



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	TOT CLAIMS	IND CLAIMS
62/421,821	11/14/2016		130	16-1098P		

92629
Esmael H. Dinan
13633 Cedar Run Lane
Herndon, VA 20171

CONFIRMATION NO. 3407
FILING RECEIPT



0000000087407593

Date Mailed: 11/25/2016

Receipt is acknowledged of this provisional patent application. It will not be examined for patentability and will become abandoned not later than twelve months after its filing date. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Alireza Babaei, Ashburn, VA;
Esmael Hejazi Dinan, Herndon, VA;

Applicant(s)

Alireza Babaei, Ashburn, VA;
Esmael Hejazi Dinan, Herndon, VA;

Power of Attorney:

Esmael Dinan--64478

Permission to Access Application via Priority Document Exchange: No

Permission to Access Search Results: No

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 11/22/2016

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 62/421,821**

Projected Publication Date: None, application is not eligible for pre-grant publication

Non-Publication Request: No

Early Publication Request: No

**** SMALL ENTITY ****

Title

MAC Configuration in a Wireless Network

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at <http://www.uspto.gov/web/offices/pac/doc/general/index.html>.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, <http://www.stopfakes.gov>. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier

license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign Assets Control, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

SelectUSA

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The U.S. offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to promote and facilitate business investment. SelectUSA provides information assistance to the international investor community; serves as an ombudsman for existing and potential investors; advocates on behalf of U.S. cities, states, and regions competing for global investment; and counsels U.S. economic development organizations on investment attraction best practices. To learn more about why the United States is the best country in the world to develop technology, manufacture products, deliver services, and grow your business, visit <http://www.SelectUSA.gov> or call +1-202-482-6800.

