding to PDCCH
Mode 1	DCI format 0	Common and UE specific by C-RNTI	Single-antenna port, port 10 (see subclause 8.0.1)
Mode 2	DCI format 0	Common and UE specific by C-RNTI	Single-antenna port, port 10 (see subclause 8.0.1)

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the Temporary C-RNTI regardless of whether UE is configured or not configured to decode PDCCHs with the CRC scrambled by the C-RNTI, the UE shall decode the PDCCH according to the combination defined in Table 8-6 and transmit the corresponding PUSCH. The scrambling initialization of PUSCH corresponding to these PDCCH is by Temporary C-RNTI.

If a Temporary C-RNTI is set by higher layers, the scrambling of PUSCH corresponding to the Random Access Response Grant in Section 6.2 and the PUSCH retransmission for the same transport block is by Temporary C-RNTI. Else, the scrambling of PUSCH corresponding to the Random Access Response Grant in Section 6.2 and the PUSCH retransmission for the same transport block is by C-RNTI.

Table 8-6: PDCCH configured by Temporary C-RNTI

DCI format	Search Space
DCI format 0	Common

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the TPC-PUCCH-RNTI, the UE shall decode the PDCCH according to the combination defined in table 8-7. The notation 3/3A implies that the UE shall receive either DCI format 3 or DCI format 3A depending on the configuration.

Table 8-7: PDCCH configured by TPC-PUCCH-RNTI

DCI format	Search Space
DCI format 3/3A	Common

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the TPC-PUSCH-RNTI, the UE shall decode the PDCCH according to the combination defined in table 8.8. The notation 3/3A implies that the UE shall receive either DCI format 3 or DCI format 3A depending on the configuration.

Table 8-8: PDCCH configured by TPC-PUSCH-RNTI

DCI format	Search Space
DCI format 3/3A	Common

8.0.1 Single-antenna port scheme

For the single-antenna port transmission schemes (port 10) of the PUSCH, the UE transmission on the PUSCH is performed according to Section 5.3.2A.1 of [3].

8.0.2 Closed-loop spatial multiplexing scheme

For the closed-loop spatial multiplexing transmission scheme of the PUSCH, the UE transmission on the PUSCH is performed according to the applicable number of transmission layers as defined in Section 5.3.2A.2 of [3].

8.1 Resource Allocation for PDCCH with uplink DCI Format

Two resource allocation schemes Type 0 and Type 1 are supported for PDCCH with uplink DCI format.

If the resource allocation type bit is not present in the uplink DCI format, only resource allocation type 0 is supported.

If the resource allocation type bit is present in the uplink DCI format, the selected resource allocation type for a decoded PDCCH is indicated by a resource allocation type bit where type 0 is indicated by 0 value and type 1 is indicated otherwise. The UE shall interpret the resource allocation field depending on the resource allocation type bit in the uplink PDCCH DCI format detected.

8.1.1 Uplink Resource allocation type 0

The resource allocation information for uplink resource allocation type 0 indicates to a scheduled UE a set of contiguously allocated virtual resource block indices denoted by n_{VRB} . A resource allocation field in the scheduling grant consists of a resource indication value (RIV) corresponding to a starting resource block (RB_{START}) and a length in terms of contiguously allocated resource blocks ($L_{\text{CRBs}} \geq 1$). The resource indication value is defined by

if $(L_{\text{CRBs}} - 1) \leq \lfloor N_{\text{RB}}^{\text{UL}} / 2 \rfloor$ then

$$RIV = N_{\text{RB}}^{\text{UL}} (L_{\text{CRBs}} - 1) + RB_{\text{START}}$$

else

$$RIV = N_{\text{RB}}^{\text{UL}} (N_{\text{RB}}^{\text{UL}} - L_{\text{CRBs}} + 1) + (N_{\text{RB}}^{\text{UL}} - 1 - RB_{\text{START}})$$

8.1.2 Uplink Resource allocation type 1

The resource allocation information for uplink resource allocation type 1 indicates to a scheduled UE two sets of resource blocks with each set including one or more consecutive resource block groups of size P as given in table

7.1.6.1-1 assuming N_{RB}^{UL} as the system bandwidth. A combinatorial index r consists of $\left\lceil \log_2 \left(\binom{\left\lceil N_{RB}^{UL} / P + 1 \right\rceil}{4} \right) \right\rceil$ bits.

The bits from the resource allocation field in the scheduling grant represent r unless the number of bits in the resource allocation field in the scheduling grant is

- smaller than required to fully represent r , in which case the bits in the resource allocation field in the scheduling grant occupy the LSBs of r and the value of the remaining bits of r shall be assumed to be 0; or
- larger than required to fully represent r , in which case r occupies the LSBs of the resource allocation field in the scheduling grant.

The combinatorial index r corresponds to a starting and ending RBG index of resource block set 1, s_0 and $s_1 - 1$, and resource block set 2, s_2 and $s_3 - 1$ respectively, where r is given by equation $r = \sum_{i=0}^{M-1} \left\langle \frac{N - s_i}{M - i} \right\rangle$ defined in section 7.2.1

with $M=4$ and $N = \left\lceil N_{RB}^{UL} / P \right\rceil + 1$. Section 7.2.1 also defines ordering properties and range of values that s_i (RBG indices) map to. Only a single RBG is allocated for a set at the starting RBG index if the corresponding ending RBG index equals the starting RBG index.

8.2 UE sounding procedure

A UE shall transmit Sounding Reference Symbol (SRS) on per serving cell SRS resources based on two trigger types:

- trigger type 0: higher layer signalling
- trigger type 1: DCI formats 0/4/1A for FDD and TDD and DCI formats 2B/2C for TDD.

In case both trigger type 0 and trigger type 1 SRS transmissions would occur in the same subframe in the same serving cell, the UE shall only transmit the trigger type 1 SRS transmission.

A UE may be configured with SRS parameters for trigger type 0 and trigger type 1 on each serving cell. The following SRS parameters are serving cell specific and semi-statically configurable by higher layers for trigger type 0 and for trigger type 1.

- Transmission comb $\bar{k}_{TC}$, as defined in Section 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1
- Starting physical resource block assignment n_{RRC} , as defined in Section 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1
- *duration*: single or indefinite (until disabled), as defined in [11] for trigger type 0
- *srs-ConfigIndex* I_{SRS} for SRS periodicity T_{SRS} and SRS subframe offset T_{offset} , as defined in Table 8.2-1 and Table 8.2-2 for trigger type 0 and SRS periodicity $T_{SRS,1}$ and SRS subframe offset $T_{offset,1}$, as defined in Table 8.2-4 and Table 8.2-5 trigger type 1
- SRS bandwidth B_{SRS} , as defined in Section 5.5.3.2 of [3] for trigger type 0 and each configuration of trigger type 1
- Frequency hopping bandwidth, b_{hop} , as defined in Section 5.5.3.2 of [3] for trigger type 0
- Cyclic shift n_{SRS}^{cs} , as defined in Section 5.5.3.1 of [3] for trigger type 0 and each configuration of trigger type 1
- Number of antenna ports N_p for trigger type 0 and each configuration of trigger type 1

For trigger type 1 and DCI format 4 three sets of SRS parameters, *srs-ConfigApDCI-Format4*, are configured by higher layer signalling. The 2-bit SRS request field [4] in DCI format 4 indicates the SRS parameter set given in Table 8.1-1. For trigger type 1 and DCI format 0, a single set of SRS parameters, *srs-ConfigApDCI-Format0*, is configured by higher layer signalling. For trigger type 1 and DCI formats 1A/2B/2C, a single common set of SRS parameters, *srs-ConfigApDCI-Format1a2b2c*, is configured by higher layer signalling. The SRS request field is 1 bit [4] for DCI formats 0/1A/2B/2C, with a type 1 SRS triggered if the value of the SRS request field is set to '1'. A 1-bit SRS request field shall be included in DCI formats 0/1A for frame structure type 1 and 0/1A/2B/2C for frame structure type 2 if the UE is configured with SRS parameters for DCI formats 0/1A/2B/2C by higher-layer signalling.

Table 8.1-1: SRS request value for trigger type 1 in DCI format 4

Value of SRS request field	Description
'00'	No type 1 SRS trigger
'01'	The 1 st SRS parameter set configured by higher layers
'10'	The 2 nd SRS parameter set configured by higher layers
'11'	The 3 rd SRS parameter set configured by higher layers

The serving cell specific SRS transmission bandwidths C_{SRS} are configured by higher layers. The allowable values are given in Section 5.5.3.2 of [3].

The serving cell specific SRS transmission sub-frames are configured by higher layers. The allowable values are given in Section 5.5.3.3 of [3].

When antenna selection is enabled for a given serving cell for a UE that supports transmit antenna selection, the index $a(n_{SRS})$, of the UE antenna that transmits the SRS at time n_{SRS} is given by

$a(n_{SRS}) = n_{SRS} \bmod 2$, for both partial and full sounding bandwidth, and when frequency hopping is disabled (i.e., $b_{hop} \geq B_{SRS}$),

$$a(n_{SRS}) = \begin{cases} (n_{SRS} + \lfloor n_{SRS}/2 \rfloor + \beta \cdot \lfloor n_{SRS}/K \rfloor) \bmod 2 & \text{when } K \text{ is even} \\ n_{SRS} \bmod 2 & \text{when } K \text{ is odd} \end{cases}, \beta = \begin{cases} 1 & \text{where } K \bmod 4 = 0 \\ 0 & \text{otherwise} \end{cases}$$

when frequency hopping is enabled (i.e., $b_{hop} < B_{SRS}$),

where values B_{SRS} , b_{hop} , N_b , and n_{SRS} are given in Section 5.5.3.2 of [3], and $K = \prod_{b'=b_{hop}}^{B_{SRS}} N_{b'}$, (where $N_{b_{hop}} = 1$

regardless of the N_b value), except when a single SRS transmission is configured for the UE. If a UE is configured with more than one serving cell, the UE is not expected to transmit SRS on different antenna ports simultaneously.

A UE may be configured to transmit SRS on N_p antenna ports of a serving cell where N_p may be configured by higher layer signalling. For PUSCH transmission mode 1 $N_p \in \{0,1,2,4\}$ and for PUSCH transmission mode 2 $N_p \in \{0,1,2\}$ with two antenna ports configured for PUSCH and $N_p \in \{0,1,4\}$ with 4 antenna ports configured for PUSCH. A UE configured for SRS transmission on multiple antenna ports of a serving cell shall transmit SRS for all the configured transmit antenna ports within one SC-FDMA symbol of the same subframe of the serving cell. The SRS transmission bandwidth and starting physical resource block assignment are the same for all the configured antenna ports of a given serving cell.

A UE shall not transmit SRS whenever SRS and PUSCH transmissions happen to coincide in the same symbol.

For TDD, when one SC-FDMA symbol exists in UpPTS of a given serving cell, it can be used for SRS transmission. When two SC-FDMA symbols exist in UpPTS of a given serving cell, both can be used for SRS transmission and both can be assigned to the same UE.

A UE shall not transmit type 0 triggered SRS whenever type 0 triggered SRS and PUCCH format 2/2a/2b transmissions happen to coincide in the same subframe. A UE shall not transmit type 1 triggered SRS whenever type 1 triggered SRS and PUCCH format 2a/2b or format 2 with HARQ-ACK transmissions happen to coincide in the same subframe. A UE shall not transmit PUCCH format 2 without HARQ-ACK whenever type 1 triggered SRS and PUCCH format 2 without HARQ-ACK transmissions happen to coincide in the same subframe.

A UE shall not transmit SRS whenever SRS transmission and PUCCH transmission carrying HARQ-ACK and/or positive SR happen to coincide in the same subframe if the parameter *ackNackSRS-SimultaneousTransmission* is *FALSE*. A UE shall transmit SRS whenever SRS transmission and PUCCH transmission carrying HARQ-ACK and/or positive SR using shortened format as defined in Sections 5.4.1 and 5.4.2A of [3] happen to coincide in the same subframe if the parameter *ackNackSRS-SimultaneousTransmission* is *TRUE*.

A UE shall not transmit SRS whenever SRS transmission on any serving cells and PUCCH transmission carrying HARQ-ACK and/or positive SR using normal PUCCH format as defined in Sections 5.4.1 and 5.4.2A of [3] happen to coincide in the same subframe.

In UpPTS, whenever SRS transmission instance overlaps with the PRACH region for preamble format 4 or exceeds the range of uplink system bandwidth configured in the serving cell, the UE shall not transmit SRS.

The parameter *ackNackSRS-SimultaneousTransmission* provided by higher layers determines if a UE is configured to support the transmission of HARQ-ACK on PUCCH and SRS in one subframe. If it is configured to support the transmission of HARQ-ACK on PUCCH and SRS in one subframe, then in the cell specific SRS subframes of the primary cell UE shall transmit HARQ-ACK and SR using the shortened PUCCH format as defined in Sections 5.4.1 and 5.4.2A of [3], where the HARQ-ACK or the SR symbol corresponding to the SRS location is punctured. This shortened PUCCH format shall be used in a cell specific SRS subframe of the primary cell even if the UE does not transmit SRS in that subframe. The cell specific SRS subframes are defined in Section 5.5.3.3 of [3]. Otherwise, the UE shall use the normal PUCCH format 1/1a/1b as defined in Section 5.4.1 of [3] or normal PUCCH format 3 as defined in Section 5.4.2A of [3] for the transmission of HARQ-ACK and SR.

Trigger type 0 SRS configuration of a UE in a serving cell for SRS periodicity, T_{SRS} , and SRS subframe offset, T_{offset} , is defined in Table 8.2-1 and Table 8.2-2, for FDD and TDD, respectively. The periodicity T_{SRS} of the SRS transmission is serving cell specific and is selected from the set $\{2, 5, 10, 20, 40, 80, 160, 320\}$ ms or subframes. For the SRS periodicity T_{SRS} of 2 ms in TDD, two SRS resources are configured in a half frame containing UL subframe(s) of a given serving cell.

Type 0 triggered SRS transmission instances in a given serving cell for TDD with $T_{\text{SRS}} > 2$ and for FDD are the subframes satisfying $(10 \cdot n_f + k_{\text{SRS}} - T_{\text{offset}}) \bmod T_{\text{SRS}} = 0$, where for FDD $k_{\text{SRS}} = \{0, 1, \dots, 9\}$ is the subframe index within the frame, for TDD k_{SRS} is defined in Table 8.2-3. The SRS transmission instances for TDD with $T_{\text{SRS}} = 2$ are the subframes satisfying $(k_{\text{SRS}} - T_{\text{offset}}) \bmod 5 = 0$.

Trigger type 1 SRS configuration of a UE in a serving cell for SRS periodicity, $T_{\text{SRS},1}$, and SRS subframe offset, $T_{\text{offset},1}$, is defined in Table 8.2-4 and Table 8.2-5, for FDD and TDD, respectively. The periodicity $T_{\text{SRS},1}$ of the SRS transmission is serving cell specific and is selected from the set $\{2, 5, 10\}$ ms or subframes. For the SRS periodicity $T_{\text{SRS},1}$ of 2 ms in TDD, two SRS resources are configured in a half frame containing UL subframe(s) of a given serving cell.

A UE configured for type 1 triggered SRS transmission in serving cell c and not configured with a carrier indicator field shall transmit SRS on serving cell c upon detection of a positive SRS request in PDCCH scheduling PUSCH/PDSCH on serving cell c .

A UE configured for type 1 triggered SRS transmission in serving cell c and configured with a carrier indicator field shall transmit SRS on serving cell c upon detection of a positive SRS request in PDCCH scheduling PUSCH/PDSCH with the value of carrier indicator field corresponding to serving cell c .

A UE configured for type 1 triggered SRS transmission on serving cell c upon detection of a positive SRS request in subframe n of serving cell c shall commence SRS transmission in the first subframe satisfying $n + k, k \geq 4$ and

$$(10 \cdot n_f + k_{\text{SRS}} - T_{\text{offset},1}) \bmod T_{\text{SRS},1} = 0 \quad \text{for TDD with } T_{\text{SRS},1} > 2 \quad \text{and for FDD,}$$

$$(k_{\text{SRS}} - T_{\text{offset},1}) \bmod 5 = 0 \quad \text{for TDD with } T_{\text{SRS},1} = 2$$

where for FDD $k_{\text{SRS}} = \{0,1,\dots,9\}$ is the subframe index within the frame n_f , for TDD k_{SRS} is defined in Table 8.2-3.

A UE configured for type 1 triggered SRS transmission is not expected to receive type 1 SRS triggering events associated with different values of trigger type 1 SRS transmission parameters, as configured by higher layer signalling, for the same subframe and the same serving cell.

A UE shall not transmit SRS whenever SRS and a PUSCH transmission corresponding to a Random Access Response Grant or a retransmission of the same transport block as part of the contention based random access procedure coincide in the same subframe.

Table 8.2-1: UE Specific SRS Periodicity T_{SRS} and Subframe Offset Configuration T_{offset} for trigger type 0, FDD

SRS Configuration Index l_{SRS}	SRS Periodicity T_{SRS} (ms)	SRS Subframe Offset T_{offset}
0 – 1	2	l_{SRS}
2 – 6	5	$l_{\text{SRS}} - 2$
7 – 16	10	$l_{\text{SRS}} - 7$
17 – 36	20	$l_{\text{SRS}} - 17$
37 – 76	40	$l_{\text{SRS}} - 37$
77 – 156	80	$l_{\text{SRS}} - 77$
157 – 316	160	$l_{\text{SRS}} - 157$
317 – 636	320	$l_{\text{SRS}} - 317$
637 – 1023	reserved	reserved

Table 8.2-2: UE Specific SRS Periodicity T_{SRS} and Subframe Offset Configuration T_{offset} for trigger type 0, TDD

SRS Configuration Index l_{SRS}	SRS Periodicity T_{SRS} (ms)	SRS Subframe Offset T_{offset}
0	2	0, 1
1	2	0, 2
2	2	1, 2
3	2	0, 3
4	2	1, 3
5	2	0, 4
6	2	1, 4
7	2	2, 3
8	2	2, 4
9	2	3, 4
10 – 14	5	$l_{\text{SRS}} - 10$
15 – 24	10	$l_{\text{SRS}} - 15$
25 – 44	20	$l_{\text{SRS}} - 25$
45 – 84	40	$l_{\text{SRS}} - 45$
85 – 164	80	$l_{\text{SRS}} - 85$
165 – 324	160	$l_{\text{SRS}} - 165$
325 – 644	320	$l_{\text{SRS}} - 325$
645 – 1023	reserved	reserved

Table 8.2-3: k_{SRS} for TDD

	subframe index n											
	0	1		2	3	4	5	6		7	8	9
		1st symbol of UpPTS	2nd symbol of UpPTS					1st symbol of UpPTS	2nd symbol of UpPTS			
k_{SRS} in case UpPTS length of 2 symbols		0	1	2	3	4		5	6	7	8	9
k_{SRS} in case UpPTS length of 1 symbol		1		2	3	4		6		7	8	9

Table 8.2-4: UE Specific SRS Periodicity $T_{\text{SRS},1}$ and Subframe Offset Configuration $T_{\text{offset},1}$ for trigger type 1, FDD

SRS Configuration Index I_{SRS}	SRS Periodicity $T_{\text{SRS},1}$ (ms)	SRS Subframe Offset $T_{\text{offset},1}$
0 – 1	2	I_{SRS}
2 – 6	5	$I_{\text{SRS}} - 2$
7 – 16	10	$I_{\text{SRS}} - 7$
17 – 31	reserved	reserved

Table 8.2-5: UE Specific SRS Periodicity $T_{\text{SRS},1}$ and Subframe Offset Configuration $T_{\text{offset},1}$ for trigger type 1, TDD

SRS Configuration Index I_{SRS}	SRS Periodicity $T_{\text{SRS},1}$ (ms)	SRS Subframe Offset $T_{\text{offset},1}$
0	2	0, 1
1	2	0, 2
2	2	1, 2
3	2	0, 3
4	2	1, 3
5	2	0, 4
6	2	1, 4
7	2	2, 3
8	2	2, 4
9	2	3, 4
10 – 14	5	$I_{\text{SRS}} - 10$
15 – 24	10	$I_{\text{SRS}} - 15$
25 – 31	reserved	reserved

8.3 UE HARQ-ACK procedure

For Frame Structure type 1, an HARQ-ACK received on the PHICH assigned to a UE in subframe i is associated with the PUSCH transmission in subframe $i-4$.

For Frame Structure type 2 UL/DL configuration 1-6, an HARQ-ACK received on the PHICH assigned to a UE in subframe i is associated with the PUSCH transmission in the subframe $i-k$ as indicated by the following table 8.3-1.

For Frame Structure type 2 UL/DL configuration 0, an HARQ-ACK received on the PHICH in the resource corresponding to $I_{\text{PHICH}} = 0$, as defined in Section 9.1.2, assigned to a UE in subframe i is associated with the PUSCH transmission in the subframe $i-k$ as indicated by the following table 8.3-1. For Frame Structure type 2 UL/DL configuration 0, an HARQ-ACK received on the PHICH in the resource corresponding to $I_{\text{PHICH}} = 1$, as defined in

Section 9.1.2, assigned to a UE in subframe i is associated with the PUSCH transmission in the subframe $i-6$.

Table 8.3-1 k for TDD configurations 0-6

TDD UL/DL Configuration	subframe number i									
	0	1	2	3	4	5	6	7	8	9
0	7	4				7	4			
1		4			6		4			6
2				6					6	
3	6								6	6
4									6	6
5									6	
6	6	4				7	4			6

The physical layer in the UE shall deliver indications to the higher layers as follows:

For downlink subframe i , if a transport block was transmitted in the associated PUSCH subframe then:

- if ACK is decoded on the PHICH corresponding to that transport block in subframe i , or if that transport block is disabled by PDCCH received in downlink subframe i , ACK for that transport block shall be delivered to the higher layers;
- else NACK for that transport block shall be delivered to the higher layers.

8.4 UE PUSCH Hopping procedure

The UE shall perform PUSCH frequency hopping if the single bit frequency hopping (FH) field in a corresponding PDCCH with DCI format 0 is set to 1 and the uplink resource block assignment is type 0 otherwise no PUSCH frequency hopping is performed.

A UE performing PUSCH frequency hopping shall determine its PUSCH resource allocation (RA) for the first slot of a subframe (SI) including the lowest index PRB ($n_{PRB}^{SI}(n)$) in subframe n from the resource allocation field in the latest PDCCH with DCI format 0 for the same transport block. If there is no PDCCH for the same transport block, the UE shall determine its hopping type based on

- the hopping information in the most recent semi-persistent scheduling assignment PDCCH, 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.

The resource allocation field in DCI format 0 excludes either 1 or 2 bits used for hopping information as indicated by Table 8.4-1 below where the number of PUSCH resource blocks is defined as

$$N_{RB}^{PUSCH} = \begin{cases} N_{RB}^{UL} - \tilde{N}_{RB}^{HO} - (N_{RB}^{UL} \bmod 2) & \text{Type 1 PUSCH hopping} \\ N_{RB}^{UL} & \text{Type 2 } N_{sb} = 1 \text{ PUSCH hopping} \\ N_{RB}^{UL} - \tilde{N}_{RB}^{HO} & \text{Type 2 } N_{sb} > 1 \text{ PUSCH hopping} \end{cases}$$

For type 1 and type 2 PUSCH hopping, $\tilde{N}_{RB}^{HO} = N_{RB}^{HO} + 1$ if N_{RB}^{HO} is an odd number where N_{RB}^{HO} defined in [3]. $\tilde{N}_{RB}^{HO} = N_{RB}^{HO}$ in other cases. The size of the resource allocation field in DCI format 0 after excluding either 1 or 2 bits shall be $y = \lceil \log_2 (N_{RB}^{UL} (N_{RB}^{UL} + 1) / 2) \rceil - N_{UL_hop}$, where $N_{UL_hop} = 1$ or 2 bits. The number of contiguous RBs that can be assigned to a type-1 hopping user is limited to $\lfloor 2^y / N_{RB}^{UL} \rfloor$. The number of contiguous RBs that can be assigned to a type-2 hopping user is limited to $\min \left(\lfloor 2^y / N_{RB}^{UL} \rfloor, \lfloor N_{RB}^{PUSCH} / N_{sb} \rfloor \right)$, where the number of sub-bands N_{sb} is given by higher layers.

A UE performing PUSCH frequency hopping shall use one of two possible PUSCH frequency hopping types based on the hopping information. PUSCH hopping type 1 is described in section 8.4.1 and type 2 is described in section 8.4.2.

Table 8.4-1: Number of Hopping Bits N_{UL_hop} vs. System Bandwidth

System BW N_{RB}^{UL}	#Hopping bits for 2nd slot RA (N_{UL_hop})
6-49	1
50-110	2

The parameter *Hopping-mode* provided by higher layers determines if PUSCH frequency hopping is “inter-subframe” or “intra and inter-subframe”.

8.4.1 Type 1 PUSCH Hopping

For PUSCH hopping type 1 the hopping bit or bits indicated in Table 8.4-1 determine $\tilde{n}_{PRB}(i)$ as defined in Table 8.4-2.

The lowest index PRB ($n_{PRB}^{S1}(i)$) of the 1st slot RA in subframe i is defined as $n_{PRB}^{S1}(i) = \tilde{n}_{PRB}^{S1}(i) + \tilde{N}_{RB}^{HO} / 2$, where $n_{PRB}^{S1}(i) = RB_{START}$, and RB_{START} is obtained from the uplink scheduling grant as in Section 8.4 and Section 8.1.

The lowest index PRB ($n_{PRB}(i)$) of the 2nd slot RA in subframe i is defined as $n_{PRB}(i) = \tilde{n}_{PRB}(i) + \tilde{N}_{RB}^{HO} / 2$.

The set of physical resource blocks to be used for PUSCH transmission are L_{CRBs} contiguously allocated resource blocks from PRB index $n_{PRB}^{S1}(i)$ for the 1st slot, and from PRB index $n_{PRB}(i)$ for the 2nd slot, respectively, where L_{CRBs} is obtained from the uplink scheduling grant as in Section 8.4 and Section 8.1.

If the *Hopping-mode* is "inter-subframe", the 1st slot RA is applied to even CURRENT_TX_NB, and the 2nd slot RA is applied to odd CURRENT_TX_NB, where CURRENT_TX_NB is defined in [8].

8.4.2 Type 2 PUSCH Hopping

In PUSCH hopping type 2 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 [3] section 5.3.4. If the system frame number is not acquired by the UE yet, the UE shall not transmit PUSCH with type-2 hopping and $N_{sb} > 1$ for TDD, where N_{sb} is defined in [3].

Table 8.4-2: PDCCH DCI Format 0 Hopping Bit Definition

System BW N_{RB}^{UL}	Number of Hopping bits	Information in hopping bits	$\tilde{n}_{PRB}(i)$
6 – 49	1	0	$\left(\left\lfloor N_{RB}^{PUSCH} / 2 \right\rfloor + \tilde{n}_{PRB}^{S1}(i) \right) \bmod N_{RB}^{PUSCH}$,
		1	Type 2 PUSCH Hopping
50 – 110	2	00	$\left(\left\lfloor N_{RB}^{PUSCH} / 4 \right\rfloor + \tilde{n}_{PRB}^{S1}(i) \right) \bmod N_{RB}^{PUSCH}$
		01	$\left(- \left\lfloor N_{RB}^{PUSCH} / 4 \right\rfloor + \tilde{n}_{PRB}^{S1}(i) \right) \bmod N_{RB}^{PUSCH}$
		10	$\left(\left\lfloor N_{RB}^{PUSCH} / 2 \right\rfloor + \tilde{n}_{PRB}^{S1}(i) \right) \bmod N_{RB}^{PUSCH}$
		11	Type 2 PUSCH Hopping

8.5 UE Reference Symbol procedure

If UL sequence-group hopping or sequence hopping is configured in a serving cell, it applies to all reference symbols (SRS, PUSCH and PUCCH RS). If disabling of the sequence-group hopping and sequence hopping is configured for the UE in the serving cell through the higher-layer parameter *Disable-sequence-group-hopping*, the sequence-group hopping and sequence hopping for PUSCH RS are disabled.

8.6 Modulation order, redundancy version and transport block size determination

To determine the modulation order, redundancy version and transport block size for the physical uplink shared channel, the UE shall first

- read the “modulation and coding scheme and redundancy version” field (I_{MCS}), and
- check the “CSI request” bit field, and
- compute the total number of allocated PRBs (N_{PRB}) based on the procedure defined in Section 8.1, and
- compute the number of coded symbols for control information.

8.6.1 Modulation order and redundancy version determination

For $0 \leq I_{MCS} \leq 28$, the modulation order (Q_m) is determined as follows:

- If the UE is capable of supporting 64QAM in PUSCH and has not been configured by higher layers to transmit only QPSK and 16QAM, the modulation order is given by Q_m' in Table 8.6.1-1.
- If the UE is not capable of supporting 64QAM in PUSCH or has been configured by higher layers to transmit only QPSK and 16QAM, Q_m' is first read from Table 8.6.1-1. The modulation order is set to $Q_m = \min(4, Q_m')$.
- If the parameter *ttiBundling* provided by higher layers is set to *TRUE*, then the resource allocation size is restricted to $N_{PRB} \leq 3$ and the modulation order is set to $Q_m = 2$.

For $29 \leq I_{MCS} \leq 31$ the modulation order (Q_m) is determined as follows:

- if DCI format 0 is used and $I_{MCS} = 29$ or, if DCI format 4 is used and only 1 TB is enabled and $I_{MCS} = 29$ for the enabled TB and the signalled number of transmission layers is 1, and if

- the “CSI request” bit field is 1 bit and the bit is set to trigger an aperiodic report and, $N_{\text{PRB}} \leq 4$ or,
- the “CSI request” bit field is 2 bits and is triggering an aperiodic CSI report for one serving cell according to Table 7.2.1-1A, and, $N_{\text{PRB}} \leq 4$ or,
- the “CSI request” bit field is 2 bits and is triggering an aperiodic CSI report for more than one serving cell according to Table 7.2.1-1A and, $N_{\text{PRB}} \leq 20$,

then the modulation order is set to $Q_m = 2$.

- Otherwise, the modulation order shall be determined from the DCI transported in the latest PDCCH with DCI format 0/4 for the same transport block using $0 \leq I_{\text{MCS}} \leq 28$. If there is no PDCCH with DCI format 0/4 for the same transport block using $0 \leq I_{\text{MCS}} \leq 28$, the modulation order shall be determined from
 - the most recent semi-persistent scheduling assignment PDCCH, 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.

The UE shall use I_{MCS} and Table 8.6.1-1 to determine the redundancy version (rv_{idx}) to use in the physical uplink shared channel.

Table 8.6.1-1: Modulation, TBS index and redundancy version table for PUSCH

MCS Index I_{MCS}	Modulation Order Q_m	TBS Index I_{TBS}	Redundancy Version r_{Vidx}
0	2	0	0
1	2	1	0
2	2	2	0
3	2	3	0
4	2	4	0
5	2	5	0
6	2	6	0
7	2	7	0
8	2	8	0
9	2	9	0
10	2	10	0
11	4	10	0
12	4	11	0
13	4	12	0
14	4	13	0
15	4	14	0
16	4	15	0
17	4	16	0
18	4	17	0
19	4	18	0
20	4	19	0
21	6	19	0
22	6	20	0
23	6	21	0
24	6	22	0
25	6	23	0
26	6	24	0
27	6	25	0
28	6	26	0
29	reserved		1
30			2
31			3

8.6.2 Transport block size determination

For $0 \leq I_{\text{MCS}} \leq 28$, the UE shall first determine the TBS index (I_{TBS}) using I_{MCS} and Table 8.6.1-1 except if the transport block is disabled in DCI format 4 as specified below. For a transport block that is not mapped to two-layer spatial multiplexing, the TBS is determined by the procedure in Section 7.1.7.2.1. For a transport block that is mapped to two-layer spatial multiplexing, the TBS is determined by the procedure in Section 7.1.7.2.2.

For $29 \leq I_{\text{MCS}} \leq 31$,

- if DCI format 0 is used and $I_{\text{MCS}} = 29$ or, if DCI format 4 is used and only 1 TB is enabled and $I_{\text{MCS}} = 29$ for the enabled TB and the number of transmission layers is 1, and if
 - the “CSI request” bit field is 1 bit and is set to trigger an aperiodic CSI report and $N_{\text{PRB}} \leq 4$, or
 - the “CSI request” bit field is 2 bits and is triggering an aperiodic CSI report for one serving cell according to Table 7.2.1-1A, and, $N_{\text{PRB}} \leq 4$ or,
 - the “CSI request” bit field is 2 bits and is triggering aperiodic CSI report for more than one serving cell according to Table 7.2.1-1A and, $N_{\text{PRB}} \leq 20$,

then there is no transport block for the UL-SCH and only the control information feedback for the current PUSCH reporting mode is transmitted by the UE.

- Otherwise, the transport block size shall be determined from the initial PDCCH for the same transport block using $0 \leq I_{\text{MCS}} \leq 28$. If there is no initial PDCCH with an uplink DCI format for the same transport block using $0 \leq I_{\text{MCS}} \leq 28$, the transport block size shall be determined from
 - the most recent semi-persistent scheduling assignment PDCCH, 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.

In DCI format 4 a transport block is disabled if either the combination of $I_{\text{MCS}} = 0$ and $N_{\text{PRB}} > 1$ or the combination of $I_{\text{MCS}} = 28$ and $N_{\text{PRB}} = 1$ is signalled, otherwise the transport block is enabled.

8.6.3 Control information MCS offset determination

Offset values are defined for single codeword PUSCH transmission and multiple codeword PUSCH transmission.

Single codeword PUSCH transmission offsets $\beta_{\text{offset}}^{\text{HARQ-ACK}}$, $\beta_{\text{offset}}^{\text{RI}}$ and $\beta_{\text{offset}}^{\text{CQI}}$ shall be configured to values according to Table 8.6.3-1,2,3 with the higher layer signalled indexes $I_{\text{offset}}^{\text{HARQ-ACK}}$, $I_{\text{offset}}^{\text{RI}}$, and $I_{\text{offset}}^{\text{CQI}}$, respectively.

Multiple codeword PUSCH transmission offsets $\beta_{\text{offset}}^{\text{HARQ-ACK}}$, $\beta_{\text{offset}}^{\text{RI}}$ and $\beta_{\text{offset}}^{\text{CQI}}$ shall be configured to values according to Table 8.6.3-1,2,3 with the higher layer signalled indexes $I_{\text{offset,MC}}^{\text{HARQ-ACK}}$, $I_{\text{offset,MC}}^{\text{RI}}$ and $I_{\text{offset,MC}}^{\text{CQI}}$, respectively.

Table 8.6.3-1: Mapping of HARQ-ACK offset values and the index signalled by higher layers

$I_{\text{offset}}^{\text{HARQ-ACK}}$ or $I_{\text{offset,MC}}^{\text{HARQ-ACK}}$	$\beta_{\text{offset}}^{\text{HARQ-ACK}}$
0	2.000
1	2.500
2	3.125
3	4.000
4	5.000
5	6.250
6	8.000
7	10.000
8	12.625
9	15.875
10	20.000
11	31.000
12	50.000
13	80.000
14	126.000

15	1.0
----	-----

Table 8.6.3-2: Mapping of RI offset values and the index signalled by higher layers

I_{offset}^{RI} or $I_{offset,MC}^{RI}$	β_{offset}^{RI}
0	1.250
1	1.625
2	2.000
3	2.500
4	3.125
5	4.000
6	5.000
7	6.250
8	8.000
9	10.000
10	12.625
11	15.875
12	20.000
13	reserved
14	reserved
15	reserved

Table 8.6.3-3: Mapping of CQI offset values and the index signalled by higher layers

I_{offset}^{CQI} or $I_{offset,MC}^{CQI}$	β_{offset}^{CQI}
0	reserved
1	reserved
2	1.125
3	1.250
4	1.375
5	1.625
6	1.750
7	2.000
8	2.250
9	2.500
10	2.875

11	3.125
12	3.500
13	4.000
14	5.000
15	6.250

8.7 UE Transmit Antenna Selection

UE transmit antenna selection is configured by higher layers via parameters *ue-TransmitAntennaSelection* and *ue-TransmitAntennaSelection-r10*.

A UE configured with transmit antenna selection for a serving cell is not expected to

- be configured with more than one antenna port for any uplink physical channel or signal for any configured serving cell, or
- be configured with trigger type 1 SRS transmission on any configured serving cell, or
- be configured with simultaneous PUCCH and PUSCH transmission, or
- be configured with demodulation reference signal for PUSCH with OCC for any configured serving cell (see [3], subclause 5.5.2.1.1), or
- receive DCI Format 0 indicating uplink resource allocation type 1 for any serving cell.

If UE transmit antenna selection is disabled or not supported by the UE, the UE shall transmit from UE port 0.

If closed-loop UE transmit antenna selection is enabled by higher layers the UE shall perform transmit antenna selection in response to the most recent command received via DCI Format 0 in section 5.3.3.2 of [4]. If a UE is configured with more than one serving cell, the UE may assume the same transmit antenna port value is indicated in each DCI format 0 PDCCH grant in a given subframe.

If open-loop UE transmit antenna selection is enabled by higher layers, the transmit antenna to be selected by the UE is not specified.

9 Physical downlink control channel procedures

9.1 UE procedure for determining physical downlink control channel assignment

9.1.1 PDCCH Assignment Procedure

The control region of each serving cell consists of a set of CCEs, numbered from 0 to $N_{\text{CCE},k} - 1$ according to Section 6.8.1 in [3], where $N_{\text{CCE},k}$ is the total number of CCEs in the control region of subframe k . The UE shall monitor a set of PDCCH candidates on one or more activated serving cells as configured by higher layer signalling for control information in every non-DRX subframe, where monitoring implies attempting to decode each of the PDCCHs in the set according to all the monitored DCI formats.

The set of PDCCH candidates to monitor are defined in terms of search spaces, where a search space $S_k^{(L)}$ at aggregation level $L \in \{1, 2, 4, 8\}$ is defined by a set of PDCCH candidates. For each serving cell on which PDCCH is monitored, the CCEs corresponding to PDCCH candidate m of the search space $S_k^{(L)}$ are given by

$$L \left\{ (Y_k + m') \bmod \left\lfloor N_{\text{CCE},k} / L \right\rfloor \right\} + i$$

where Y_k is defined below, $i = 0, \dots, L-1$. For the common search space $m' = m$. For the UE specific search space, for the serving cell on which PDCCH is monitored, if the monitoring UE is configured with carrier indicator field then $m' = m + M^{(L)} \cdot n_{\text{CI}}$ where n_{CI} is the carrier indicator field value, else if the monitoring UE is not configured with carrier indicator field then $m' = m$, where $m = 0, \dots, M^{(L)} - 1$. $M^{(L)}$ is the number of PDCCH candidates to monitor in the given search space.

Note that the carrier indicator field value is the same as *ServCellIndex* given in [11].

The UE shall monitor one common search space at each of the aggregation levels 4 and 8 on the primary cell.

A UE not configured with a carrier indicator field shall monitor one UE-specific search space at each of the aggregation levels 1, 2, 4, 8 on each activated serving cell. A UE configured with a carrier indicator field shall monitor one or more UE-specific search spaces at each of the aggregation levels 1, 2, 4, 8 on one or more activated serving cells as configured by higher layer signalling.

The common and UE-specific search spaces on the primary cell may overlap.

A UE configured with the carrier indicator field associated with monitoring PDCCH on serving cell c shall monitor PDCCH configured with carrier indicator field and with CRC scrambled by C-RNTI in the UE specific search space of serving cell c .

A UE configured with the carrier indicator field associated with monitoring PDCCH on the primary cell shall monitor PDCCH configured with carrier indicator field and with CRC scrambled by SPS C-RNTI in the UE specific search space of the primary cell.

The UE shall monitor the common search space for PDCCH without carrier indicator field.

For the serving cell on which PDCCH is monitored, if the UE is not configured with a carrier indicator field, it shall monitor the UE specific search space for PDCCH without carrier indicator field, if the UE is configured with a carrier indicator field it shall monitor the UE specific search space for PDCCH with carrier indicator field.

A UE is not expected to monitor the PDCCH of a secondary cell if it is configured to monitor PDCCH with carrier indicator field corresponding to that secondary cell in another serving cell. For the serving cell on which PDCCH is monitored, the UE shall monitor PDCCH candidates at least for the same serving cell.

A UE configured to monitor PDCCH candidates with CRC scrambled by C-RNTI or SPS C-RNTI with a common payload size and with the same first CCE index n_{CCE} (as described in section 10.1) but with different sets of DCI information fields as defined in [4] in the

- common search space
- UE specific search space

on the primary cell shall assume that only the PDCCH in the common search space is transmitted by the primary cell.

A UE configured to monitor PDCCH candidates in a given serving cell with a given DCI format size with CIF, and CRC scrambled by C-RNTI, where the PDCCH candidates may have one or more possible values of CIF for the given DCI format size, shall assume that a PDCCH candidate with the given DCI format size may be transmitted in the given serving cell in any UE specific search space corresponding to any of the possible values of CIF for the given DCI format size.

The aggregation levels defining the search spaces are listed in Table 9.1.1-1. The DCI formats that the UE shall monitor depend on the configured transmission mode per each serving cell as defined in Section 7.1.

Table 9.1.1-1: PDCCH candidates monitored by a UE.

Type	Search space $S_k^{(L)}$		Number of PDCCH candidates $M^{(L)}$
	Aggregation level L	Size [in CCEs]	
UE-specific	1	6	6
	2	12	6
	4	8	2
	8	16	2
Common	4	16	4
	8	16	2

For the common search spaces, Y_k is set to 0 for the two aggregation levels $L = 4$ and $L = 8$.

For the UE-specific search space $S_k^{(L)}$ at aggregation level L , the variable Y_k is defined by

$$Y_k = (A \cdot Y_{k-1}) \bmod D$$

where $Y_{-1} = n_{\text{RNTI}} \neq 0$, $A = 39827$, $D = 65537$ and $k = \lfloor n_s/2 \rfloor$, n_s is the slot number within a radio frame. The RNTI value used for n_{RNTI} is defined in section 7.1 in downlink and section 8 in uplink.

9.1.2 PHICH Assignment Procedure

For PUSCH transmissions scheduled from serving cell c in subframe n , a UE shall determine the corresponding PHICH resource of serving cell c in subframe $n + k_{\text{PHICH}}$, where k_{PHICH} is always 4 for FDD and is given in table 9.1.2-1 for TDD. For subframe bundling operation, the corresponding PHICH resource is associated with the last subframe in the bundle.

Table 9.1.2-1: k_{PHICH} for TDD

TDD UL/DL Configuration	subframe index n									
	0	1	2	3	4	5	6	7	8	9
0			4	7	6			4	7	6
1			4	6				4	6	
2			6					6		
3			6	6	6					
4			6	6						
5			6							
6			4	6	6			4	7	

The PHICH resource is identified by the index pair $(n_{\text{PHICH}}^{\text{group}}, n_{\text{PHICH}}^{\text{seq}})$ 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 as defined by:

$$n_{\text{PHICH}}^{\text{group}} = (I_{\text{PRB_RA}} + n_{\text{DMRS}}) \bmod N_{\text{PHICH}}^{\text{group}} + I_{\text{PHICH}} N_{\text{PHICH}}^{\text{group}}$$

$$n_{\text{PHICH}}^{\text{seq}} = (\lfloor I_{\text{PRB_RA}} / N_{\text{PHICH}}^{\text{group}} \rfloor + n_{\text{DMRS}}) \bmod 2N_{\text{SF}}^{\text{PHICH}}$$

where

- n_{DMRS} is mapped from the cyclic shift for DMRS field (according to Table 9.1.2-2) in the most recent PDCCH with uplink DCI format [4] for the transport block(s) associated with the corresponding PUSCH transmission. n_{DMRS} shall be set to zero, if there is no PDCCH with uplink DCI format for the same transport block, 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.
- N_{SF}^{PHICH} is the spreading factor size used for PHICH modulation as described in section 6.9.1 in [3].
- $I_{PRB_RA} = \begin{cases} I_{PRB_RA}^{lowest_index} & \text{for the first TB of a PUSCH with associated PDCCH or for the case of no associated PDCCH when the number of negatively acknowledged TBs is not equal to the number of TBs indicated in the most recent PDCCH associated with the corresponding PUSCH} \\ I_{PRB_RA}^{lowest_index} + 1 & \text{for a second TB of a PUSCH with associated PDCCH} \end{cases}$

where $I_{PRB_RA}^{lowest_index}$ is the lowest PRB index in the first slot of the corresponding PUSCH transmission
- N_{PHICH}^{group} is the number of PHICH groups configured by higher layers as described in section 6.9 of [3],
- $I_{PHICH} = \begin{cases} 1 & \text{for TDD UL/DL configuration 0 with PUSCH transmission in subframe } n = 4 \text{ or } 9 \\ 0 & \text{otherwise} \end{cases}$

Table 9.1.2-2: Mapping between n_{DMRS} and the cyclic shift for DMRS field in PDCCH with uplink DCI format in [4]

Cyclic Shift for DMRS Field in PDCCH with uplink DCI format in [4]	n_{DMRS}
000	0
001	1
010	2
011	3
100	4
101	5
110	6
111	7

9.1.3 Control Format Indicator assignment procedure

PHICH duration is signalled by higher layers according to Table 6.9.3-1 in [3]. The duration signalled puts a lower limit on the size of the control region determined from the control format indicator (CFI). When $N_{RB}^{DL} > 10$, if extended PHICH duration is indicated by higher layers then the UE shall assume that CFI is equal to PHICH duration.

9.2 PDCCH validation for semi-persistent scheduling

A UE shall validate a Semi-Persistent Scheduling assignment PDCCH only if all the following conditions are met:

- the CRC parity bits obtained for the PDCCH payload are scrambled with the Semi-Persistent Scheduling C-RNTI
- the new data indicator field is set to '0'. In case of DCI formats 2, 2A, 2B and 2C, the new data indicator field refers to the one for the enabled transport block.

Validation is achieved if all the fields for the respective used DCI format are set according to Table 9.2-1 or Table 9.2-1A.

If validation is achieved, the UE shall consider the received DCI information accordingly as a valid semi-persistent activation or release.

If validation is not achieved, the received DCI format shall be considered by the UE as having been received with a non-matching CRC.

Table 9.2-1: Special fields for Semi-Persistent Scheduling Activation PDCCH Validation

	DCI format 0	DCI format 1/1A	DCI format 2/2A/2B/2C
TPC command for scheduled PUSCH	set to '00'	N/A	N/A
Cyclic shift DM RS	set to '000'	N/A	N/A
Modulation and coding scheme and redundancy version	MSB is set to '0'	N/A	N/A
HARQ process number	N/A	FDD: set to '000' TDD: set to '0000'	FDD: set to '000' TDD: set to '0000'
Modulation and coding scheme	N/A	MSB is set to '0'	For the enabled transport block: MSB is set to '0'
Redundancy version	N/A	set to '00'	For the enabled transport block: set to '00'

Table 9.2-1A: Special fields for Semi-Persistent Scheduling Release PDCCH Validation

	DCI format 0	DCI format 1A
TPC command for scheduled PUSCH	set to '00'	N/A
Cyclic shift DM RS	set to '000'	N/A
Modulation and coding scheme and redundancy version	set to '1111'	N/A
Resource block assignment and hopping resource allocation	Set to all '1's	N/A
HARQ process number	N/A	FDD: set to '000' TDD: set to '0000'
Modulation and coding scheme	N/A	set to '1111'
Redundancy version	N/A	set to '00'
Resource block assignment	N/A	Set to all '1's

For the case that the DCI format indicates a semi-persistent downlink scheduling activation, the TPC command for PUCCH field shall be used as an index to one of the four PUCCH resource values configured by higher layers, with the mapping defined in Table 9.2-2

Table 9.2-2: PUCCH Resource value for Downlink Semi-Persistent Scheduling

Value of 'TPC command for PUCCH'	$n_{\text{PUCCH}}^{(1,p)}$
'00'	The first PUCCH resource value configured by the higher layers
'01'	The second PUCCH resource value configured by the higher layers
'10'	The third PUCCH resource value configured by the higher layers
'11'	The fourth PUCCH resource value configured by the higher layers

9.3 PDCCH control information procedure

A UE shall discard the PDCCH if consistent control information is not detected.

10 Physical uplink control channel procedures

10.1 UE procedure for determining physical uplink control channel assignment

If the UE is configured for a single serving cell and is not configured for simultaneous PUSCH and PUCCH transmissions, then in subframe n uplink control information (UCI) shall be transmitted

- on PUCCH using format 1/1a/1b/3 or 2/2a/2b if the UE is not transmitting on PUSCH
- on PUSCH if the UE is transmitting on PUSCH in subframe n 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, in which case UCI is not transmitted

If the UE is configured for a single serving cell and simultaneous PUSCH and PUCCH transmission, then in subframe n UCI shall be transmitted

- on PUCCH using format 1/1a/1b/3 if the UCI consists only of HARQ-ACK and/or SR
- on PUCCH using format 2 if the UCI consists only of periodic CSI
- on PUCCH using format 2/2a/2b if the UCI consists of periodic CSI and HARQ-ACK and if the UE is not transmitting PUSCH
- on PUCCH and PUSCH if the UCI consists of HARQ-ACK/HARQ-ACK+SR/positive SR and periodic/aperiodic CSI in which case the HARQ-ACK/HARQ-ACK+SR/positive SR is transmitted on PUCCH using format 1/1a/1b/3 and the periodic/aperiodic CSI transmitted on PUSCH 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, in which case periodic/aperiodic CSI is not transmitted

If the UE is configured with more than one serving cell and is not configured for simultaneous PUSCH and PUCCH transmission, then in subframe n UCI shall be transmitted

- on PUCCH using format 1/1a/1b/3 or 2/2a/2b if the UE is not transmitting PUSCH

- on PUSCH of the serving cell given in section 7.2.1 if the UCI consists of aperiodic CSI or aperiodic CSI and HARQ-ACK
- on primary cell PUSCH if the UCI consists of periodic CSI and/or HARQ-ACK and if the UE is transmitting on the primary cell PUSCH in subframe n unless the primary cell 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, in which case UCI is not transmitted
- on PUSCH of the secondary cell with smallest $SCellIndex$ if the UCI consists of periodic CSI and/or HARQ-ACK and if the UE is not transmitting PUSCH on primary cell but is transmitting PUSCH on at least one secondary cell

If the UE is configured with more than one serving cell and simultaneous PUSCH and PUCCH transmission, then in subframe n UCI shall be transmitted

- on PUCCH using format 1/1a/1b/3 if the UCI consists only of HARQ-ACK and/or SR
- on PUCCH using format 2 if the UCI consists only of periodic CSI
- as described in section 10.1.1, if the UCI consists of periodic CSI and HARQ-ACK and if the UE is not transmitting on PUSCH
- on PUCCH and primary cell PUSCH if the UCI consists of HARQ-ACK and periodic CSI and the UE is transmitting PUSCH on the primary cell, in which case the HARQ-ACK is transmitted on PUCCH using format 1a/1b/3 and the periodic CSI is transmitted on PUSCH unless the primary cell 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, in which case periodic CSI is not transmitted
- on PUCCH and PUSCH of the secondary cell with the smallest $SCellIndex$ if the UCI consists of HARQ-ACK and periodic CSI and if the UE is not transmitting PUSCH on primary cell but is transmitting PUSCH on at least one secondary cell, in which case, the HARQ-ACK is transmitted on PUCCH using format 1a/1b/3 and the periodic CSI is transmitted on PUSCH
- on PUCCH and PUSCH if the UCI consists of HARQ-ACK/HARQ-ACK+SR/positive SR and aperiodic CSI in which case the HARQ-ACK/HARQ-ACK+SR/positive SR is transmitted on PUCCH using format 1/1a/1b/3 and the aperiodic CSI is transmitted on PUSCH of the serving cell given in Section 7.2.1

If the UE is configured with more than one serving cell, then reporting prioritization and collision handling of periodic CSI reports of a certain PUCCH reporting type is given in Section 7.2.2.

A UE transmits PUCCH only on the primary cell.

A UE is configured by higher layers to transmit PUCCH on one antenna port ($p = p_0$) or two antenna ports ($p \in [p_0, p_1]$).

For FDD with two configured serving cells and PUCCH format 1b with channel selection or for FDD with two or more configured serving cells and PUCCH format 3, $n_{\text{HARQ}} = \sum_{c=0}^{N_{\text{cells}}^{\text{DL}}-1} N_c^{\text{received}}$ where $N_{\text{cells}}^{\text{DL}}$ is the number of configured cells and N_c^{received} is the number of transport blocks or the SPS release PDCCH, if any, received in subframe $n-4$ in serving cell c .

For TDD with two configured serving cells and PUCCH format 1b with channel selection and a subframe n with $M = 1$, or for TDD UL-DL configuration 0 and PUCCH format 3, $n_{\text{HARQ}} = \sum_{c=0}^{N_{\text{cells}}^{\text{DL}}-1} \sum_{k \in K} N_{k,c}^{\text{received}}$, where $N_{k,c}^{\text{received}}$ is the number of transport blocks or the SPS release PDCCH, if any, received in subframe $n-k$ in serving cell c , where $k \in K$, and M is the number of elements in K .

For TDD UL-DL configurations 1-6 and PUCCH format 3, or for TDD with two configured serving cells and PUCCH format 1b with channel selection and $M = 2$, $n_{\text{HARQ}} = \sum_{c=0}^{N_{\text{cells}}^{\text{DL}}-1} \left(\left((V_{\text{DAI},c}^{\text{DL}} - U_{\text{DAI},c}) \bmod 4 \right) \cdot n_c^{\text{ACK}} + \sum_{k \in K} N_{k,c}^{\text{received}} \right)$ where $V_{\text{DAI},c}^{\text{DL}}$ is the $V_{\text{DAI}}^{\text{DL}}$ in serving cell c , $U_{\text{DAI},c}$ is the U_{DAI} in serving cell c , and n_c^{ACK} is the number of HARQ-ACK bits corresponding to the configured DL transmission mode on serving cell c . In case spatial HARQ-ACK bundling is applied, $n_c^{\text{ACK}} = 1$ and $N_{k,c}^{\text{received}}$ is the number of PDCCH or PDSCH without a corresponding PDCCH received in subframe $n - k$ and serving cell c , where $k \in K$ and M is the number of elements in K . In case spatial HARQ-ACK bundling is not applied, $N_{k,c}^{\text{received}}$ is the number of transport blocks received or the SPS release PDCCH received in subframe $n - k$ in serving cell c , where $k \in K$ and M is the number of elements in K . $V_{\text{DAI},c}^{\text{DL}} = 0$ if no transport block or SPS release PDCCH is detected in subframe(s) $n - k$ in serving cell c , where $k \in K$.

For TDD with two configured serving cells and PUCCH format 1b with channel selection and $M = 3$ or 4 , $n_{\text{HARQ}} = 2$ if UE receives PDSCH or PDCCH indicating downlink SPS release only on one serving cell within subframes $n - k$, where $k \in K$; otherwise $n_{\text{HARQ}} = 4$.

Throughout the following sections, subframes are numbered in monotonically increasing order; if the last subframe of a radio frame is denoted as k , the first subframe of the next radio frame is denoted as $k + 1$.

10.1.1 PUCCH format information

Using the PUCCH formats defined in section 5.4.1 and 5.4.2 in [3], the following combinations of UCI on PUCCH are supported:

- Format 1a for 1-bit HARQ-ACK or in case of FDD for 1-bit HARQ-ACK with positive SR
- Format 1b for 2-bit HARQ-ACK or for 2-bit HARQ-ACK with positive SR
- Format 1b for up to 4-bit HARQ-ACK with channel selection when the UE is configured with more than one serving cell or, in the case of TDD, when the UE is configured with a single serving cell
- Format 1 for positive SR
- Format 2 for a CSI report when not multiplexed with HARQ-ACK
- Format 2a for a CSI report multiplexed with 1-bit HARQ-ACK for normal cyclic prefix
- Format 2b for a CSI report multiplexed with 2-bit HARQ-ACK for normal cyclic prefix
- Format 2 for a CSI report multiplexed with HARQ-ACK for extended cyclic prefix
- Format 3 for up to 10-bit HARQ-ACK for FDD and for up to 20-bit HARQ-ACK for TDD
- Format 3 for up to 11-bit corresponding to 10-bit HARQ-ACK and 1-bit positive/negative SR for FDD and for up to 21-bit corresponding to 20-bit HARQ-ACK and 1-bit positive/negative SR for TDD.

For a UE configured with PUCCH format 3 and HARQ-ACK transmission on PUSCH or PUCCH, or for a UE configured with two serving cells and PUCCH format 1b with channel selection and HARQ-ACK transmission on PUSCH, or for UE configured with one serving cell and PUCCH format 1b with channel selection according to Tables 10.1.3-5, 10.1.3-6, 10.1.3-7 and HARQ-ACK transmission on PUSCH.

- If the configured downlink transmission mode for a serving cell supports up to 2 transport blocks and only one transport block is received in a subframe, the UE shall generate a NACK for the other transport block if spatial HARQ-ACK bundling is not applied.
- If neither PDSCH nor PDCCH indicating downlink SPS release is detected in a subframe for a serving cell, the UE shall generate two NACKs when the configured downlink transmission mode supports up to 2 transport blocks and the UE shall generate a single NACK when the configured downlink transmission mode supports a single transport block.

The scrambling initialization of PUCCH format 2, 2a, 2b and 3 is by C-RNTI.

For a UE that is configured with a single serving cell and is not configured with PUCCH format 3, in case of collision between a periodic CSI report and an HARQ-ACK in a same subframe without PUSCH, the periodic CSI report is multiplexed with HARQ-ACK on PUCCH if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE*, otherwise the CSI is dropped.

For TDD and for a UE that is configured with a single serving cell and with PUCCH format 3, in case of collision between a periodic CSI report and an HARQ-ACK in a same subframe without PUSCH, if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE*, the periodic CSI report is multiplexed with HARQ-ACK or dropped as described in section 7.3, otherwise the CSI is dropped.

For FDD and for a UE that is configured with more than one serving cell, in case of collision between a periodic CSI report and an HARQ-ACK in a same subframe without PUSCH, the periodic CSI report is multiplexed with HARQ-ACK on PUCCH if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE* and if the HARQ-ACK corresponds to a PDSCH transmission or PDCCH indicating downlink SPS release only on the primary cell, otherwise CSI is dropped.

For TDD and for a UE that is configured with more than one serving cell, in case of collision between a periodic CSI report and an HARQ-ACK in a same subframe without PUSCH, if the parameter *simultaneousAckNackAndCQI* provided by higher layers is set *TRUE*, the periodic CSI report is multiplexed with HARQ-ACK or dropped as described in section 7.3, otherwise the CSI is dropped. In case of collision between a periodic CSI report and an HARQ-ACK in a same subframe with PUSCH, the periodic CSI is multiplexed with the HARQ-ACK in the PUSCH transmission in that subframe if the UE is not configured by higher layers simultaneous PUCCH and PUSCH transmissions. Otherwise, if the UE is configured by higher layers simultaneous PUCCH and PUSCH transmissions, the HARQ-ACK is transmitted in the PUCCH and the periodic CSI is transmitted in the PUSCH.

10.1.2 FDD HARQ-ACK feedback procedures

For FDD and for a UE transmitting HARQ-ACK using PUCCH format 1b with channel selection or PUCCH format 3, the UE shall determine the number of HARQ-ACK bits, O , based on the number of configured serving cells and the downlink transmission modes configured for each serving cell. The UE shall use two HARQ-ACK bits for a serving cell configured with a downlink transmission mode that support up to two transport blocks; and one HARQ-ACK bit otherwise.

A UE that supports aggregating at most 2 serving cells with frame structure type 1 shall use PUCCH format 1b with channel selection for transmission of HARQ-ACK when configured with more than one serving cell with frame structure type 1.

A UE that supports aggregating more than 2 serving cells with frame structure type 1 is configured by higher layers to use either PUCCH format 1b with channel selection or PUCCH format 3 for transmission of HARQ-ACK when configured with more than one serving cell with frame structure type 1.

The FDD HARQ-ACK feedback procedure for one configured serving cell is given in section 10.1.2.1 and procedures for more than one configured serving cell are given in section 10.1.2.2.

10.1.2.1 FDD HARQ-ACK procedure for one configured serving cell

HARQ-ACK transmission on two antenna ports ($p \in [p_0, p_1]$) is supported for PUCCH format 1a/1b.

For FDD and one configured serving cell, the UE shall use PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ for transmission of HARQ-ACK in subframe n for $\tilde{p}$ mapped to antenna port p for PUCCH format 1a/1b [3], where

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe $n-4$, or for a PDCCH indicating downlink SPS release (defined in section 9.2) in subframe $n-4$, the UE shall use $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{CCE}} + N_{\text{PUCCH}}^{(1)}$ for antenna port p_0 , where n_{CCE} is the number of the first CCE (i.e. lowest CCE index used to construct the PDCCH) used for transmission of the corresponding DCI assignment and $N_{\text{PUCCH}}^{(1)}$

is configured by higher layers. For two antenna port transmission the PUCCH resource for antenna port p_1 is given by $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{CCE}} + 1 + N_{\text{PUCCH}}^{(1)}$.

- for a PDSCH transmission on the primary cell where there is not a corresponding PDCCH detected in subframe $n-4$, the value of $n_{\text{PUCCH}}^{(1,\tilde{p})}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port p_1 , otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0 .

10.1.2.2 FDD HARQ-ACK procedures for more than one configured serving cell

The FDD HARQ-ACK feedback procedures for more than one configured serving cell are either based on a PUCCH format 1b with channel selection HARQ-ACK procedure as described in section 10.1.2.2.1 or a PUCCH format 3 HARQ-ACK procedure as described in section 10.1.2.2.2.

HARQ-ACK transmission on two antenna ports ($p \in [p_0, p_1]$) is supported for PUCCH format 3.

10.1.2.2.1 PUCCH format 1b with channel selection HARQ-ACK procedure

For FDD with two configured serving cells and PUCCH format 1b with channel selection, the UE shall transmit $b(0)b(1)$ on PUCCH resource $n_{\text{PUCCH}}^{(1)}$ selected from A PUCCH resources, $n_{\text{PUCCH},j}^{(1)}$ where $0 \leq j \leq A-1$ and $A \in \{2,3,4\}$, according to Table 10.1.2.2.1-3, Table 10.1.2.2.1-4, Table 10.1.2.2.1-5 in subframe n using PUCCH format 1b. HARQ-ACK(j) denotes the ACK/NACK/DTX response for a transport block or SPS release PDCCH associated with serving cell c , where the transport block and serving cell for HARQ-ACK(j) and A PUCCH resources are given by Table 10.1.2.2.1-1.

A UE configured with a transmission mode that supports up to two transport blocks on serving cell, c , shall use the same HARQ-ACK response for both the transport blocks in response to a PDSCH transmission with a single transport block or a PDCCH indicating downlink SPS release associated with the serving cell c .

Table 10.1.2.2.1-1: Mapping of Transport Block and Serving Cell to HARQ-ACK(j) for PUCCH format 1b HARQ-ACK channel selection

A	HARQ-ACK(j)			
	HARQ-ACK(0)	HARQ-ACK(1)	HARQ-ACK(2)	HARQ-ACK(3)
2	TB1 Primary cell	TB1 Secondary cell	NA	NA
3	TB1 Serving cell1	TB2 Serving cell1	TB1 Serving cell2	NA
4	TB1 Primary cell	TB2 Primary cell	TB1 Secondary cell	TB2 Secondary cell

The UE shall determine the A PUCCH resources, $n_{\text{PUCCH},j}^{(1)}$ associated with HARQ-ACK(j) where $0 \leq j \leq A-1$ in Table 10.1.2.2.1-1, according to

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe $n-4$ on the primary cell, or for a PDCCH indicating downlink SPS release (defined in section 9.2) in subframe $n-4$ on the primary cell, the PUCCH resource is $n_{\text{PUCCH},j}^{(1)} = n_{\text{CCE}} + N_{\text{PUCCH}}^{(1)}$, and for transmission mode that supports up to two transport blocks, the PUCCH resource $n_{\text{PUCCH},j+1}^{(1)}$ is given by $n_{\text{PUCCH},j+1}^{(1)} = n_{\text{CCE}} + 1 + N_{\text{PUCCH}}^{(1)}$ where n_{CCE} is the number of the first CCE used for transmission of the corresponding PDCCH and $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers.

- for a PDSCH transmission on the primary cell where there is not a corresponding PDCCH detected in subframe $n-4$, the value of $n_{\text{PUCCH},j}^{(1)}$ is determined according to higher layer configuration and Table 9.2-2. For transmission mode that supports up to two transport blocks, the PUCCH resource $n_{\text{PUCCH},j+1}^{(1)}$ is given by $n_{\text{PUCCH},j+1}^{(1)} = n_{\text{PUCCH},j}^{(1)} + 1$
- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe $n-4$ on the secondary cell, the value of $n_{\text{PUCCH},j}^{(1)}$, and the value of $n_{\text{PUCCH},j+1}^{(1)}$ for the transmission mode that supports up to two transport blocks is determined according to higher layer configuration and Table 10.1.2.2.1-2. The TPC field in the DCI format of the corresponding PDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.1-2. For a UE configured for a transmission mode that supports up to two transport blocks a PUCCH resource value in Table 10.1.2.2.1-2 maps to two PUCCH resources $(n_{\text{PUCCH},j}^{(1)}, n_{\text{PUCCH},j+1}^{(1)})$, otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH},j}^{(1)}$.

Table 10.1.2.2.1-2: PUCCH Resource Value for HARQ-ACK Resource for PUCCH

Value of 'TPC command for PUCCH'	$n_{\text{PUCCH},j}^{(1)}$ or $(n_{\text{PUCCH},j}^{(1)}, n_{\text{PUCCH},j+1}^{(1)})$
'00'	The 1st PUCCH resource value configured by the higher layers
'01'	The 2nd PUCCH resource value configured by the higher layers
'10'	The 3rd PUCCH resource value configured by the higher layers
'11'	The 4th PUCCH resource value configured by the higher layers

Table 10.1.2.2.1-3: Transmission of Format 1b HARQ-ACK channel selection for $A = 2$

HARQ-ACK(0)	HARQ-ACK(1)	$n_{\text{PUCCH}}^{(1)}$	$b(0)b(1)$
ACK	ACK	$n_{\text{PUCCH},1}^{(1)}$	1,1
ACK	NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	1,1
NACK/DTX	ACK	$n_{\text{PUCCH},1}^{(1)}$	0,0
NACK	NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	0,0
DTX	NACK/DTX	No Transmission	

Table 10.1.2.2.1-4: Transmission of Format 1b HARQ-ACK channel selection for $A = 3$

HARQ-ACK(0)	HARQ-ACK(1)	HARQ-ACK(2)	$n_{\text{PUCCH}}^{(1)}$	$b(0)b(1)$
ACK	ACK	ACK	$n_{\text{PUCCH},1}^{(1)}$	1,1
ACK	NACK/DTX	ACK	$n_{\text{PUCCH},1}^{(1)}$	1,0
NACK/DTX	ACK	ACK	$n_{\text{PUCCH},1}^{(1)}$	0,1
NACK/DTX	NACK/DTX	ACK	$n_{\text{PUCCH},2}^{(1)}$	1,1
ACK	ACK	NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	1,1
ACK	NACK/DTX	NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	1,0
NACK/DTX	ACK	NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	0,1
NACK/DTX	NACK/DTX	NACK	$n_{\text{PUCCH},2}^{(1)}$	0,0
NACK	NACK/DTX	DTX	$n_{\text{PUCCH},0}^{(1)}$	0,0
NACK/DTX	NACK	DTX	$n_{\text{PUCCH},0}^{(1)}$	0,0
DTX	DTX	DTX	No Transmission	

Table 10.1.2.2.1-5: Transmission of Format 1b HARQ-ACK channel selection for $A = 4$

HARQ-ACK(0)	HARQ-ACK(1)	HARQ-ACK(2)	HARQ-ACK(3)	$n_{\text{PUCCH}}^{(1)}$	$b(0)b(1)$
ACK	ACK	ACK	ACK	$n_{\text{PUCCH},1}^{(1)}$	1,1
ACK	NACK/DTX	ACK	ACK	$n_{\text{PUCCH},2}^{(1)}$	0,1
NACK/DTX	ACK	ACK	ACK	$n_{\text{PUCCH},1}^{(1)}$	0,1
NACK/DTX	NACK/DTX	ACK	ACK	$n_{\text{PUCCH},3}^{(1)}$	1,1
ACK	ACK	ACK	NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	1,0
ACK	NACK/DTX	ACK	NACK/DTX	$n_{\text{PUCCH},2}^{(1)}$	0,0
NACK/DTX	ACK	ACK	NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	0,0
NACK/DTX	NACK/DTX	ACK	NACK/DTX	$n_{\text{PUCCH},3}^{(1)}$	1,0
ACK	ACK	NACK/DTX	ACK	$n_{\text{PUCCH},2}^{(1)}$	1,1
ACK	NACK/DTX	NACK/DTX	ACK	$n_{\text{PUCCH},2}^{(1)}$	1,0
NACK/DTX	ACK	NACK/DTX	ACK	$n_{\text{PUCCH},3}^{(1)}$	0,1
NACK/DTX	NACK/DTX	NACK/DTX	ACK	$n_{\text{PUCCH},3}^{(1)}$	0,0
ACK	ACK	NACK/DTX	NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	1,1
ACK	NACK/DTX	NACK/DTX	NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	1,0
NACK/DTX	ACK	NACK/DTX	NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	0,1
NACK/DTX	NACK	NACK/DTX	NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	0,0
NACK	NACK/DTX	NACK/DTX	NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	0,0
DTX	DTX	NACK/DTX	NACK/DTX	No Transmission	

10.1.2.2.2 PUCCH format 3 HARQ-ACK procedure

For FDD with PUCCH format 3, the UE shall use PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ or $n_{\text{PUCCH}}^{(1,\tilde{p})}$ for transmission of HARQ-ACK in subframe n for $\tilde{p}$ mapped to antenna port p where

- for a PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-4$, or for a PDCCH indicating downlink SPS release (defined in section 9.2) in subframe $n-4$ on the primary cell, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ with $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = n_{\text{CCE}} + N_{\text{PUCCH}}^{(1)}$ for antenna port p_0 , where n_{CCE} is the number of the first CCE (i.e. lowest CCE index used to construct the PDCCH) used for transmission of the corresponding PDCCH and $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by $n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{CCE}} + 1 + N_{\text{PUCCH}}^{(1)}$.
- for a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH detected in subframe $n-4$, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ where the value of

$n_{\text{PUCCH}}^{(1,\tilde{p})}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission for PUCCH format 1a/1b, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port p_1 , otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0 .

- for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH in subframe $n - 4$, the UE shall use PUCCH format 3 and PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\text{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1. The TPC field in the DCI format of the corresponding PDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. For a UE configured for two antenna port transmission for PUCCH format 3, a PUCCH resource value in Table 10.1.2.2.2-1 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_1)}$ for antenna port p_1 , otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_0)}$ for antenna port p_0 . A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted in each DCI format of the corresponding secondary cell PDCCH assignments in a given subframe.

Table 10.1.2.2.2-1: PUCCH Resource Value for HARQ-ACK Resource for PUCCH

Value of 'TPC command for PUCCH'	$n_{\text{PUCCH}}^{(3,\tilde{p})}$
'00'	The 1st PUCCH resource value configured by the higher layers
'01'	The 2 nd PUCCH resource value configured by the higher layers
'10'	The 3 rd PUCCH resource value configured by the higher layers
'11'	The 4 th PUCCH resource value configured by the higher layers

10.1.3 TDD HARQ-ACK feedback procedures

For TDD and a UE that does not support aggregating more than one serving cell with frame structure type 2, two HARQ-ACK feedback modes are supported by higher layer configuration.

- HARQ-ACK bundling and
- HARQ-ACK multiplexing

For TDD UL-DL configuration 5 and a UE that does not support aggregating more than one serving cell with frame structure type 2, only HARQ-ACK bundling is supported.

A UE that supports aggregating more than one serving cell with frame structure type 2 is configured by higher layers to use either PUCCH format 1b with channel selection or PUCCH format 3 for transmission of HARQ-ACK when configured with more than one serving cell with frame structure type 2.

A UE that supports aggregating more than one serving cell with frame structure type 2 is configured by higher layers to use HARQ-ACK bundling, PUCCH format 1b with channel selection according to the set of Tables 10.1.3-2/3/4 or according to the set of Tables 10.1.3-5/6/7, or PUCCH format 3 for transmission of HARQ-ACK when configured with one serving cell with frame structure type 2.

PUCCH format 1b with channel selection according to the set of Tables 10.1.3-2/3/4 or according to the set of Tables 10.1.3-5/6/7 is not supported for TDD UL-DL configuration 5.

TDD HARQ-ACK bundling is performed per codeword across M multiple DL subframes associated with a single UL subframe n , where M is the number of elements in the set K defined in Table 10.1.3.1-1, by a logical AND operation of all the individual PDSCH transmission (with and without corresponding PDCCH) HARQ-ACKs and ACK in response to PDCCH indicating downlink SPS release. For one configured serving cell the bundled 1 or 2 HARQ-ACK bits are transmitted using PUCCH format 1a or PUCCH format 1b, respectively.

For TDD HARQ-ACK multiplexing and a subframe n with $M > 1$, where M is the number of elements in the set K defined in Table 10.1.3.1-1, spatial HARQ-ACK bundling across multiple codewords within a DL subframe is performed by a logical AND operation of all the corresponding individual HARQ-ACKs. PUCCH format 1b with channel selection is used in case of one configured serving cell. For TDD HARQ-ACK multiplexing and a subframe n with $M = 1$, spatial HARQ-ACK bundling across multiple codewords within a DL subframe is not performed, 1 or 2 HARQ-ACK bits are transmitted using PUCCH format 1a or PUCCH format 1b, respectively for one configured serving cell.

In the case of TDD and more than one configured serving cell with PUCCH format 1b with channel selection and more than 4 HARQ-ACK bits for M multiple DL subframes associated with a single UL subframe n , where M is the number of elements in the set K defined in Table 10.1.3.1-1 and for the configured serving cells, spatial HARQ-ACK bundling across multiple codewords within a DL subframe for all configured cells is performed and the bundled HARQ-ACK bits for each configured serving cell is transmitted using PUCCH format 1b with channel selection. For TDD and more than one configured serving cell with PUCCH format 1b with channel selection and up to 4 HARQ-ACK bits for M multiple DL subframes associated with a single UL subframe n , where M is the number of elements in the set K defined in Table 10.1.3.1-1 and for the configured serving cells, spatial HARQ-ACK bundling is not performed and the HARQ-ACK bits are transmitted using PUCCH format 1b with channel selection.

In the case of TDD and more than one configured serving cell with PUCCH format 3 and more than 20 HARQ-ACK bits for M multiple DL subframes associated with a single UL subframe n , where M is the number of elements in the set K defined in Table 10.1.3.1-1 and for the configured serving cells, spatial HARQ-ACK bundling across multiple codewords within a DL subframe is performed for each serving cell by a logical AND operation of all of the corresponding individual HARQ-ACKs and PUCCH format 3 is used. For TDD and more than one configured serving cell with PUCCH format 3 and up to 20 HARQ-ACK bits for M multiple DL subframes associated with a single UL subframe n , where M is the number of elements in the set K defined in Table 10.1.3.1-1 and for the configured serving cells, spatial HARQ-ACK bundling is not performed and the HARQ-ACK bits are transmitted using PUCCH format 3.

For TDD with PUCCH format 3, a UE shall determine the number of HARQ-ACK bits, O , associated with an UL subframe n based on the number of configured serving cells, the downlink transmission modes configured for each serving cell and M which is the number of elements in the set K defined in Table 10.1.3.1-1 according to

$$O = \sum_{c=1}^{N_{cells}^{DL}} O_c^{ACK} \quad \text{where } N_{cells}^{DL} \text{ is the number of configured cells, and } O_c^{ACK} \text{ is the number of HARQ-bits for the } c\text{-th serving cell defined in section 7.3.}$$

the c -th serving cell defined in section 7.3.

TDD HARQ-ACK feedback procedures for one configured serving cell are given in section 10.1.3.1 and procedures for more than one configured serving cell are given in section 10.1.3.2.

10.1.3.1 TDD HARQ-ACK procedure for one configured serving cell

HARQ-ACK transmission on two antenna ports ($p \in [p_0, p_1]$) is supported for PUCCH format 1a/1b with TDD HARQ-ACK bundling feedback mode and for PUCCH format 3.

The TDD HARQ-ACK procedure for a UE configured with PUCCH format 3 is as described in section 10.1.3.2.2 when the UE receives PDSCH and/or SPS release PDCCH only on the primary cell.

For TDD HARQ-ACK bundling or TDD HARQ-ACK multiplexing for one configured serving cell and a subframe n with $M = 1$ where M is the number of elements in the set K defined in Table 10.1.3.1-1, the UE shall use PUCCH resource $n_{PUCCH}^{(1,p)}$ for transmission of HARQ-ACK in subframe n for $\tilde{p}$ mapped to antenna port p for PUCCH format 1a/1b, where

- If there is PDSCH transmission indicated by the detection of corresponding PDCCH or there is PDCCH indicating downlink SPS release within subframe(s) $n - k$, where $k \in K$ and K (defined in Table 10.1.3.1-1) is a set of M elements $\{k_0, k_1, \dots, k_{M-1}\}$ depending on the subframe n and the UL-DL configuration (defined in

Table 4.2-2 in [3]), the UE first selects a c value out of $\{0, 1, 2, 3\}$ which makes $N_c \leq n_{\text{CCE}} < N_{c+1}$ and shall use $n_{\text{PUCCH}}^{(1, \tilde{p}_0)} = (M - m - 1) \cdot N_c + m \cdot N_{c+1} + n_{\text{CCE}} + N_{\text{PUCCH}}^{(1)}$ for antenna port p_0 , where $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers, $N_c = \max\left\{0, \left\lfloor \frac{N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)}{36} \right\rfloor\right\}$, and n_{CCE} is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n - k_m$ and the corresponding m , where k_m is the smallest value in set K such that UE detects a PDCCH in subframe $n - k_m$. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for HARQ-ACK bundling for antenna port p_1 is given by $n_{\text{PUCCH}}^{(1, \tilde{p}_1)} = (M - m - 1) \cdot N_c + m \cdot N_{c+1} + n_{\text{CCE}} + 1 + N_{\text{PUCCH}}^{(1)}$.

- If there is only a PDSCH transmission where there is not a corresponding PDCCH detected within subframe(s) $n - k$, where $k \in K$ and K is defined in Table 10.1.3.1-1, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1, \tilde{p})}$ with the value of $n_{\text{PUCCH}}^{(1, \tilde{p})}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission for PUCCH format 1a/1b and HARQ-ACK bundling, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(1, \tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(1, \tilde{p}_1)}$ for antenna port p_1 , otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(1, \tilde{p}_0)}$ for antenna port p_0 .

Table 10.1.3.1-1: Downlink association set index $K : \{k_0, k_1, \dots, k_{M-1}\}$ for TDD

UL-DL Configuration	Subframe n								
	0	1	2	3	4	5	6	7	8
0	-	-	6	-	4	-	-	6	-
1	-	-	7, 6	4	-	-	-	7, 6	4
2	-	-	8, 7, 4, 6	-	-	-	-	8, 7, 4, 6	-
3	-	-	7, 6, 11	6, 5	5, 4	-	-	-	-
4	-	-	12, 8, 7, 11	6, 5, 4, 7	-	-	-	-	-
5	-	-	13, 12, 9, 8, 7, 5, 4, 11, 6	-	-	-	-	-	-
6	-	-	7	7	5	-	-	7	7

For TDD HARQ-ACK multiplexing and sub-frame n with $M > 1$ and one configured serving cell, where M is the number of elements in the set K defined in Table 10.1.3.1-1, denote $n_{\text{PUCCH},i}^{(1)}$ as the PUCCH resource derived from sub-frame $n - k_i$ and HARQ-ACK(i) as the ACK/NACK/DTX response from sub-frame $n - k_i$, where $k_i \in K$ (defined in Table 10.1.3.1-1) and $0 \leq i \leq M - 1$.

- For a PDSCH transmission indicated by the detection of corresponding PDCCH or a PDCCH indicating downlink SPS release in sub-frame $n - k_i$ where $k_i \in K$, the PUCCH resource $n_{\text{PUCCH},i}^{(1)} = (M - i - 1) \cdot N_c + i \cdot N_{c+1} + n_{\text{CCE},i} + N_{\text{PUCCH}}^{(1)}$, where c is selected from $\{0, 1, 2, 3\}$ such that $N_c \leq n_{\text{CCE},i} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor \frac{N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)}{36} \right\rfloor\right\}$, $n_{\text{CCE},i}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n - k_i$, and $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers.
- For a PDSCH transmission where there is not a corresponding PDCCH detected in subframe $n - k_i$, the value of $n_{\text{PUCCH},i}^{(1)}$ is determined according to higher layer configuration and Table 9.2-2.

Based on higher layer signalling a UE configured with a single serving cell will perform channel selection either according to the set of Tables 10.1.3-2, 10.1.3-3, and 10.1.3-4 or according to the set of Tables 10.1.3-5, 10.1.3-6, and 10.1.3-7. For the selected table set indicated by higher layer signalling, the UE shall transmit $b(0), b(1)$ on PUCCH resource $n_{\text{PUCCH}}^{(1)}$ in sub-frame n using PUCCH format 1b according to section 5.4.1 in [3]. The value of $b(0), b(1)$ and the PUCCH resource $n_{\text{PUCCH}}^{(1)}$ are generated by channel selection according to the selected set of Tables for $M = 2, 3$, and 4 respectively.

Table 10.1.3-2: Transmission of HARQ-ACK multiplexing for $M = 2$

HARQ-ACK(0), HARQ-ACK(1)	$n_{\text{PUCCH}}^{(1)}$	$b(0), b(1)$
ACK, ACK	$n_{\text{PUCCH},1}^{(1)}$	1, 1
ACK, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	0, 1
NACK/DTX, ACK	$n_{\text{PUCCH},1}^{(1)}$	0, 0
NACK/DTX, NACK	$n_{\text{PUCCH},1}^{(1)}$	1, 0
NACK, DTX	$n_{\text{PUCCH},0}^{(1)}$	1, 0
DTX, DTX	No transmission	

Table 10.1.3-3: Transmission of HARQ-ACK multiplexing for $M = 3$

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	$n_{\text{PUCCH}}^{(1)}$	$b(0), b(1)$
ACK, ACK, ACK	$n_{\text{PUCCH},2}^{(1)}$	1, 1
ACK, ACK, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	1, 1
ACK, NACK/DTX, ACK	$n_{\text{PUCCH},0}^{(1)}$	1, 1
ACK, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	0, 1
NACK/DTX, ACK, ACK	$n_{\text{PUCCH},2}^{(1)}$	1, 0
NACK/DTX, ACK, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	0, 0
NACK/DTX, NACK/DTX, ACK	$n_{\text{PUCCH},2}^{(1)}$	0, 0
DTX, DTX, NACK	$n_{\text{PUCCH},2}^{(1)}$	0, 1
DTX, NACK, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	1, 0
NACK, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	1, 0
DTX, DTX, DTX	No transmission	

Table 10.1.3-4: Transmission of HARQ-ACK multiplexing for $M = 4$

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	$n_{\text{PUCCH}}^{(1)}$	$b(0), b(1)$
ACK, ACK, ACK, ACK	$n_{\text{PUCCH},1}^{(1)}$	1, 1
ACK, ACK, ACK, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	1, 0
NACK/DTX, NACK/DTX, NACK, DTX	$n_{\text{PUCCH},2}^{(1)}$	1, 1
ACK, ACK, NACK/DTX, ACK	$n_{\text{PUCCH},1}^{(1)}$	1, 0
NACK, DTX, DTX, DTX	$n_{\text{PUCCH},0}^{(1)}$	1, 0
ACK, ACK, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	1, 0
ACK, NACK/DTX, ACK, ACK	$n_{\text{PUCCH},3}^{(1)}$	0, 1
NACK/DTX, NACK/DTX, NACK/DTX, NACK	$n_{\text{PUCCH},3}^{(1)}$	1, 1
ACK, NACK/DTX, ACK, NACK/DTX	$n_{\text{PUCCH},2}^{(1)}$	0, 1
ACK, NACK/DTX, NACK/DTX, ACK	$n_{\text{PUCCH},0}^{(1)}$	0, 1
ACK, NACK/DTX, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	1, 1
NACK/DTX, ACK, ACK, ACK	$n_{\text{PUCCH},3}^{(1)}$	0, 1
NACK/DTX, NACK, DTX, DTX	$n_{\text{PUCCH},1}^{(1)}$	0, 0
NACK/DTX, ACK, ACK, NACK/DTX	$n_{\text{PUCCH},2}^{(1)}$	1, 0
NACK/DTX, ACK, NACK/DTX, ACK	$n_{\text{PUCCH},3}^{(1)}$	1, 0
NACK/DTX, ACK, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	0, 1
NACK/DTX, NACK/DTX, ACK, ACK	$n_{\text{PUCCH},3}^{(1)}$	0, 1
NACK/DTX, NACK/DTX, ACK, NACK/DTX	$n_{\text{PUCCH},2}^{(1)}$	0, 0
NACK/DTX, NACK/DTX, NACK/DTX, ACK	$n_{\text{PUCCH},3}^{(1)}$	0, 0
DTX, DTX, DTX, DTX	No transmission	

Table 10.1.3-5: Transmission of HARQ-ACK multiplexing for $M = 2$

HARQ-ACK(0), HARQ-ACK(1)	$n_{\text{PUCCH}}^{(1)}$	$b(0)b(1)$
ACK, ACK	$n_{\text{PUCCH},1}^{(1)}$	1, 0
ACK, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	1, 1
NACK/DTX, ACK	$n_{\text{PUCCH},1}^{(1)}$	0, 1
NACK, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	0, 0
DTX, NACK/DTX	No Transmission	

Table 10.1.3-6: Transmission of HARQ-ACK multiplexing for $M = 3$

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	$n_{\text{PUCCH}}^{(1)}$	$b(0)b(1)$
ACK, ACK, ACK	$n_{\text{PUCCH},2}^{(1)}$	1, 1
ACK, ACK, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	1, 0

ACK, NACK/DTX, ACK	$n_{\text{PUCCH},2}^{(1)}$	1, 0
ACK, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	1, 1
NACK/DTX, ACK, ACK	$n_{\text{PUCCH},2}^{(1)}$	0, 1
NACK/DTX, ACK, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	0, 1
NACK/DTX, NACK/DTX, ACK	$n_{\text{PUCCH},2}^{(1)}$	0, 0
NACK, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	0, 0
DTX, NACK/DTX, NACK/DTX	No Transmission	

Table 10.1.3-7: Transmission of HARQ-ACK multiplexing for $M = 4$

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	$n_{\text{PUCCH}}^{(1)}$	$b(0)b(1)$
ACK, ACK, ACK, ACK	$n_{\text{PUCCH},1}^{(1)}$	1, 1
ACK, ACK, ACK, NACK/DTX	$n_{\text{PUCCH},2}^{(1)}$	1, 1
ACK, ACK, NACK/DTX, ACK	$n_{\text{PUCCH},0}^{(1)}$	1, 0
ACK, ACK, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	1, 0
ACK, NACK/DTX, ACK, ACK	$n_{\text{PUCCH},3}^{(1)}$	1, 1
ACK, NACK/DTX, ACK, NACK/DTX	$n_{\text{PUCCH},2}^{(1)}$	1, 0
ACK, NACK/DTX, NACK/DTX, ACK	$n_{\text{PUCCH},0}^{(1)}$	0, 1
ACK, NACK/DTX, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	1, 1
NACK/DTX, ACK, ACK, ACK	$n_{\text{PUCCH},1}^{(1)}$	0, 0
NACK/DTX, ACK, ACK, NACK/DTX	$n_{\text{PUCCH},2}^{(1)}$	0, 1
NACK/DTX, ACK, NACK/DTX, ACK	$n_{\text{PUCCH},3}^{(1)}$	1, 0
NACK/DTX, ACK, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	0, 1
NACK/DTX, NACK/DTX, ACK, ACK	$n_{\text{PUCCH},3}^{(1)}$	0, 1
NACK/DTX, NACK/DTX, ACK, NACK/DTX	$n_{\text{PUCCH},2}^{(1)}$	0, 0
NACK/DTX, NACK/DTX, NACK/DTX, ACK	$n_{\text{PUCCH},3}^{(1)}$	0, 0
NACK, NACK/DTX, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	0, 0
DTX, NACK/DTX, NACK/DTX, NACK/DTX	No Transmission	

10.1.3.2 TDD HARQ-ACK procedure for more than one configured serving cell

The TDD HARQ-ACK feedback procedures for more than one configured serving cell are either based on a PUCCH format 1b with channel selection HARQ-ACK procedure as described in section 10.1.3.2.1 or a PUCCH format 3 HARQ-ACK procedure as described in section 10.1.3.2.2.

HARQ-ACK transmission on two antenna ports ($p \in [p_0, p_1]$) is supported for PUCCH format 3 and TDD with more than one configured serving cell. TDD UL-DL configuration 5 with PUCCH format 3 is only supported for up to two configured serving cells. TDD UL-DL configuration 5 with PUCCH format 1b with channel selection for two configured serving cells is not supported.

10.1.3.2.1 PUCCH format 1b with channel selection HARQ-ACK procedure

For TDD HARQ-ACK multiplexing with PUCCH format 1b with channel selection and two configured serving cells and a subframe n with $M=1$ where M is the number of elements in the set K defined in Table 10.1.3.1-1, a UE shall determine the number of HARQ-ACK bits, O , based on the number of configured serving cells and the downlink transmission modes configured for each serving cell. The UE shall use two HARQ-ACK bits for a serving cell configured with a downlink transmission mode that supports up to two transport blocks; and one HARQ-ACK bit otherwise.

For TDD HARQ-ACK multiplexing with PUCCH format 1b with channel selection and two configured serving cells and a subframe n with $M \leq 2$ where M is the number of elements in the set K defined in Table 10.1.3.1-1, the UE shall transmit $b(0)b(1)$ on PUCCH resource $n_{\text{PUCCH}}^{(1)}$ selected from A PUCCH resources, $n_{\text{PUCCH},j}^{(1)}$ where

$0 \leq j \leq A-1$ and $A \in \{2,3,4\}$, according to Tables 10.1.3.2-1, 10.1.3.2-2, and 10.1.3.2-3 in subframe n using PUCCH format 1b. For a subframe n with $M=1$, HARQ-ACK(j) denotes the ACK/NACK/DTX response for a transport block or SPS release PDCCH associated with serving cell, where the transport block and serving cell for HARQ-ACK(j) and A PUCCH resources are given by Table 10.1.2.2.1-1. For a subframe n with $M=2$, HARQ-ACK(j) denotes the ACK/NACK/DTX response for a PDSCH transmission or SPS release PDCCH within subframe(s) given by set K on each serving cell, where the subframes on each serving cell for HARQ-ACK(j) and A PUCCH resources are given by Table 10.1.3.2-4. The UE shall determine the A PUCCH resources, $n_{\text{PUCCH},j}^{(1)}$ associated with HARQ-ACK(j) where $0 \leq j \leq A-1$ in Table 10.1.2.2.1-1 for $M=1$ and Table 10.1.3.2-4 for $M=2$, according to

- for a PDSCH transmission indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ on the primary cell, or for a PDCCH indicating downlink SPS release (defined in section 9.2) in subframe $n-k_m$, where $k_m \in K$ on the primary cell, the PUCCH resource is $n_{\text{PUCCH},j}^{(1)} = (M-m-1) \cdot N_c + m \cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{(1)}$, where c is selected from $\{0, 1, 2, 3\}$ such that $N_c \leq n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor \frac{N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)}{36} \right\rfloor\right\}$ where $N_{\text{RB}}^{\text{DL}}$ is determined from the primary cell, and for a subframe n with $M=1$ and a transmission mode that supports up to two transport blocks on the serving cell where the corresponding PDSCH transmission occurs, the PUCCH resource $n_{\text{PUCCH},j+1}^{(1)}$ is given by $n_{\text{PUCCH},j+1}^{(1)} = (M-m-1) \cdot N_c + m \cdot N_{c+1} + n_{\text{CCE},m} + 1 + N_{\text{PUCCH}}^{(1)}$ where $n_{\text{CCE},m}$ is the number of the first CCE used for transmission of the corresponding DCI assignment and $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers.
- for a PDSCH transmission on the primary cell where there is not a corresponding PDCCH detected within subframe(s) $n-k$, where $k \in K$, the value of $n_{\text{PUCCH},j}^{(1)}$ is determined according to higher layer configuration and Table 9.2-2.
- for a PDSCH transmission indicated by the detection of a corresponding PDCCH within subframe(s) $n-k$, where $k \in K$ on the secondary cell, the value of $n_{\text{PUCCH},j}^{(1)}$, and the value of $n_{\text{PUCCH},j+1}^{(1)}$ for a subframe n with $M=2$ or for a subframe n with $M=1$ and a transmission mode on the secondary cell that supports up to two transport blocks is determined according to higher layer configuration and Table 10.1.2.2.1-2. The TPC field in the DCI format of the corresponding PDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.1-2. For a UE configured for a transmission mode on the secondary cell that supports up to two transport blocks and a subframe n with $M=1$, or for a subframe n with $M=2$, a PUCCH resource value in Table 10.1.2.2.1-2 maps to two PUCCH resources ($n_{\text{PUCCH},j}^{(1)}, n_{\text{PUCCH},j+1}^{(1)}$), otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH},j}^{(1)}$. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted in the TPC field on all PDCCH assignments on the secondary cell within subframe(s) $n-k$, where $k \in K$.

Table 10.1.3.2-1: Transmission of HARQ-ACK multiplexing for $A=2$

HARQ-ACK(0), HARQ-ACK(1)	$n_{\text{PUCCH}}^{(1)}$	$b(0)b(1)$
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ACK, ACK	$n_{\text{PUCCH},1}^{(1)}$	1, 0
ACK, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	1, 1
NACK/DTX, ACK	$n_{\text{PUCCH},1}^{(1)}$	0, 1
NACK, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	0, 0
DTX, NACK/DTX	No Transmission	

Table 10.1.3.2-2: Transmission of HARQ-ACK multiplexing for $A = 3$

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	$n_{\text{PUCCH}}^{(1)}$	$b(0)b(1)$
ACK, ACK, ACK	$n_{\text{PUCCH},2}^{(1)}$	1, 1
ACK, ACK, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	1, 0
ACK, NACK/DTX, ACK	$n_{\text{PUCCH},2}^{(1)}$	1, 0
ACK, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	1, 1
NACK/DTX, ACK, ACK	$n_{\text{PUCCH},2}^{(1)}$	0, 1
NACK/DTX, ACK, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	0, 1
NACK/DTX, NACK/DTX, ACK	$n_{\text{PUCCH},2}^{(1)}$	0, 0
NACK, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	0, 0
DTX, NACK/DTX, NACK/DTX	No Transmission	

Table 10.1.3.2-3: Transmission of HARQ-ACK multiplexing for $A = 4$

HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	$n_{\text{PUCCH}}^{(1)}$	$b(0)b(1)$
ACK, ACK, ACK, ACK	$n_{\text{PUCCH},1}^{(1)}$	1, 1
ACK, ACK, ACK, NACK/DTX	$n_{\text{PUCCH},2}^{(1)}$	1, 1
ACK, ACK, NACK/DTX, ACK	$n_{\text{PUCCH},0}^{(1)}$	1, 0
ACK, ACK, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	1, 0
ACK, NACK/DTX, ACK, ACK	$n_{\text{PUCCH},3}^{(1)}$	1, 1
ACK, NACK/DTX, ACK, NACK/DTX	$n_{\text{PUCCH},2}^{(1)}$	1, 0
ACK, NACK/DTX, NACK/DTX, ACK	$n_{\text{PUCCH},0}^{(1)}$	0, 1
ACK, NACK/DTX, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	1, 1
NACK/DTX, ACK, ACK, ACK	$n_{\text{PUCCH},1}^{(1)}$	0, 0
NACK/DTX, ACK, ACK, NACK/DTX	$n_{\text{PUCCH},2}^{(1)}$	0, 1
NACK/DTX, ACK, NACK/DTX, ACK	$n_{\text{PUCCH},3}^{(1)}$	1, 0
NACK/DTX, ACK, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	0, 1
NACK/DTX, NACK/DTX, ACK, ACK	$n_{\text{PUCCH},3}^{(1)}$	0, 1
NACK/DTX, NACK/DTX, ACK, NACK/DTX	$n_{\text{PUCCH},2}^{(1)}$	0, 0
NACK/DTX, NACK/DTX, NACK/DTX, ACK	$n_{\text{PUCCH},3}^{(1)}$	0, 0

NACK, NACK/DTX, NACK/DTX, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	0, 0
DTX, NACK/DTX, NACK/DTX, NACK/DTX	No Transmission	

**Table 10.1.3.2-4: Mapping of subframes on each serving cell to HARQ-ACK(j) for PUCCH format 1b
HARQ-ACK channel selection for TDD with $M = 2$**

A	HARQ-ACK(j)			
	HARQ-ACK(0)	HARQ-ACK(1)	HARQ-ACK(2)	HARQ-ACK(3)
4	The first subframe of Primary cell	The second subframe of Primary cell	The first subframe of Secondary cell	The second subframe of Secondary cell

For TDD HARQ-ACK multiplexing with PUCCH format 1b with channel selection and sub-frame n with $M > 2$ and two configured serving cells, where M is the number of elements in the set K defined in Table 10.1.3.1-1, denotes $n_{\text{PUCCH},i}^{(1)}$ $0 \leq i \leq 3$ as the PUCCH resource derived from the transmissions in M DL sub-frames associated with the UL subframe n . $n_{\text{PUCCH},0}^{(1)}$ and $n_{\text{PUCCH},1}^{(1)}$ are associated with the PDSCH transmission(s) or a PDCCH indicating downlink SPS release (defined in section 9.2) on the primary cell and $n_{\text{PUCCH},2}^{(1)}$ and $n_{\text{PUCCH},3}^{(1)}$ are associated with the PDSCH transmission(s) on the secondary cell.

For Primary cell:

- If there is a PDSCH transmission on the primary cell without a corresponding PDCCH detected within the subframe(s) $n-k$, where $k \in K$,
 - o the value of $n_{\text{PUCCH},0}^{(1)}$ is determined according to higher layer configuration and Table 9.2-2.
 - o for a PDSCH transmission on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X) or a PDCCH indicating downlink SPS release (defined in section 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1', the PUCCH resource $n_{\text{PUCCH},1}^{(1)} = (M-m-1) \cdot N_c + m \cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{(1)}$ where c is selected from $\{0, 1, 2, 3\}$ such that $N_c \leq n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor \frac{N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)}{36} \right\rfloor\right\}$, where $n_{\text{CCE},m}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n-k_m$ and $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers.
 - o HARQ-ACK(0) is the ACK/NACK/DTX response for the PDSCH transmission without a corresponding PDCCH. HARQ-ACK(j), $1 \leq j \leq M-1$, is the ACK/NACK/DTX response for the PDSCH transmission with a corresponding PDCCH and DAI value in the PDCCH equal to 'j', or for the PDCCH indicating downlink SPS release and with DAI value in the PDCCH equal to 'j'.
- Otherwise,
 - o for a PDSCH transmission on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to either '1' or '2' or a PDCCH indicating downlink SPS release (defined in section 9.2) in subframe $n-k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to either '1' or '2', the PUCCH resource $n_{\text{PUCCH},i}^{(1)} = (M-m-1) \cdot N_c + m \cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{(1)}$, where c is selected from $\{0, 1, 2, 3\}$ such that $N_c \leq n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor \frac{N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)}{36} \right\rfloor\right\}$, where

$n_{\text{CCE},m}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n - k_m$, $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers, $i = 0$ for the corresponding PDCCH with the DAI value equal to '1' and $i = 1$ for the corresponding PDCCH with the DAI value equal to '2'.

- HARQ-ACK(j), $0 \leq j \leq M - 1$, is the ACK/NACK/DTX response for the PDSCH transmission with corresponding PDCCH and DAI value in the PDCCH equal to ' $j + 1$ ', or for the PDCCH indicating downlink SPS release and with DAI value in the PDCCH equal to ' $j + 1$ '.

For Secondary cell:

- for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH on the primary cell in subframe $n - k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to either '1' or '2', the PUCCH resources $n_{\text{PUCCH},i}^{(1)} = (M - m - 1) \cdot N_c + m \cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{(1)}$, where c is selected from $\{0, 1, 2, 3\}$ such that $N_c \leq n_{\text{CCE},m} < N_{c+1}$, $N_c = \max\left\{0, \left\lfloor \frac{N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)}{36} \right\rfloor\right\}$, where $N_{\text{RB}}^{\text{DL}}$ is determined from the primary cell, $n_{\text{CCE},m}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n - k_m$, $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers, $i = 2$ for the corresponding PDCCH with the DAI value equal to '1' and $i = 3$ for the corresponding PDCCH with the DAI value equal to '2'.
- for a PDSCH transmission indicated by the detection of a corresponding PDCCH within the subframe(s) $n - k$, where $k \in K$ on the secondary cell, the value of $n_{\text{PUCCH},2}^{(1)}$ and $n_{\text{PUCCH},3}^{(1)}$ is determined according to higher layer configuration and Table 10.1.2.2.1-2. The TPC field in the DCI format of the corresponding PDCCH shall be used to determine the PUCCH resource values from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.1-2. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted in the TPC field on all PDCCH assignments on the secondary cell within subframe(s) $n - k$, where $k \in K$.
- HARQ-ACK(j), $0 \leq j \leq M - 1$, is the ACK/NACK/DTX response for the PDSCH transmission with a corresponding PDCCH and DAI value in the PDCCH equal to ' $j + 1$ '.

A UE shall perform channel selection according to the Tables 10.1.3.2-5, and 10.1.3.2-6 and transmit $b(0), b(1)$ on PUCCH resource $n_{\text{PUCCH}}^{(1)}$ in sub-frame n using PUCCH format 1b according to section 5.4.1 in [3] where "any" represents any response of ACK, NACK, or DTX. The value of $b(0), b(1)$ and the PUCCH resource $n_{\text{PUCCH}}^{(1)}$ are generated by channel selection according to Tables 10.1.3.2-5, and 10.1.3.2-6 for $M = 3$, and 4 respectively.

Table 10.1.3.2-5: Transmission of HARQ-ACK multiplexing for $M = 3$

Primary Cell	Secondary Cell	Resource	Constellation	RM Code Input Bits
HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2)	$n_{\text{PUCCH}}^{(1)}$	$b(0), b(1)$	$o(0), o(1), o(2), o(3)$
ACK, ACK, ACK	ACK, ACK, ACK	$n_{\text{PUCCH},1}^{(1)}$	1, 1	1,1,1,1
ACK, ACK, NACK/DTX	ACK, ACK, ACK	$n_{\text{PUCCH},1}^{(1)}$	0, 0	1,0,1,1
ACK, NACK/DTX, any	ACK, ACK, ACK	$n_{\text{PUCCH},3}^{(1)}$	1, 1	0,1,1,1
NACK/DTX, any, any	ACK, ACK, ACK	$n_{\text{PUCCH},3}^{(1)}$	0, 1	0,0,1,1
ACK, ACK, ACK	ACK, ACK, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	1, 0	1,1,1,0
ACK, ACK, NACK/DTX	ACK, ACK, NACK/DTX	$n_{\text{PUCCH},3}^{(1)}$	1, 0	1,0,1,0

ACK, NACK/DTX, any	ACK, ACK, NACK/DTX	$n_{\text{PUCCH},0}^{(1)}$	0, 1	0,1,1,0
NACK/DTX, any, any	ACK, ACK, NACK/DTX	$n_{\text{PUCCH},3}^{(1)}$	0, 0	0,0,1,0
ACK, ACK, ACK	ACK, NACK/DTX, any	$n_{\text{PUCCH},2}^{(1)}$	1, 1	1, 1, 0, 1
ACK, ACK, NACK/DTX	ACK, NACK/DTX, any	$n_{\text{PUCCH},2}^{(1)}$	0, 1	1, 0, 0, 1
ACK, NACK/DTX, any	ACK, NACK/DTX, any	$n_{\text{PUCCH},2}^{(1)}$	1, 0	0, 1, 0, 1
NACK/DTX, any, any	ACK, NACK/DTX, any	$n_{\text{PUCCH},2}^{(1)}$	0, 0	0, 0, 0, 1
ACK, ACK, ACK	NACK/DTX, any, any	$n_{\text{PUCCH},1}^{(1)}$	1, 0	1, 1, 0, 0
ACK, ACK, NACK/DTX	NACK/DTX, any, any	$n_{\text{PUCCH},1}^{(1)}$	0, 1	1, 0, 0, 0
ACK, NACK/DTX, any	NACK/DTX, any, any	$n_{\text{PUCCH},0}^{(1)}$	1, 1	0, 1, 0, 0
NACK, any, any	NACK/DTX, any, any	$n_{\text{PUCCH},0}^{(1)}$	0, 0	0, 0, 0, 0
DTX, any, any	NACK/DTX, any, any	No Transmission		0, 0, 0, 0

Table 10.1.3.2-6: Transmission of HARQ-ACK multiplexing for $M = 4$

Primary Cell	Secondary Cell	Resource	Constellation	RM Code Input Bits
HARQ-ACK(0), HARQ-ACK(1), HARQ-ACK(2), HARQ-ACK(3)	HARQ-ACK(0), HARQ- ACK(1), HARQ-ACK(2), HARQ-ACK(3)	$n_{\text{PUCCH}}^{(1)}$	$b(0), b(1)$	$o(0), o(1), o(2), o(3)$
ACK, ACK, ACK, NACK/DTX	ACK, ACK, ACK, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	1, 1	1, 1, 1, 1
ACK, ACK, NACK/DTX, any	ACK, ACK, ACK, NACK/DTX	$n_{\text{PUCCH},1}^{(1)}$	0, 0	1, 0, 1, 1
ACK, DTX, DTX, DTX	ACK, ACK, ACK, NACK/DTX	$n_{\text{PUCCH},3}^{(1)}$	1, 1	0, 1, 1, 1
ACK, ACK, ACK, ACK	ACK, ACK, ACK, NACK/DTX	$n_{\text{PUCCH},3}^{(1)}$	1, 1	0, 1, 1, 1
NACK/DTX, any, any, any	ACK, ACK, ACK, NACK/DTX	$n_{\text{PUCCH},3}^{(1)}$	0, 1	0, 0, 1, 1
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	ACK, ACK, ACK, NACK/DTX	$n_{\text{PUCCH},3}^{(1)}$	0, 1	0, 0, 1, 1
ACK, ACK, ACK, NACK/DTX	ACK, ACK, NACK/DTX, any	$n_{\text{PUCCH},0}^{(1)}$	1, 0	1, 1, 1, 0
ACK, ACK, NACK/DTX, any	ACK, ACK, NACK/DTX, any	$n_{\text{PUCCH},3}^{(1)}$	1, 0	1, 0, 1, 0
ACK, DTX, DTX, DTX	ACK, ACK, NACK/DTX, any	$n_{\text{PUCCH},0}^{(1)}$	0, 1	0, 1, 1, 0
ACK, ACK, ACK, ACK	ACK, ACK, NACK/DTX, any	$n_{\text{PUCCH},0}^{(1)}$	0, 1	0, 1, 1, 0
NACK/DTX, any, any, any	ACK, ACK, NACK/DTX, any	$n_{\text{PUCCH},3}^{(1)}$	0, 0	0, 0, 1, 0
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	ACK, ACK, NACK/DTX, any	$n_{\text{PUCCH},3}^{(1)}$	0, 0	0, 0, 1, 0
ACK, ACK, ACK, NACK/DTX	ACK, DTX, DTX, DTX	$n_{\text{PUCCH},2}^{(1)}$	1, 1	1, 1, 0, 1
ACK, ACK, ACK, NACK/DTX	ACK, ACK, ACK, ACK	$n_{\text{PUCCH},2}^{(1)}$	1, 1	1, 1, 0, 1
ACK, ACK, NACK/DTX, any	ACK, DTX, DTX, DTX	$n_{\text{PUCCH},2}^{(1)}$	0, 1	1, 0, 0, 1
ACK, ACK, NACK/DTX, any	ACK, ACK, ACK, ACK	$n_{\text{PUCCH},2}^{(1)}$	0, 1	1, 0, 0, 1
ACK, DTX, DTX, DTX	ACK, DTX, DTX, DTX	$n_{\text{PUCCH},2}^{(1)}$	1, 0	0, 1, 0, 1

ACK, DTX, DTX, DTX	ACK, ACK, ACK, ACK	$n_{\text{PUCCH},2}^{(1)}$	1, 0	0, 1, 0, 1
ACK, ACK, ACK, ACK	ACK, DTX, DTX, DTX	$n_{\text{PUCCH},2}^{(1)}$	1, 0	0, 1, 0, 1
ACK, ACK, ACK, ACK	ACK, ACK, ACK, ACK	$n_{\text{PUCCH},2}^{(1)}$	1, 0	0, 1, 0, 1
NACK/DTX, any, any, any	ACK, DTX, DTX, DTX	$n_{\text{PUCCH},2}^{(1)}$	0, 0	0, 0, 0, 1
NACK/DTX, any, any, any	ACK, ACK, ACK, ACK	$n_{\text{PUCCH},2}^{(1)}$	0, 0	0, 0, 0, 1
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	ACK, DTX, DTX, DTX	$n_{\text{PUCCH},2}^{(1)}$	0, 0	0, 0, 0, 1
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	ACK, ACK, ACK, ACK	$n_{\text{PUCCH},2}^{(1)}$	0, 0	0, 0, 0, 1
ACK, ACK, ACK, NACK/DTX	NACK/DTX, any, any, any	$n_{\text{PUCCH},1}^{(1)}$	1, 0	1, 1, 0, 0
ACK, ACK, ACK, NACK/DTX	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n_{\text{PUCCH},1}^{(1)}$	1, 0	1, 1, 0, 0
ACK, ACK, NACK/DTX, any	NACK/DTX, any, any, any	$n_{\text{PUCCH},1}^{(1)}$	0, 1	1, 0, 0, 0
ACK, ACK, NACK/DTX, any	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n_{\text{PUCCH},1}^{(1)}$	0, 1	1, 0, 0, 0
ACK, DTX, DTX, DTX	NACK/DTX, any, any, any	$n_{\text{PUCCH},0}^{(1)}$	1, 1	0, 1, 0, 0
ACK, DTX, DTX, DTX	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n_{\text{PUCCH},0}^{(1)}$	1, 1	0, 1, 0, 0
ACK, ACK, ACK, ACK	NACK/DTX, any, any, any	$n_{\text{PUCCH},0}^{(1)}$	1, 1	0, 1, 0, 0
ACK, ACK, ACK, ACK	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n_{\text{PUCCH},0}^{(1)}$	1, 1	0, 1, 0, 0
NACK, any, any, any	NACK/DTX, any, any, any	$n_{\text{PUCCH},0}^{(1)}$	0, 0	0, 0, 0, 0
NACK, any, any, any	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n_{\text{PUCCH},0}^{(1)}$	0, 0	0, 0, 0, 0
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	NACK/DTX, any, any, any	$n_{\text{PUCCH},0}^{(1)}$	0, 0	0, 0, 0, 0
(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	$n_{\text{PUCCH},0}^{(1)}$	0, 0	0, 0, 0, 0
DTX, any, any, any	NACK/DTX, any, any, any	No Transmission		0, 0, 0, 0
DTX, any, any, any	(ACK, NACK/DTX, any, any), except for (ACK, DTX, DTX, DTX)	No Transmission		0, 0, 0, 0

10.1.3.2.2 PUCCH format 3 HARQ-ACK procedure

For TDD HARQ-ACK transmission with PUCCH format 3 and sub-frame n with $M \geq 1$ and more than one configured serving cell, where M is the number of elements in the set K defined in Table 10.1.3.1-1, the UE shall use PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ or $n_{\text{PUCCH}}^{(1,\tilde{p})}$ for transmission of HARQ-ACK in subframe n for $\tilde{p}$ mapped to antenna port p where

- for a single PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n - k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X), or for a PDCCH indicating downlink SPS release (defined in section 9.2) in subframe $n - k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1', the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ with $n_{\text{PUCCH}}^{(1,\tilde{p}_0)} = (M - m - 1) \cdot N_c + m \cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{(1)}$ for antenna port p_0 , where $N_{\text{PUCCH}}^{(1)}$ is configured by higher layers, c is selected from $\{0, 1, 2, 3\}$ such that $N_c \leq n_{\text{CCE},m} < N_{c+1}$,

$$N_c = \max\left\{0, \left\lfloor \frac{N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)}{36} \right\rfloor\right\}$$
, and $n_{\text{CCE},m}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n - k_m$ where $k_m \in K$. When two antenna port transmission is configured for PUCCH format 1a/1b, the PUCCH resource for antenna port p_1 is given by

$$n_{\text{PUCCH}}^{(1,\tilde{p}_1)} = n_{\text{PUCCH}}^{(1,\tilde{p}_0)} + 1$$
- for a single PDSCH transmission only on the primary cell where there is not a corresponding PDCCH detected within subframe(s) $n - k$, where $k \in K$ and no PDCCH indicating downlink SPS release (defined in section 9.2) within subframe(s) $n - k$, where $k \in K$, the UE shall use PUCCH format 1a/1b and PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ with the value of $n_{\text{PUCCH}}^{(1,\tilde{p})}$ is determined according to higher layer configuration and Table 9.2-2. For a UE configured for two antenna port transmission for PUCCH format 1a/1b, a PUCCH resource value in Table 9.2-2 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_1)}$ for antenna port p_1 , otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p}_0)}$ for antenna port p_0 .
- for $M > 1$ and a PDSCH transmission only on the primary cell where there is not a corresponding PDCCH detected within subframe(s) $n - k$, where $k \in K$ and an additional PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n - k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1' (defined in Table 7.3-X) or a PDCCH indicating downlink SPS release (defined in section 9.2) in subframe $n - k_m$, where $k_m \in K$ with the DAI value in the PDCCH equal to '1', the UE shall transmit $b(0), b(1)$ in subframe n using PUCCH format 1b on PUCCH resource $n_{\text{PUCCH}}^{(i)}$ selected from A PUCCH resources $n_{\text{PUCCH},i}^{(i)}$ where $0 \leq i \leq A - 1$, according to Table 10.1.3.2-1 and Table 10.1.3.2-2 for $A = 2$ and $A = 3$, respectively. For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, $A = 3$; otherwise, $A = 2$.
 - o The PUCCH resource $n_{\text{PUCCH},0}^{(i)}$ is determined according to higher layer configuration and Table 9.2-2. The PUCCH resource $n_{\text{PUCCH},1}^{(i)}$ is determined as

$$n_{\text{PUCCH},1}^{(i)} = (M - m - 1) \cdot N_c + m \cdot N_{c+1} + n_{\text{CCE},m} + N_{\text{PUCCH}}^{(i)}$$
, where $N_{\text{PUCCH}}^{(i)}$ is configured by higher layers, c is selected from $\{0, 1, 2, 3\}$ such that $N_c \leq n_{\text{CCE},m} < N_{c+1}$,

$$N_c = \max\left\{0, \left\lfloor \frac{N_{\text{RB}}^{\text{DL}} \cdot (N_{\text{sc}}^{\text{RB}} \cdot c - 4)}{36} \right\rfloor\right\}$$
, and $n_{\text{CCE},m}$ is the number of the first CCE used for transmission of the corresponding PDCCH in subframe $n - k_m$ where $k_m \in K$. For a UE configured with a transmission mode that supports up to two transport blocks on the primary cell, the PUCCH resource $n_{\text{PUCCH},2}^{(i)}$ is determined as $n_{\text{PUCCH},2}^{(i)} = n_{\text{PUCCH},1}^{(i)} + 1$. HARQ-ACK(0) is the ACK/NACK/DTX response for the PDSCH without a corresponding PDCCH detected. HARQ-ACK(1) is the ACK/NACK/DTX response for the first transport block of the PDSCH indicated by the detection of a corresponding PDCCH for which the value of the DAI field in the corresponding DCI format is equal to '1' or for the PDCCH indicating downlink SPS release for which the value of the DAI field in the corresponding DCI format is equal to '1'. HARQ-ACK(2) is the ACK/NACK/DTX response for the second transport block of the PDSCH indicated by the detection of a corresponding PDCCH for which the value of the DAI field in the corresponding DCI format is equal to '1'.

- for $M > 1$ and a PDSCH transmission only on the primary cell indicated by the detection of a corresponding PDCCH in subframe $n - k_m$, where $k_m \in K$ with the DAI value in the PDCCH greater than '1' (defined in Table 7.3-X) or a PDCCH indicating downlink SPS release (defined in section 9.2) in subframe $n - k_m$, where $k_m \in K$ with the DAI value in the PDCCH greater than '1', the UE shall use PUCCH format 3 and PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\text{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1 and the TPC field in a PDCCH assignment with DAI value greater than '1' shall be used to determine the PUCCH resource value from one of the four PUCCH resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all PDCCH assignments used to determine the PUCCH resource values within the subframe(s) $n - k$, where $k \in K$.
- for a PDSCH transmission on the secondary cell indicated by the detection of a corresponding PDCCH within subframe(s) $n - k$, where $k \in K$, the UE shall use PUCCH format 3 and PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ where the value of $n_{\text{PUCCH}}^{(3,\tilde{p})}$ is determined according to higher layer configuration and Table 10.1.2.2.2-1 and the TPC field in the corresponding PDCCH shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. If a PDCCH corresponding to a PDSCH on the primary cell within subframe(s) $n - k$, where $k \in K$, or a PDCCH indicating downlink SPS release (defined in section 9.2) within subframe(s) $n - k$, where $k \in K$, is detected, the TPC field in the PDCCH with the DAI value greater than '1' shall be used to determine the PUCCH resource value from one of the four resource values configured by higher layers, with the mapping defined in Table 10.1.2.2.2-1. A UE shall assume that the same HARQ-ACK PUCCH resource value is transmitted on all PDCCH assignments in the primary cell and in each secondary cell that are used to determine the PUCCH resource value within the subframe(s) $n - k$, where $k \in K$.
- For PUCCH format 3 and PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p})}$ and a UE configured for two antenna port transmission, a PUCCH resource value in Table 10.1.2.2.2-1 maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_1)}$ for antenna port p_1 , otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH}}^{(3,\tilde{p}_0)}$ for antenna port p_0 .

10.1.4 HARQ-ACK Repetition procedure

HARQ-ACK repetition is enabled or disabled by a UE specific parameter *ackNackRepetition* configured by higher layers. Once enabled, the UE shall repeat any HARQ-ACK transmission with a repetition factor N_{ANRep} , where N_{ANRep} is provided by higher layers and includes the initial HARQ-ACK transmission, until HARQ-ACK repetition is disabled by higher layers. For a PDSCH transmission without a corresponding PDCCH detected, the UE shall transmit the corresponding HARQ-ACK response N_{ANRep} times using PUCCH resource $n_{\text{PUCCH}}^{(1,\tilde{p})}$ configured by higher layers. For a PDSCH transmission with a corresponding PDCCH detected, or for a PDCCH indicating downlink SPS release, the UE shall first transmit the corresponding HARQ-ACK response once using PUCCH resource derived from the corresponding PDCCH CCE index (as described in Sections 10.1.2 and 10.1.3), and repeat the transmission of the corresponding HARQ-ACK response $N_{\text{ANRep}} - 1$ times always using PUCCH resource $n_{\text{PUCCH,ANRep}}^{(1,\tilde{p})}$, where $n_{\text{PUCCH,ANRep}}^{(1,\tilde{p})}$ is configured by higher layers.

HARQ-ACK repetition is only applicable for UEs configured with one serving cell for FDD and TDD. For TDD, HARQ-ACK repetition is only applicable for HARQ-ACK bundling.

HARQ-ACK repetition can be enabled with PUCCH format 1a/1b on two antenna ports. For a UE configured for two antenna port transmission for HARQ-ACK repetition with PUCCH format 1a/1b, a PUCCH resource value $n_{\text{PUCCH,ANRep}}^{(1,\tilde{p})}$ maps to two PUCCH resources with the first PUCCH resource $n_{\text{PUCCH,ANRep}}^{(1,\tilde{p}_0)}$ for antenna port p_0 and the second PUCCH resource $n_{\text{PUCCH,ANRep}}^{(1,\tilde{p}_1)}$ for antenna port p_1 , otherwise, the PUCCH resource value maps to a single PUCCH resource $n_{\text{PUCCH,ANRep}}^{(1,\tilde{p}_0)}$ for antenna port p_0 .

10.1.5 Scheduling Request (SR) procedure

A UE is configured by higher layers to transmit the scheduling request (SR) on one antenna port or two antenna ports. The scheduling request shall be transmitted on the PUCCH resource(s) $n_{\text{PUCCH}}^{(1,\tilde{p})} = n_{\text{PUCCH,SRI}}^{(1,\tilde{p})}$ for $\tilde{p}$ mapped to antenna port p as defined in [3], where $n_{\text{PUCCH,SRI}}^{(1,\tilde{p})}$ is configured by higher layers unless the SR coincides in time with the transmission of HARQ-ACK using PUCCH Format 3 in which case the SR is multiplexed with HARQ-ACK according to section 5.2.3.1 of [4]. The SR configuration for SR transmission periodicity $SR_{\text{PERIODICITY}}$ and SR subframe offset $N_{\text{OFFSET,SR}}$ is defined in Table 10.1.5-1 by the parameter $sr\text{-}ConfigIndex$ I_{SR} given by higher layers.

SR transmission instances are the uplink subframes satisfying

$$(10 \times n_f + \lfloor n_s / 2 \rfloor - N_{\text{OFFSET,SR}}) \bmod SR_{\text{PERIODICITY}} = 0.$$

Table 10.1.5-1: UE-specific SR periodicity and subframe offset configuration

SR configuration Index I_{SR}	SR periodicity (ms) $SR_{\text{PERIODICITY}}$	SR subframe offset $N_{\text{OFFSET,SR}}$
0 – 4	5	I_{SR}
5 – 14	10	$I_{\text{SR}} - 5$
15 – 34	20	$I_{\text{SR}} - 15$
35 – 74	40	$I_{\text{SR}} - 35$
75 – 154	80	$I_{\text{SR}} - 75$
155 – 156	2	$I_{\text{SR}} - 155$
157	1	$I_{\text{SR}} - 157$

10.2 Uplink HARQ-ACK timing

For FDD, the UE shall upon detection of a PDSCH transmission in subframe $n-4$ intended for the UE and for which an HARQ-ACK shall be provided, transmit the HARQ-ACK response in subframe n . If HARQ-ACK repetition is enabled, upon detection of a PDSCH transmission in subframe $n-4$ intended for the UE and for which HARQ-ACK response shall be provided, and if the UE is not repeating the transmission of any HARQ-ACK in subframe n corresponding to a PDSCH transmission in subframes $n - N_{\text{ANRep}} - 3, \dots, n - 5$, the UE:

- shall transmit only the HARQ-ACK response (corresponding to the detected PDSCH transmission in subframe $n-4$) on PUCCH in subframes $n, n+1, \dots, n + N_{\text{ANRep}} - 1$;
- shall not transmit any other signal in subframes $n, n+1, \dots, n + N_{\text{ANRep}} - 1$; and
- shall not transmit any HARQ-ACK response repetitions corresponding to any detected PDSCH transmission in subframes $n-3, \dots, n + N_{\text{ANRep}} - 5$.

For TDD, the UE shall upon detection of a PDSCH transmission within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1 intended for the UE and for which HARQ-ACK response shall be provided, transmit the HARQ-ACK response in UL subframe n . If HARQ-ACK repetition is enabled, upon detection of a PDSCH transmission within subframe(s) $n-k$, where $k \in K$ and K is defined in Table 10.1.3.1-1 intended for the UE and for which HARQ-ACK response shall be provided, and if the UE is not repeating the transmission of any HARQ-ACK in subframe n corresponding to a PDSCH transmission in a DL subframe earlier than subframe $n-k$, the UE:

- shall transmit only the HARQ-ACK response (corresponding to the detected PDSCH transmission in subframe $n-k$) on PUCCH in UL subframe n and the next $N_{\text{ANRep}} - 1$ UL subframes denoted as $n_1, \dots, n_{N_{\text{ANRep}}-1}$;
- shall not transmit any other signal in UL subframe $n, n_1, \dots, n_{N_{\text{ANRep}}-1}$; and
- shall not transmit any HARQ-ACK response repetitions corresponding to any detected PDSCH transmission in subframes $n_i - k$, where $k \in K_i$, K_i is the set defined in Table 10.1.3.1-1 corresponding to UL subframe n_i , and $1 \leq i \leq N_{\text{ANRep}} - 1$.

For TDD, HARQ-ACK bundling, if the UE detects that at least one downlink assignment has been missed as described in Section 7.3, the UE shall not transmit HARQ-ACK on PUCCH if HARQ-ACK is the only UCI present in a given subframe.

The uplink timing for the ACK corresponding to a detected PDCCH indicating downlink SPS release shall be the same as the uplink timing for the HARQ-ACK corresponding to a detected PDSCH, as defined above.

11 Physical multicast channel related procedures

11.1 UE procedure for receiving the physical multicast channel

The UE shall decode the PMCH when configured by higher layers. The UE may assume that an eNB transmission on the PMCH is performed according to Section 6.5 of [3].

The I_{MCS} for the PMCH is configured by higher layers. The UE shall use I_{MCS} for the PMCH and Table 7.1.7.1-1 to determine the modulation order (Q_m) and TBS index (I_{TBS}) used in the PMCH. The UE shall then follow the procedure in Section 7.1.7.2.1 to determine the transport block size, assuming N_{PRB} is equal to $N_{\text{RB}}^{\text{DL}}$. The UE shall set the redundancy version to 0 for the PMCH.

11.2 UE procedure for receiving MCCH change notification

If a UE is configured by higher layers to decode PDCCHs with the CRC scrambled by the M-RNTI, the UE shall decode the PDCCH according to the combination defined in table 11.2-1.

Table 11.2-1: PDCCH configured by M-RNTI

DCI format	Search Space
DCI format 1C	Common

The 8-bit information for MCCH change notification [11], as signalled on the PDCCH, shall be delivered to higher layers.

Annex A (informative): Change history

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
2006-09					Draft version created		0.0.0
2006-10					Endorsed by RAN1	0.0.0	0.1.0
2007-01					Inclusion of decisions from RAN1#46bis and RAN1#47	0.1.0	0.1.1
2007-01					Endorsed by RAN1	0.1.1	0.2.0
2007-02					Inclusion of decisions from RAN1#47bis	0.2.0	0.2.1
2007-02					Endorsed by RAN1	0.2.1	0.3.0
2007-02					Editor's version including decisions from RAN1#48 & RAN1#47bis	0.3.0	0.3.1
2007-03					Updated Editor's version	0.3.1	0.3.2
2007-03	RAN#35	RP-070171			For information at RAN#35	0.3.2	1.0.0
2007-03					Random access text modified to better reflect RAN1 scope	1.0.0	1.0.1
2007-03					Updated Editor's version	1.0.1	1.0.2
2007-03					Endorsed by RAN1	1.0.2	1.1.0
2007-05					Updated Editor's version	1.1.0	1.1.1
2007-05					Updated Editor's version	1.1.1	1.1.2
2007-05					Endorsed by RAN1	1.1.2	1.2.0
2007-08					Updated Editor's version	1.2.0	1.2.1
2007-08					Updated Editor's version – uplink power control from RAN1#49bis	1.2.1	1.2.2
2007-08					Endorsed by RAN1	1.2.2	1.3.0
2007-09					Updated Editor's version reflecting RAN#50 decisions	1.3.0	1.3.1
2007-09					Updated Editor's version reflecting comments	1.3.1	1.3.2
2007-09					Updated Editor's version reflecting further comments	1.3.2	1.3.3
2007-09					Updated Editor's version reflecting further comments	1.3.3	1.3.4
2007-09					Updated Editor's version reflecting further comments	1.3.4	1.3.5
2007-09	RAN#37	RP-070731			Endorsed by RAN1	1.3.5	2.0.0
2007-09	RAN#37	RP-070737			For approval at RAN#37	2.0.0	2.1.0
12/09/07	RAN_37	RP-070737	-	-	Approved version	2.1.0	8.0.0
28/11/07	RAN_38	RP-070949	0001	2	Update of 36.213	8.0.0	8.1.0
05/03/08	RAN_39	RP-080145	0002	-	Update of TS36.213 according to changes listed in cover sheet	8.1.0	8.2.0
28/05/08	RAN_40	RP-080434	0003	1	PUCCH timing and other formatting and typo corrections	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0006	1	PUCCH power control for non-unicast information	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0008	-	UE ACK/NACK Procedure	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0009	-	UL ACK/NACK timing for TDD	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0010	-	Specification of UL control channel assignment	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0011	-	Precoding Matrix for 2Tx Open-loop SM	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0012	-	Clarifications on UE selected CQI reports	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0013	1	UL HARQ Operation and Timing	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0014	-	SRS power control	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0015	1	Correction of UE PUSCH frequency hopping procedure	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0017	4	Blind PDCCH decoding	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0019	1	Tx Mode vs DCI format is clarified	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0020	-	Resource allocation for distributed VRB	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0021	2	Power Headroom	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0022	-	Clarification for RI reporting in PUCCH and PUSCH reporting modes	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0025	-	Correction of the description of PUSCH power control for TDD	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0026	-	UL ACK/NACK procedure for TDD	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0027	-	Indication of radio problem detection	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0028	-	Definition of Relative Narrowband TX Power Indicator	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0029	-	Calculation of $\Delta_{TE}(l)$ for UL-PC	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0030	-	CQI reference and set S definition, CQI mode removal, and Miscellaneous	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0031	-	Modulation order and TBS determination for PDSCH and PUSCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080434	0032	-	On Sounding RS	8.2.0	8.3.0
28/05/08	RAN_40	RP-080426	0033	-	Multiplexing of rank and CQI/PMI reports on PUCCH	8.2.0	8.3.0
28/05/08	RAN_40	RP-080466	0034	-	Timing advance command responding time	8.2.0	8.3.0
09/09/08	RAN_41	RP-080670	37	2	SRS hopping pattern for closed loop antenna selection	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	39	2	Clarification on uplink power control	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	41	-	Clarification on DCI formats using resource allocation type 2	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	43	2	Clarification on tree structure of CCE aggregations	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	46	2	Correction of the description of PUCCH power control for TDD	8.3.0	8.4.0

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Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
09/09/08	RAN 41	RP-080670	47	1	Removal of CR0009	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	48	1	Correction of mapping of cyclic shift value to PHICH modifier	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	49	-	TBS disabling for DCI formats 2 and 2A	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	50	-	Correction of maximum TBS sizes	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	51	-	Completion of the table specifying the number of bits for the periodic feedback	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	54	-	Clarification of RNTI for PUSCH/PUCCH power control with DCI formats 3/3A	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	55	1	Clarification on mapping of Differential CQI fields	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	59	1	PUSCH Power Control	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	60	-	RB restriction and modulation order for CQI-only transmission on PUSCH	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	61	-	Modulation order determination for uplink retransmissions	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	62	2	Introducing missing L1 parameters into 36.213	8.3.0	8.4.0
09/09/08	RAN_41	RP-080670	63	2	Correcting the range and representation of delta_TF_PUCCH	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	64	1	Adjusting TBS sizes to for VoIP	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	67	-	Correction to the downlink resource allocation	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	68	-	Removal of special handling for PUSCH mapping in PUCCH region	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	69	-	Correction to the formulas for uplink power control	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	70	1	Definition of Bit Mapping for DCI Signalling	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	71	-	Clarification on PUSCH TPC commands	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	72	1	Reference for CQI/PMI Reporting Offset	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	74	-	Correction to the downlink/uplink timing	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	75	-	Correction to the time alignment command	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	77	1	Correction of offset signalling of UL Control information MCS	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	78	2	DCI format 1C	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	80	-	Correction to Precoder Cycling for Open-loop Spatial Multiplexing	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	81	1	Clarifying Periodic CQI Reporting using PUCCH	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	84	1	CQI reference measurement period	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	86	-	Correction on downlink multi-user MIMO	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	87	-	PUCCH Reporting	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	88	1	Handling of Uplink Grant in Random Access Response	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	89	-	Correction to UL Hopping operation	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	90	-	DRS EPRE	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	92	-	Uplink ACK/NACK mapping for TDD	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	93	-	UL SRI Parameters Configuration	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	94	-	Miscellaneous updates for 36.213	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	95	-	Clarifying Requirement for Max PDSCH Coding Rate	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	96	-	UE Specific SRS Configuration	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	97	-	DCI Format 1A changes needed for scheduling Broadcast Control	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	98	-	Processing of TPC bits in the random access response	8.3.0	8.4.0
09/09/08	RAN 41	RP-080670	100	1	Support of multi-bit ACK/NAK transmission in TDD	8.3.0	8.4.0
03/12/08	RAN 42	RP-081075	82	3	Corrections to RI for CQI reporting	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	83	2	Moving description of large delay CDD to 36.211	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	102	3	Reception of DCI formats	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	105	8	Alignment of RAN1/RAN2 specification	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	107	1	General correction of reset of power control and random access response message	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	108	2	Final details on codebook subset restrictions	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	109	-	Correction on the definition of Pmax	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	112	2	CQI/PMI reference measurement periods	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	113	-	Correction of introduction of shortened SR	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	114	-	RAN1/2 specification alignment on HARQ operation	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	115	-	Introducing other missing L1 parameters in 36.213	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	116	-	PDCCH blind decoding	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	117	-	PDCCH search space	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	119	-	Delta_TF for PUSCH	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	120	-	Delta_preamble_msg3 parameter values and TPC command in RA response	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	122	1	Correction of offset signaling of uplink control information MCS	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	124	-	Miscellaneous Corrections	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	125	-	Clarification of the uplink index in TDD mode	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	126	-	Clarification of the uplink transmission configurations	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	127	2	Correction to the PHICH index assignment	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	128	-	Clarification of type-2 PDSCH resource allocation for format 1C	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	129	-	Clarification of uplink grant in random access response	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	130	-	UE sounding procedure	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	134	-	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-081075	135	-	Clarifying UL VRB Allocation	8.4.0	8.5.0

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Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
03/12/08	RAN 42	RP-081075	136	1	Correction for Aperiodic CQI	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	137	1	Correction for Aperiodic CQI Reporting	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	138	1	Correction to PUCCH CQI reporting mode for $N^{DL}_{RB} \leq 7$	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	140	1	On sounding procedure in TDD	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	141	1	Alignment of RAN1/RAN3 specification	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	143	1	TTI bundling	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	144	1	ACK/NACK transmission on PUSCH for LTE TDD	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	145	1	Timing relationship between PHICH and its associated PUSCH	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	147	1	Definition of parameter for downlink reference signal transmit power	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	148	1	Radio link monitoring	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	149	1	Correction in 36.213 related to TDD downlink HARQ processes	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	151	-	Nominal PDSCH-to-RS EPRE Offset for CQI Reporting	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	152	1	Support of UL ACK/NAK repetition in Rel-8	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	155	-	Clarification of misconfiguration of aperiodic CQI and SR	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	156	1	Correction of control information multiplexing in subframe bundling mode	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	157	-	Correction to the PHICH index assignment	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	158	1	UE transmit antenna selection	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	159	-	Clarification of spatial different CQI for CQI reporting Mode 2-1	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	160	1	Corrections for TDD ACK/NACK bundling and multiplexing	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	161	-	Correction to RI for Open-Loop Spatial Multiplexing	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	162	-	Correction of differential CQI	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	163	-	Inconsistency between PMI definition and codebook index	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	164	-	PDCCH validation for semi-persistent scheduling	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	165	1	Correction to the UE behavior of PUCCH CQI piggybacked on PUSCH	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	166	-	Correction on SRS procedure when shortened PUCCH format is used	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	167	1	Transmission overlapping of physical channels/signals with PDSCH for transmission mode 7	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	169	-	Clarification of SRS and SR transmission	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	171	-	Clarification on UE behavior when skipping decoding	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	172	1	PUSCH Hopping operation corrections	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	173	-	Clarification on message 3 transmission timing	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	174	-	MCS handling for DwPTS	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	175	-	Clarification of UE-specific time domain position for SR transmission	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	176	1	Physical layer parameters for CQI reporting	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	177	-	A-periodic CQI clarification for TDD UL/DL configuration 0	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	179	1	Correction to the definitions of ρ_A and ρ_B (downlink power allocation)	8.4.0	8.5.0
03/12/08	RAN 42	RP-081075	180	-	Clarification of uplink A/N resource indication	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	181	-	PDCCH format 0 for message 3 adaptive retransmission and transmission of control information in message 3 during contention based random access procedure	8.4.0	8.5.0
03/12/08	RAN_42	RP-081075	182	-	To Fix the Discrepancy of Uplink Power Control and Channel Coding of Control Information in PUSCH	8.4.0	8.5.0
03/12/08	RAN_42	RP-081122	183	1	CQI reporting for antenna port 5	8.4.0	8.5.0
03/12/08	RAN 42	RP-081110	168	1	Clarification on path loss definition	8.4.0	8.5.0
04/03/09	RAN 43	RP-090236	184	1	Corrections to Transmitted Rank Indication	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	185	4	Corrections to transmission modes	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	186	2	Delta _{TF} configuration for control only PUSCH	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	187	1	Correction to concurrent SRS and ACK/NACK transmission	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	191	1	PDCCH release for semi-persistent scheduling	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	192	1	Correction on ACKNACK transmission on PUSCH for LTE TDD	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	193	-	Correction to subband differential CQI value to offset level mapping for aperiodic CQI reporting	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	194	-	Correction for DRS Collision handling	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	196	2	Alignment of RAN1/RAN4 specification on UE maximum output power	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	197	-	Transmission scheme for transmission mode 7 with SPS C-RNTI	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	198	-	Clarifying bandwidth parts for periodic CQI reporting and CQI reference period	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	199	2	Correction to the ACK/NACK bundling in case of transmission mode 3 and 4	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	200	-	ACK/NAK repetition for TDD ACK/NAK multiplexing	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	201	-	Clarifying UL ACK/NAK transmission in TDD	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	202	-	Corrections to UE Transmit Antenna Selection	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	203	-	Correction to UE PUSCH hopping procedure	8.5.0	8.6.0

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04/03/09	RAN 43	RP-090236	204	-	Correction to PHICH resource association in TTI bundling	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	205	-	Clarification of the length of resource assignment	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	206	-	Correction on ACK/NACK transmission for downlink SPS resource release	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	207	-	Introduction of additional values of wideband CQI/PMI periodicities	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	208	2	Correction to CQI/PMI/RI reporting field	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	209	2	Correction to rho A definition for CQI calculation	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	210	-	Correction to erroneous cases in PUSCH linear block codes	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	211	1	Removing RL monitoring start and stop	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	214	1	Correction to type-1 and type-2 PUSCH hopping	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	215	-	Contradicting statements on determination of CQI subband size	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	216	-	Corrections to SRS	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	219	2	Miscellaneous corrections on TDD ACKNACK	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	221	1	CR for Redundancy Version mapping function for DCI 1C	8.5.0	8.6.0
04/03/09	RAN_43	RP-090236	223	-	Scrambling of PUSCH corresponding to Random Access Response Grant	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	225	-	Removal of SRS with message 3	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	226	3	PRACH retransmission timing	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	227	-	Clarifying error handling of PDSCH and PUSCH assignments	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	228	-	Clarify PHICH index mapping	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	229	-	Correction of CQI timing	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	230	-	Alignment of CQI parameter names with RRC	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	231	1	Removal of 'Off' values for periodic reporting in L1	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	232	-	Default value of RI	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	233	1	Clarification of uplink timing adjustments	8.5.0	8.6.0
04/03/09	RAN 43	RP-090236	234	-	Clarification on ACK/NAK repetition	8.5.0	8.6.0
27/05/09	RAN_44	RP-090529	235	1	Correction to the condition of resetting accumulated uplink power correction	8.6.0	8.7.0
27/05/09	RAN_44	RP-090529	236	-	Correction to the random access channel parameters received from higher layer	8.6.0	8.7.0
27/05/09	RAN 44	RP-090529	237	-	Correction on TDD ACKNACK	8.6.0	8.7.0
27/05/09	RAN 44	RP-090529	238	1	Correction on CQI reporting	8.6.0	8.7.0
27/05/09	RAN 44	RP-090529	239	-	Correction on the HARQ process number	8.6.0	8.7.0
27/05/09	RAN 44	RP-090529	241	1	CR correction of the description on TTI-bundling	8.6.0	8.7.0
27/05/09	RAN_44	RP-090529	242	1	Clarify latest and initial PDCCH for PDSCH and PUSCH transmissions, and NDI for SPS activation	8.6.0	8.7.0
27/05/09	RAN 44	RP-090529	243	-	Clarify DRS EPRE	8.6.0	8.7.0
27/05/09	RAN 44	RP-090529	244	1	Clarification on TPC commands for SPS	8.6.0	8.7.0
15/09/09	RAN 45	RP-090888	245	1	Correction to PUSCH hopping and PHICH mapping procedures	8.7.0	8.8.0
15/09/09	RAN 45	RP-090888	246	-	Clarification on subband indexing in periodic CQI reporting	8.7.0	8.8.0
15/09/09	RAN 45	RP-090888	247	2	Correction to DVRB operation in TDD transmission mode 7	8.7.0	8.8.0
15/09/09	RAN_45	RP-090888	249	-	Clarification of concurrent ACKNACK and periodic PMI/RI transmission on PUCCH for TDD	8.7.0	8.8.0
15/09/09	RAN 45	RP-090888	250	-	Clarify Inter-cell synchronization text	8.7.0	8.8.0
01/12/09	RAN 46	RP-091172	248	1	Introduction of LTE positioning	8.8.0	9.0.0
01/12/09	RAN 46	RP-091172	254	-	Clarification of PDSCH and PRS in combination for LTE positioning	8.8.0	9.0.0
01/12/09	RAN 46	RP-091177	255	5	Editorial corrections to 36.213	8.8.0	9.0.0
01/12/09	RAN 46	RP-091257	256	1	Introduction of enhanced dual layer transmission	8.8.0	9.0.0
01/12/09	RAN 46	RP-091177	257	1	Add shorter SR periodicity	8.8.0	9.0.0
01/12/09	RAN 46	RP-091256	258	-	Introduction of LTE MBMS	8.8.0	9.0.0
17/12/09	RAN_46	RP-091257	256	1	Correction by MCC due to wrong implementation of CR0256r1 – Sentence is added to Single-antenna port scheme section 7.1.1	9.0.0	9.0.1
16/03/10	RAN_47	RP-100211	259	3	UE behavior when collision of antenna port 7/8 with PBCH or SCH happened and when distributed VRB is used with antenna port 7	9.0.1	9.1.0
16/03/10	RAN 47	RP-100210	260	1	MCCH change notification using DCI format 1C	9.0.1	9.1.0
16/03/10	RAN_47	RP-100211	263	-	Correction on PDSCH EPRE and UE-specific RS EPRE for Rel-9 enhanced DL transmissions	9.0.1	9.1.0
01/06/10	RAN_48	RP-100589	265	-	Clarification for TDD when multiplexing ACK/NACK with SR of ACK/NACK with CQI/PMI or RI	9.1.0	9.2.0
01/06/10	RAN 48	RP-100590	268	1	Clarification of PRS EPRE	9.1.0	9.2.0
14/09/10	RAN 49	RP-100900	269	-	Clarification on Extended CP support with Transmission Mode 8	9.2.0	9.3.0
07/12/10	RAN 50	RP-101320	270	-	Introduction of Rel-10 LTE-Advanced features in 36.213	9.3.0	10.0.0
27/12/10	-	-	-	-	Editorial change to correct a copy/past error in section 7.2.2	10.0.0	10.0.1
15/03/11	RAN 51	RP-110255	271	1	A clarification for redundancy version of PMCH	10.0.1	10.1.0
15/03/11	RAN 51	RP-110258	272	-	RLM Procedure with restricted measurements	10.0.1	10.1.0
15/03/11	RAN 51	RP-110256	273	-	Corrections to Rel-10 LTE-Advanced features in 36.213	10.0.1	10.1.0
01/06/11	RAN 52	RP-110819	274	3	Correction to HARQ-ACK procedure for TDD mode b with M=2	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	275	3	Determination of PUSCH A/N codebook size for TDD	10.1.0	10.2.0
01/06/11	RAN 52	RP-110823	276	-	The triggering of aperiodic SRS in DCI formats 2B and 2C	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	278	3	Corrections to power headroom	10.1.0	10.2.0

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
01/06/11	RAN 52	RP-110819	279	1	Removal of square brackets for PUCCH format 3 ACK/NACK	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	281	1	Correction of AN repetition and PUCCH format 3	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	282	2	Correction to timing for secondary cell activation and deactivation	10.1.0	10.2.0
01/06/11	RAN 52	RP-110823	283	1	Correction to MCS offset for multiple TBs	10.1.0	10.2.0
01/06/11	RAN 52	RP-110820	286	1	Miscellaneous Corrections	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	288	1	Corrections on UE procedure for determining PUCCH Assignment	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	289	2	Correction to Multi-cluster flag in DCI format 0	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	290	2	Joint transmission of ACK/NACK and SR with PUCCH format 3	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	291	3	Correction of uplink resource allocation type 1	10.1.0	10.2.0
01/06/11	RAN 52	RP-110821	292	1	Correction on CSI-RS configuration	10.1.0	10.2.0
01/06/11	RAN 52	RP-110818	294	-	ACK/NACK and CQI simultaneous transmission in ACK/NACK bundling in TDD	10.1.0	10.2.0
01/06/11	RAN 52	RP-110823	295	-	UE specific disabling of UL DMRS sequence hopping	10.1.0	10.2.0
01/06/11	RAN 52	RP-110821	296	-	PDSCH transmission in MBSFN subframes	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	297	-	Introduction of PCMAX for PUSCH power scaling	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	298	-	Power control for SR and ACK/NACK with PUCCH format 3	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	299	2	CR on power control for HARQ-ACK transmission on PUCCH	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	300	2	Correction to handling of search space overlap	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	301	1	Correction to simultaneous transmission of SRS and PUCCH format 2/2a/2b	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	302	1	Correction for Simultaneous PUCCH and SRS Transmissions on CA	10.1.0	10.2.0
01/06/11	RAN 52	RP-110821	303	-	Correction on 8Tx Codebook Sub-sampling for PUCCH Mode 1-1	10.1.0	10.2.0
01/06/11	RAN 52	RP-110821	304	1	Corrections on CQI type in PUCCH mode 2-1 and clarification on simultaneous PUCCH and PUSCH transmission for UL-SCH subframe bundling	10.1.0	10.2.0
01/06/11	RAN 52	RP-110818	305	1	Correction on UE behaviour upon reporting periodic CSI using PUCCH Mode1-1	10.1.0	10.2.0
01/06/11	RAN 52	RP-110818	306	-	Clarification for the definition of CQI	10.1.0	10.2.0
01/06/11	RAN 52	RP-110818	307	-	Clarification for the definition of Precoding Matrix Indicator	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	308	-	Simultaneous SRS transmissions in more than one cell	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	310	1	Miscellaneous Corrections for TS36.213	10.1.0	10.2.0
01/06/11	RAN 52	RP-110821	311	1	Configuration of pmi-RI-Report	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	312	1	Correction on the support of PUCCH format 3 and channel selection	10.1.0	10.2.0
01/06/11	RAN 52	RP-110821	313	-	Correction on UE behaviour during DM-RS transmission on subframes carrying synchronisation signals	10.1.0	10.2.0
01/06/11	RAN 52	RP-110820	314	1	36.213 CR on antenna selection	10.1.0	10.2.0
01/06/11	RAN 52	RP-110823	316	1	Number of HARQ process for UL spatial multiplexing	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	317	-	PUCCH format 3 Fallback procedure in TDD	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	318	-	Clarification on CSI reporting under an invalid downlink subframe	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	320	-	Multiple Aperiodic SRS Triggers for Same Configuration	10.1.0	10.2.0
01/06/11	RAN 52	RP-110823	321	-	UE antenna switch in UL MIMO	10.1.0	10.2.0
01/06/11	RAN 52	RP-110819	322	-	UE behaviour for PDSCH reception with limited soft buffer in CA	10.1.0	10.2.0
01/06/11	RAN 52	RP-110859	323	-	Joint transmission of ACK/NACK and SR or CSI with PUCCH format 3 and channel selection	10.1.0	10.2.0
15/09/11	RAN 53	RP-111229	277	1	Correction to reception of PRS in MBSFN subframes	10.2.0	10.3.0
15/09/11	RAN 53	RP-111230	325	3	Corrections on UE procedure for reporting HARQ-ACK	10.2.0	10.3.0
15/09/11	RAN 53	RP-111230	326	2	Corrections on Physical Uplink Control Channel Procedure	10.2.0	10.3.0
15/09/11	RAN 53	RP-111231	331	1	Correction to uplink transmission scheme usage for random access response and PHICH-triggered retransmissions	10.2.0	10.3.0
15/09/11	RAN 53	RP-111229	336	-	Corrections on transmission mode 9	10.2.0	10.3.0
15/09/11	RAN 53	RP-111230	339	-	Corrections on HARQ-ACK codebook size determination	10.2.0	10.3.0
15/09/11	RAN 53	RP-111230	340	-	Corrections on TDD PUCCH format 1b with channel selection and HARQ-ACK transmission on PUSCH	10.2.0	10.3.0
15/09/11	RAN 53	RP-111230	341	-	Corrections on NACK generation	10.2.0	10.3.0
15/09/11	RAN 53	RP-111230	342	-	Corrections on power headroom reporting	10.2.0	10.3.0
15/09/11	RAN 53	RP-111229	346	-	Correction on TBS translation table	10.2.0	10.3.0
15/09/11	RAN 53	RP-111229	347	2	Correction to the condition of enabling PMI feedback	10.2.0	10.3.0
15/09/11	RAN 53	RP-111232	348	-	Miscellaneous corrections to 36.213	10.2.0	10.3.0
15/09/11	RAN 53	RP-111229	349	-	Corrections on PUSCH and PUCCH modes	10.2.0	10.3.0
15/09/11	RAN 53	RP-111231	350	1	CR on UL HARQ ACK determination	10.2.0	10.3.0
15/09/11	RAN 53	RP-111231	351	1	Correction on UL DMRS resources for PHICH-triggered retransmission	10.2.0	10.3.0
15/09/11	RAN 53	RP-111230	352	-	Clarification on the common search space description	10.2.0	10.3.0
15/09/11	RAN 53	RP-111232	353	1	Clarification on ambiguous DCI information between UE-specific search space and common search space for DCI formats 0 and 1A	10.2.0	10.3.0
15/09/11	RAN 53	RP-111229	354	-	Clarification of Reference PDSCH Power for CSI-RS based CSI Feedback	10.2.0	10.3.0
15/09/11	RAN 53	RP-111230	355	2	Corrections on reporting Channel State Information	10.2.0	10.3.0

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
05/12/11	RAN_54	RP-111669	324	3	Accumulation of power control commands from DCI format 3/3A	10.3.0	10.4.0
05/12/11	RAN_54	RP-111666	357	1	Miscellaneous corrections on uplink power control	10.3.0	10.4.0
05/12/11	RAN_54	RP-111666	358	-	Corrections on N_c^{received}	10.3.0	10.4.0
05/12/11	RAN_54	RP-111666	359	-	Corrections on TDD PUCCH format 1b with channel selection and two configured serving cells	10.3.0	10.4.0
05/12/11	RAN_54	RP-111666	360	-	Corrections on the notation of k and k_m	10.3.0	10.4.0
05/12/11	RAN_54	RP-111668	361	1	Corrections on PUCCH mode 2-1	10.3.0	10.4.0
05/12/11	RAN_54	RP-111668	362	3	A correction to PDSCH transmission assumption for CQI calculation	10.3.0	10.4.0
05/12/11	RAN_54	RP-111666	363	1	Corrections on PUCCH Resource Notation	10.3.0	10.4.0
05/12/11	RAN_54	RP-111667	364	-	Correction on the notation of SRS transmission comb	10.3.0	10.4.0
05/12/11	RAN_54	RP-111666	365	-	Clarification on the HARQ-ACK procedure of TDD UL-DL configuration 5	10.3.0	10.4.0
05/12/11	RAN_54	RP-111666	366	2	Clarification on the determination of resource for PUCCH Format 1b with channel selection in TDD mode	10.3.0	10.4.0
05/12/11	RAN_54	RP-111666	367	1	Correction on HARQ-ACK procedure	10.3.0	10.4.0
05/12/11	RAN_54	RP-111666	368	-	Correction for A/N on PUSCH with $W=1,2$ in case of TDD channel selection	10.3.0	10.4.0
05/12/11	RAN_54	RP-111668	369	-	Clarification of PUCCH 2-1 Operation	10.3.0	10.4.0
05/12/11	RAN_54	RP-111668	370	1	Correction on PMI index	10.3.0	10.4.0
05/12/11	RAN_54	RP-111666	371	2	Correction to periodic CSI reports for carrier aggregation	10.3.0	10.4.0
05/12/11	RAN_54	RP-111666	373	1	Removal of square bracket in HARQ-ACK procedure	10.3.0	10.4.0
05/12/11	RAN_54	RP-111666	374	1	Clarification on UE's capability of supporting PUCCH format 3	10.3.0	10.4.0
05/12/11	RAN_54	RP-111666	375	1	Clarifications of UE behavior on PUSCH power control	10.3.0	10.4.0

Agenda Item:

6.2.3.1

WF on 256QAM CQI table design

Huawei, HiSilicon, CATR, Panasonic,
III, CATT, Broadcom, Nokia, NSN,
Microsoft, CMCC, CTC, Intel, Ericsson

Background

- It was agreed in RAN1 #76b for CQI table
 - Switching point of 64QAM and 256QAM should be CQI 15 in the existing table
 - The modulation order of existing CQI 15 is changed to 256QAM
 - Working assumption: down-sample low CQI entries by removing 3 QPSK entries, and add 3 new entries for 256QAM region
 - Revisit if problems if significant issues are found
 - The 3 entries to be removed are either {#1, #3, #5} or {#2, #4, #6}
 - The last 4 entries will be for 256QAM, but the actual SE is FFS
 - Order the CQI indices in the Rel-12 CQI table according to the spectral efficiencies

Observations

- Observations from submitted contributions in RAN1 77 on the open issues for CQI table design
 - Removing 3 existing QPSK entries
 - 11 companies {#2,#4,#6}
 - 5 companies {#1,#3,#5}
 - Spectrum efficiency (SE) for the first 256QAM entry
 - 14(all) companies 5.5547
 - Spectrum efficiency (SE) for the last 256QAM entry
 - 12 companies 7.4063
 - 1 company 7.4375, 1 company 7.3594
 - Spectrum efficiency (SE) for the middle 256QAM entries
 - 5 companies propose equal spectral efficiency interval: 6.1719, 6.7891
 - 10 companies propose equal SINR internal with different values

Proposals

- Confirm the working assumption
 - down-sample low CQI entries by removing 3 QPSK entries, and add 3 new entries for 256QAM region
- The 3 QPSK entries to be removed are existing {#2, #4, #6}
- Spectrum efficiency (SE) for the first 256QAM entry is 5.5547
- Spectrum efficiency (SE) for the last 256QAM entry is 7.4063
- Spectrum efficiency (SE) for the middle 256QAM entries are down-selected between 2 options in RAN1 #77
 - Option1: 6.1719, 6.7891
 - Option2*: 6.2237, 6.9153

*: average value from the results with equal SINR interval between [5,5547, 7.4063]

Proposals

- The Rel-12 CQI table with 256QAM is proposed to be selected between table 1 and table 2 in RAN1 #77 meeting

Table1:

CQI index	CQI index in current table	Modulation in current table	Modulation	Code rate x 1024	Efficiency
0	0		out of range		
1	1	QPSK	QPSK	78	0.1523
2	3	QPSK	QPSK	193	0.3770
3	5	QPSK	QPSK	449	0.8770
4	7	16QAM	16QAM	378	1.4766
5	8	16QAM	16QAM	490	1.9141
6	9	16QAM	16QAM	616	2.4063
7	10	64QAM	64QAM	466	2.7305
8	11	64QAM	64QAM	567	3.3223
9	12	64QAM	64QAM	666	3.9023
10	13	64QAM	64QAM	772	4.5234
11	14	64QAM	64QAM	873	5.1152
12	15	64QAM	256QAM	711	5.5547
13	-		256QAM	790	6.1719
14	-		256QAM	869	6.7891
15	-		256QAM	948	7.4063

Proposals

• Table 2

CQI index	CQI index in current table	Modulation in current table	Modulation	Code rate x 1024	Efficiency
0	0			out of range	
1	1	QPSK	QPSK	78	0.1523
2	3	QPSK	QPSK	193	0.3770
3	5	QPSK	QPSK	449	0.8770
4	7	16QAM	16QAM	378	1.4766
5	8	16QAM	16QAM	490	1.9141
6	9	16QAM	16QAM	616	2.4063
7	10	64QAM	64QAM	466	2.7305
8	11	64QAM	64QAM	567	3.3223
9	12	64QAM	64QAM	666	3.9023
10	13	64QAM	64QAM	772	4.5234
11	14	64QAM	64QAM	873	5.1152
12	15	64QAM	256QAM	711	5.5547
13	-		256QAM	797	6.2237
14	-		256QAM	885	6.9153
15	-		256QAM	948	7.4063

Agenda Item: 7.2.4.1
Source: Huawei, HiSilicon
Title: CQI/MCS table design for 256QAM
Document for: Discussion and decision

1 Introduction

In RAN#62, the following objective was agreed for Small Cell Enhancements work item [1]:

- Spectrum efficiency enhancement with introduction of higher order modulation, i.e., 256QAM, in the downlink transmission, while keeping existing size of CQI feedback field and MCS indication.

In this contribution, we briefly review the principles of CQI/MCS table design in previous releases. Then the analysis and proposals for the new CQI/MCS table are provided to support 256QAM.

2 Principles and proposals for CQI/MCS design

2.1 CQI table design

The CQI table is used to support downlink adaptive modulation and coding. The design principles for the current CQI table are summarized as below [2] [3][4]:

- AWGN channel is assumed for generating the CQI table
- 15-entry CQI table with approximately equal step size in equivalent SNR
 - o It starts with -7dB as the 1st point and the spacing is 1.892 dB, thus the SNR range is [-7, 19.488]dB
 - o CQI index#1 with spectral efficiency = 0.1523 is used for PDCCH only
- The modulation order switching points in the CQI table should consider the frequency selectivity
 - o The modulation order switching points (i.e., QPSK to 16QAM and 16QAM to 64QAM) are determined by further evaluating the MCSs in the frequency selective channel. As is usually observed in the OFDM transmission, it is desirable to replace a few entries having lower modulation order and higher code rate by those having higher modulation order and lower code rate for an improved performance in the frequency selective channel.

Having the above principles in mind, the analysis and considerations for new CQI entry design with the introduction of 256QAM are discussed in this sub-section.

Figure 1 shows the simulation results of spectral efficiency vs. SNR with different modulation order and coding rate in AWGN channel (BLER=0.1).

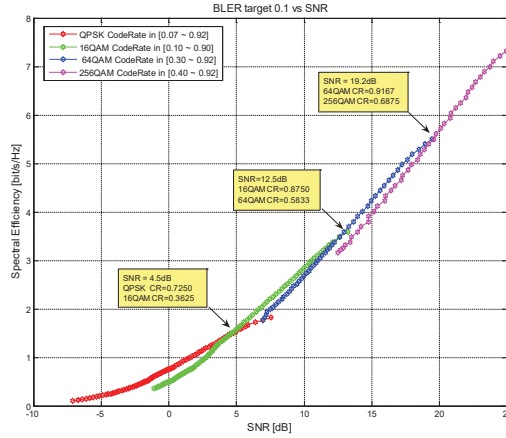


Figure 1. Spectral efficiency vs. SNR when BLER is 0.1

New CQI entries to support 256QAM

In order to support 256QAM transmission, the maximum efficiency of the current CQI table needs to be expanded. Since the maximum efficiency supported by current CQI table is 5.5547, the introduction of 256QAM can directly increase the efficiency to $5.5547 \times 8/6 = 7.4063$. The corresponding SNR where the spectral efficiency of 256QAM starts to saturate is around 25dB.

Following the previous principle, the CQI entries for 256QAM could be determined using an equal step size in equivalent SNR between 5.5547 and 7.4063. Since the curve of efficiency vs. SNR is almost linear in Figure 1, the new CQI entries for 256QAM could be samples based on approximately equal step size in spectral efficiency. For example, if 3 new CQI entries are introduced for 256QAM, the efficiency corresponding to each entry is 6.1719, 6.7891 and 7.4063. It is noted that the SNR step of the three new CQI entries is similar to the previous space size of 1.892dB due to the linearity of efficiency vs. SNR curve.

Proposal 1-1:

- The maximum efficiency for 256QAM CQI entry is $5.5547 \times 8/6 = 7.4063$
- Three new CQI entries are introduced for 256QAM, the efficiency corresponding to each entry is 6.1719, 6.7891, 7.4063

CQI index	Modulation	Code rate $\times 1024$	efficiency
13	256QAM	790	6.1719
14	256QAM	869	6.7891
15	256QAM	948	7.4063

Range of CQI region

With non-full buffer traffic, a cell edge UE may also benefit from 256QAM if the interfering cells are light-loaded or even turned off due to the traffic variation. This implies that the experienced SINR of a 256QAM UE may fluctuate in a large region in an interference limited scenario. Figure 2 shows typical CQI distribution of all UEs that using 256QAM in scenario 2b (sparse). Tx/Rx EVM is assumed as 4% and 2%. RU is about 30%. Other simulation assumptions are the same as [6]. It can be observed that the SNR region of out of range & QPSK have considerable chance to be scheduled (~12%) for 256QAM UEs. Therefore, CQI table for 256QAM should still reserve some entries for the low SNR region.

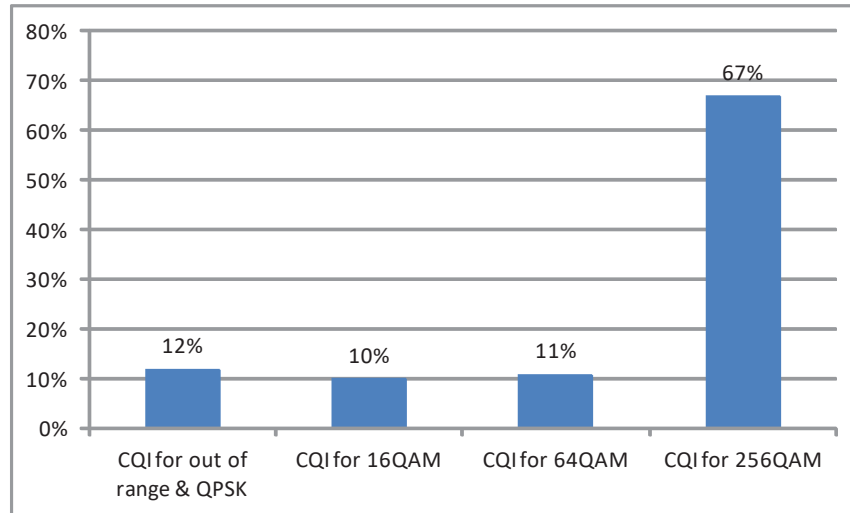


Figure 2: PDF of typical CQI distribution.

Since three new CQI entries are introduced for 256QAM transmission, three lower entries need to be removed to keep the table size as before. CQI index #0 should be reserved for out of range indication. CQI index #1 should be reserved for PDCCH transmission and downlink power control. CQI index #2 should also be reserved since it corresponds to the $I_{MCS}=0$ in the MCS table, which is the starting point of the interpolation of spectral efficiencies for the following MCS entries. Thus, one possibility is to remove the current CQI entries #3, #5 and #7. Other CQI entries should be remained unchanged in order to save standards effort in the following MCS and TBS table designs.

There are proposals to enlarge the CQI range to include 256QAM, e.g., [-7dB, 25dB], where each entry has approximately equal, but larger step size in equivalent SNR. This method requires totally new design of the CQI entries, and would result in the new design of the entire MCS and TBS tables, which is a significant standard effort and is therefore undesirable.

Proposal 1-2:

- **CQI table for 256QAM should reserve some entries for low SNR region**
 - o **Current CQI entries #0, #1 and #2 should be reserved**
 - o **Current CQI entries #3, #5 and #7 can be removed**
- **Other CQI entries should be reserved**

Switching point design of 64QAM and 256QAM

As summarized in the beginning of the section, the modulation order switching points in the CQI table should consider frequency selectivity. Thus we provide the link level simulations in Figure 3 and Figure 4 to evaluate the BLER of the same spectral efficiency with rank 1 and rank 2, respectively, but with different modulation order and coding rate in the EPA channel to find a reasonable switching point between 64QAM and 256QAM. CQI=14.5 means an average spectral efficiency of CQI index 14 and CQI index 15.

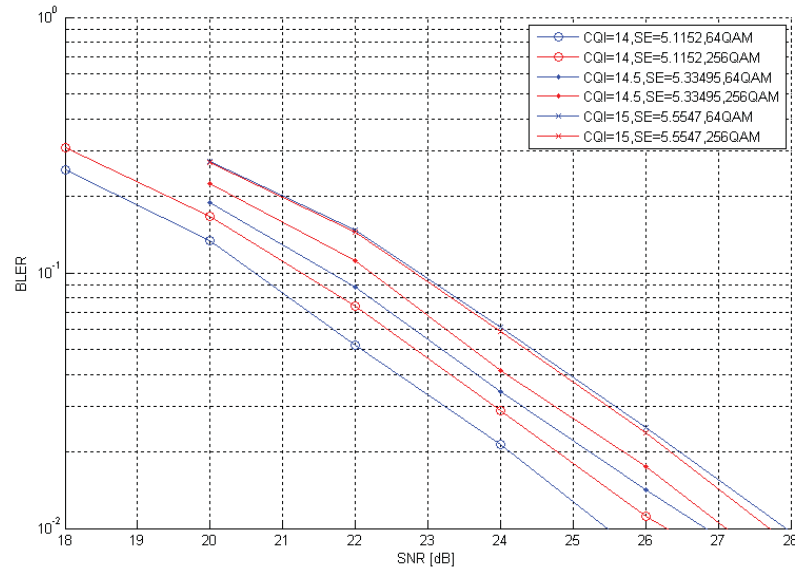


Figure 3: 64QAM/256QAM BLER comparison of the same spectral efficiency in the EPA channel with rank 1

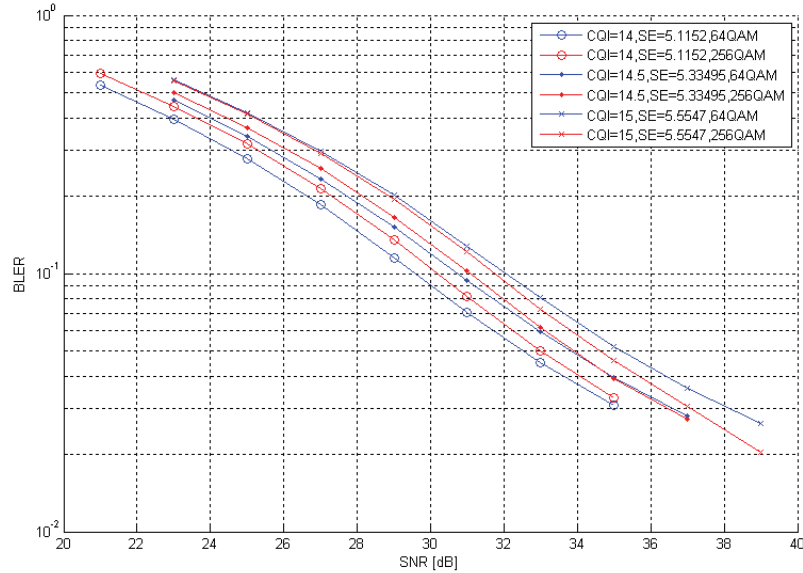


Figure 4: 64QAM/256QAM BLER comparison of the same spectral efficiency in the EPA channel with rank 2

It is observed that the spectral efficiency of 5.33495 for 64QAM outperforms 256QAM, while the spectral efficiency of 5.5547 for 256QAM outperforms 64QAM. Thus the switching point of 64QAM and 256QAM spectral efficiency should be lower than 5.5547.

The spectral efficiency of CQI index 15 in the current table is 5.5547, thus 256QAM will outperforms 64QAM in a frequency selective channel. It is therefore proposed that the modulation scheme of CQI index 15 is changed to 256QAM, while the spectral efficiency value could be maintained to reduce impact on MCS/TBS tables.

Proposal 1-3:

- **The modulation order of CQI index 15 is changed to 256QAM**
 - **The spectral efficiency could be maintained to reduce impact on MCS/TBS tables**

An example based on the above principles is shown as Table 1:

Table 1: Proposed 4-bit CQI table for 256QAM

CQI index	CQI index in current table	Modulation	Code rate x 1024	Efficiency
0	0	out of range		
1	1	QPSK	78	0.1523
2	2	QPSK	120	0.2344
3	4	QPSK	308	0.6016
4	6	QPSK	602	1.1758
5	8	16QAM	490	1.9141
6	9	16QAM	616	2.4063
7	10	64QAM	466	2.7305
8	11	64QAM	567	3.3223
9	12	64QAM	666	3.9023
10	13	64QAM	772	4.5234
11	14	64QAM	873	5.1152
12	15	256QAM	711	5.5547
13	-	256QAM	790	6.1719
14	-	256QAM	869	6.7891
15	-	256QAM	948	7.4063

2.2 MCS table design

The design principles for the current MCS table are summarized as below [4]:

- A 5-bit MCS table with 3 reserved entries for modulation order signaling
- CQI values taken as starting point for design
 - o 14 out of the 15 CQI values appear in the CQI table, i.e., CQI index 2~15
- Two MCSs defined in the overlap region ($r=0.66$ QPSK and $r=0.33$ 16QAM) and ($r=0.64$ 16QAM and $r=0.43$ 64QAM)
- The remaining 13 MCS entries chosen as equally spaced between adjacent spectral efficiencies.

As described above, the spectral efficiency of each MCS/TBS entry can be mapped to CQI entry as in Table 2, along with the corresponding spectral efficiency. According to the design in Table 1, current CQI entries #3, #5 and #7 are removed, thus the 7 MCS entries interpolated by #3, #5 and #7 need to be removed, which are marked as yellow below. The MCS/TBS entries mapped to CQI entries #3, #5 and #7 are maintained in order to avoid the redesign of TBS table.

Table 2: Map of current MCS/TBS entries to CQI index

MCS Index I_{MCS}	Modulation Order Q_m	TBS Index I_{TBS}	CQI index	Spectral efficiency
0	2	0	2	0.2344
1	2	1		0.3057
2	2	2	3	0.3770
3	2	3		0.4893
4	2	4	4	0.6016
5	2	5		0.7393
6	2	6	5	0.8770
7	2	7		1.0264
8	2	8	6	1.1758
9	2	9		1.3262
10	4	9		1.3262
11	4	10	7	1.4766
12	4	11		1.69535
13	4	12	8	1.9141
14	4	13		2.1602
15	4	14	9	2.4063
16	4	15		2.5684
17	6	15		2.5684
18	6	16	10	2.7305
19	6	17		3.0264
20	6	18	11	3.3223
21	6	19		3.6123
22	6	20	12	3.9023
23	6	21		4.21285
24	6	22	13	4.5234
25	6	23		4.8193
26	6	24	14	5.1152
27	6	25		5.33495
28	6	26	15	5.5547
29	2	reserved		
30	4			
31	6			

With the introduction of 256QAM, 7 MCS entries (i.e., I_{TBS} #27~#33) need to be added to reflect the corresponding efficiency or interpolated efficiency for the proposed CQI index #12~#15 for 256QAM. Moreover, the previous MCS entry corresponding to I_{TBS} #26 needs to be removed since the modulation type has been changed to 256QAM and the previous value is no longer applicable.

As shown in Figure 1, the switching point of 64QAM and 256QAM spectral efficiency is about 5.55 in an AWGN channel. The spectral efficiency of MCS entry corresponding to I_{TBS} #25 is 5.33495, and the spectral efficiency of MCS entry corresponding to I_{TBS} #27 is 5.5547. According to the switching point of 64QAM and 256QAM spectral efficiency in AWGN channel and EPA channel, the modulation scheme of MCS entry corresponding to I_{TBS} #27 should be 256QAM and the modulation scheme of MCS entry corresponding to I_{TBS} #25 should be 64QAM, no matter in AWGN channel or EPA channel. Therefore, there is no need to define overlap entry for 64QAM/256QAM.

Another MCS entry is needed for 256QAM retransmission, as the other modulation order.

Proposal 2:

- Define 8 MCS entries for 256QAM

- 7 MCS entries (i.e., I_{TBS} #27~#33) reflect the corresponding efficiency or interpolated efficiency for the proposed CQI index #12~#15 for 256QAM.

- 1 MCS entry for 256QAM retransmission
- 8 entries in Rel-8 MCS table should be dropped
 - 7 MCS entries (i.e., I_{TBS} #1, 3, 5, 7, 9, 11) if the previous CQI entries #3, 5, 7 are dropped
 - 1 MCS entry (i.e., I_{TBS} #26) if the modulation order of CQI index #15 is changed to 256QAM
- Other MCS/TBS entries should be remained unchanged

An example based on above principles is shown as Table 3, where the TBS entries are defined in [7].

Table 3. Proposed 5-bit MCS table for 256QAM

MCS Index I_{MCS}	MCS Index I_{MCS} in current table	Modulation Order Q_m	TBS Index I_{TBS}
0	0	2	0
1	2	2	2
2	4	2	4
3	6	2	6
4	8	2	8
5	11	4	10
6	13	4	12
7	14	4	13
8	15	4	14
9	16	4	15
10	17	6	15
11	18	6	16
12	19	6	17
13	20	6	18
14	21	6	19
15	22	6	20
16	23	6	21
17	24	6	22
18	25	6	23
19	26	6	24
20	27	6	25
21	-	8	27
22	-	8	28
23	-	8	29
24	-	8	30
25	-	8	31
26	-	8	32
27	-	8	33
28	29	2	reserved
29	30	4	
30	31	6	
31	-	8	

2.3 Signaling for 256QAM

It was agreed in [6] that “Higher layer signalling is used to configure CQI/MCS table and/or 256QAM”. When considering carrier aggregation or dual connectivity between macro and small cell layer, it might be a common case that different carriers/cells would be configured with different CQI/MCS tables. The same situation might happen in CoMP scenarios when different transmission points might have different modulation configurations due to the channel and interference environment variation.

Proposal 3:

- CQI/MCS table and/or 256QAM is configured by higher layer signaling per CC and transmission point.

3 Conclusions

In this contribution, standard impacts to support 256QAM are analyzed, and the proposals are summarized as follows.

Proposals for CQI table:

- The maximum efficiency for 256QAM CQI entry is $5.5547 \times 8/6 = 7.4063$;
- Introduce three new CQI entries for 256QAM
 - o The efficiency corresponding to each entry is 6.1719, 6.7891, 7.4063
- CQI table for 256QAM should reserve some entries for low SNR region
 - o Current CQI entries #0, #1 and #2 should be reserved
 - o Current CQI entries #3, #5 and #7 can be removed
- The modulation order of CQI index 15 is changed to 256QAM
 - o The spectral efficiency could be maintained to reduce impact on MCS/TBS table
- Other CQI entries should be remained unchanged

Proposals for MCS table:

- Introduce 8 MCS entries for 256QAM
 - o 7 MCS entries (i.e., I_{TBS} #27~#33) reflect the corresponding efficiency or interpolated efficiency for the proposed CQI index #12-#15 for 256QAM.
 - o 1 MCS entry for 256QAM retransmission
- 8 entries in Rel-8 MCS table should be dropped
 - o 7 MCS entries (i.e., I_{TBS} #1, 3, 5, 7, 9, 11) if the previous CQI entries #3,5,7 are dropped
 - o 1 MCS entry (i.e., I_{TBS} #26) if the modulation order of CQI index #15 is changed to 256QAM
- Other MCS/TBS entries should be remained unchanged

Proposals for signaling:

- CQI/MCS table and/or 256QAM is configured by higher layer signaling per CC and transmission point

The examples of CQI and MCS tables for 256QAM are provided in Table 1 and Table 3.

References

- [1] RP-132073, "New WI proposal: Small cell enhancements - Physical layer aspects", Huawei, CATR, HiSilicon, RAN#62, Dec. 3-6, 2013.
- [2] R1-075069, "Summary of Ad Hoc session on 6.4.5", Ad Hoc Chairman, RAN1#51, Nov. 5-9, 2007.
- [3] RAN1 Reflector Discussion on LTE CQI, "4-bit CQI Proposal", Nokia Siemens Networks, Nokia, Dec. 2007.

- [4] R1-081638, “TBS and MCS Signaling and Tables”, Motorola, RAN1 #52b, Mar. 31-Apr. 4, 2008.
- [5] R1-080049, “Summary of email discussion on CQI reporting”, Samsung, Jan. 14-18, 2008.
- [6] 3GPP TR 36.872, “Small cell enhancements for E-UTRA and E-UTRAN Evaluation assumptions for small cell enhancements- Physical layer aspects”, v12.0.0, Sept. 2013.
- [7] R1-140035, “TBS table design for 256QAM”, Huawei, HiSilicon, RAN1#76, Feb. 10-14, 2014.

Appendix

Table 4: Link level simulation assumptions

Bandwidth	10MHz
Carrier frequency	2GHz
Channel model	AWGN, EPA
Transmission mode	TM4
MIMO configuration	1x1 for AWGN 2x2 with low correlation for EPA
CRS configuration	Antenna ports 0,1
Rank adaptation	Fixed as 1 or 2
Link adaptation	Off
HARQ	Off
UE receiver	MMSE-IRC
Channel estimation	ideal
Interference estimation	ideal
PDP estimation	ideal
Received timing delay (us)	0
Frequency offset (Hz)	0
UE speed	3km/h
Data Allocation	4 RBs
Channel coding	Turbo
Overhead assumption	3 PDCCH symbols;
	2-port CRS;

Agenda item: 7.2.4.1
Source: FiberHome
Title: Discussion on CQI/MCS table design for 256QAM
Document for: Discussion and Decision

1 Introduction

In order to introduce the 256QAM modulation, the CQI, MCS and TBS tables need to be re-designed. At RAN1#76 meeting, the 256QAM design principles were discussed and the following agreements were achieved [1]:

Agreement:

- CQI table
 - Support SE in the entire range from $X1$ bps/Hz to $X2$ bps/Hz
 - Down-sample low CQI entries by removing $Y1$ entries, and add $Y1$ new entries for 256QAM region with even spacing
 - **Note:** One company (Panasonic) express a concern that test and implied spec change is unnecessary high
 - CQI #0 to be equaled to out of range
 - Switching point of 64QAM and 256QAM should be CQI Z ($Z=14$ or 15 in the existing table)
 - FFS the positions of the CQI entries in the Rel-12 CQI table – to be decided between the following two options
 - Option1: order the CQI indices according to the spectral efficiencies]
 - Option2: keep the CQI indices the same for the common CQIs between Rel-8 and Rel-12 CQI table
- Modulation and TBS index table
 - Definition of N ($N=3$ or 4) reserved entries for adaptive retransmission
 - Modulation and TBS table design should provide the support of all the VoIP TBS at least for Format 1A, FFS for Format 2x
 - The need of overlapping spectral efficiency of different modulations is FFS
 - FFS the position of Modulation and TBS entries in the Rel-12 Modulation and TBS table

In this contribution, we will further discuss the design for new CQI table and Modulation and TBS index table and provide our suggestions.

2 Discussion

2.1 CQI table design

In order to support 256QAM in downlink for higher spectral efficiency, the new CQI table that include 256QAM need to be defined in the specification. At the RAN1#76 meeting, it was agreed that down-sample low CQI entries by removing $Y1$ entries, and add $Y1$ new entries for 256QAM region with even spacing. Therefore, we need to determine how many entries and which entries to be removed from the legacy CQI table.

For the legacy CQI table, it starts with -7dB as the first point and the step size is 1.892dB, the MCSs are derived by uniformly quantizing SNR over the SNR range of [-7, 19.488] dB. Therefore, for the new CQI table, it seems reasonable to follow the previous principle, the 256QAM MCSs could be introduced with the same SNR step size of 1.892dB. Moreover, considering the maximum code rate for 256QAM is about 0.93 and the corresponding SNR to support this MCS is about 25dB. Therefore, the SNRs for 256QAM can be 21.380dB, 23.272dB and 25.164dB. In other words, it is reasonable to introduce three CQI entries for 256QAM transmission with the same SNR step size of 1.892dB to form the new CQI table. Since three new CQI entries will be introduced for 256QAM modulation, three lower entries need to be removed to keep the table size as before. Considering CQI index #0 should be reserved for out of range indication and CQI index #1 should be reserved for PDCCH transmission. Thus, it is reasonable to remove the current CQI entries #2, #4 and #6.

Therefore, according to the above analysis, we have the following proposal:

Proposal 1: Current CQI entries #2, #4 and #6 should be removed to down-sample low CQI entries and add three new entries for 256QAM.

If the 256QAM modulation is introduced, the maximum spectral efficiency of the current CQI table will be changed. Considering the maximum efficiency supported by current CQI table is 5.5547, therefore, the maximum spectral efficiency with 256 QAM can be $5.5547 \times 8/6 = 7.4063$. In the above section, we proposed to add 3 new entries for 256QAM, so the spectral efficiency of two more 256QAM entries can be $5.1151 \times 8/6 = 6.0313$ and $4.5234 \times 8/6 = 6.8203$. Moreover, CQI index#1 with spectral efficiency = 0.1523 is used for PDCCH. Therefore, we have the following proposal:

Proposal 2: The new CQI table should support spectral efficiency from 0.1523 bps/Hz to 7.4063 bps/Hz.

For the switching point of 64QAM and 256QAM, we think the 256QAM will outperforms 64QAM when the CQI index is 15 in the current CQI table under frequency selective channel. Therefore, it is reasonable to change the CQI index 15 to 256QAM and the spectral efficiency value should be maintained. For the positions of the CQI entries in the Rel-12 CQI table, there are two options:

- *Option1: order the CQI indices according to the spectral efficiencies*
- *Option2: keep the CQI indices the same for the common CQIs between Rel-8 and Rel-12 CQI table*

Obviously, the option 1 is a straightforward way since the Rel-8 CQI table is designed with the option 1. The main advantage of option 2 is to mitigate the problem of RRC configuration ambiguity during the new CQI table configuration. However, even the option 2 used, the RRC configuration ambiguity still existed since the some QPSK entries are replaced by the 256QAM. Moreover, we can use special DCI format during the RRC configuration ambiguity period to resolve the ambiguity issues. These special DCI formats do not support 256QAM, such as DCI format 1A and DCI format 2C. Therefore, we have the following proposal:

Proposal 3: We suggest that the new CQI table should order the CQI indices according to the spectral efficiencies.

According to the above discussion, we propose the following Table 1 as the new CQI table for a UE configured with 256QAM.

Table 1 4-bit proposed CQI table

CQI index	modulation	code rate x 1024	efficiency
0	out of range		
1	QPSK	78	0.1523
2	QPSK	193	0.3770
3	QPSK	449	0.8770
4	16QAM	378	1.4766
5	16QAM	490	1.9141
6	16QAM	616	2.4063
7	64QAM	466	2.7305
8	64QAM	567	3.3223
9	64QAM	666	3.9023
10	64QAM	772	4.5234
11	64QAM	873	5.1152
12	256QAM	711	5.5547
13	256QAM	772	6.0313
14	256QAM	873	6.8203
15	256QAM	948	7.4063

2.2 Modulation and TBS index table design

In order to align with the CQI table design, some low spectral efficiency MCS entries in the legacy table need to be deleted and 256QAM MCS entries need to be added. According to the design in Table 1, current CQI entries #2, #4 and #6 are removed, thus the MCS entries interpolated by #2, #4 and #6 need to be removed. Moreover, considering don't

removing the MCS entries that directly come from the CQI entries, thus the Modulation and TBS index table entries mapped to CQI entries #2, #4 and #6 are maintained.

Moreover, in Rel-8 Modulation and TBS index table, in order to support both frequency-flat and frequency-selective channel, the overlapping TBS indices between modulation switching points are introduced. Nevertheless, channel under small cell deployment is expected to be frequency-flat. As a result, overlapping TBS indices at each modulation switching point is not necessary. Moreover, considering $I_{MCS} = 9$ and 16 will be more robust than $I_{MCS} = 10$ and 17 respectively under small cell deployments. Therefore, we think there is no need to introduce the overlapping TBS indices at modulation switching point and remove $I_{MCS} = 10$ and $I_{MCS} = 17$.

Proposal 4: It is not necessary to introduce the overlapping TBS indices at modulation switching point and we suggest to remove $I_{MCS} = 10$ and $I_{MCS} = 17$.

Furthermore, in the Rel-8 Modulation and TBS index table, there are three modulation orders and thus three reserved entries for adaptive re-transmission. For the new Modulation and TBS index table, the retransmission procedure may use one of the four modulation schemes. Therefore, it is reasonable to define four reserved entries for adaptive retransmission.

According to the above discussion, we propose the following Table 2 as new Modulation and TBS index table for introducing 256QAM.

Table 2 Proposed Modulation and TBS index table for PDSCH

MCS Index I_{MCS}	Modulation Order Q_m	TBS Index I_{TBS}
0	2	0
1	2	2
2	2	4
3	2	6
4	2	8
5	4	10
6	4	11
7	4	12
8	4	13
9	4	14
10	4	15
11	6	16
12	6	17
13	6	18
14	6	19
15	6	20
16	6	21
17	6	22
18	6	23
19	6	24
20	6	25
21	6	26
22	8	27
23	8	28
24	8	29
25	8	30
26	8	31
27	8	32
28	2	reserved
29	4	
30	6	
31	8	

3 Conclusion

In this contribution, we discuss the CQI/MCS table design for introducing 256QAM and we kindly suggest that RAN1 agree on the following proposals:

Proposal 1: Current CQI entries #2, #4 and #6 should be removed to down-sample low CQI entries and add three new entries for 256QAM.

Proposal 2: The new CQI table should support spectral efficiency from 0.1523 bps/Hz to 7.4063 bps/Hz.

Proposal 3: We suggest that the new CQI table should order the CQI indices according to the spectral efficiencies.

Proposal 4: It is not necessary to introduce the overlapping TBS indices at modulation switching point and we suggest to remove IMCS = 10 and IMCS = 17.

4 References

[1] R1-14xxxx, "Draft Report of 3GPP TSG RAN WG1 #76 v0.2.0", February, 2014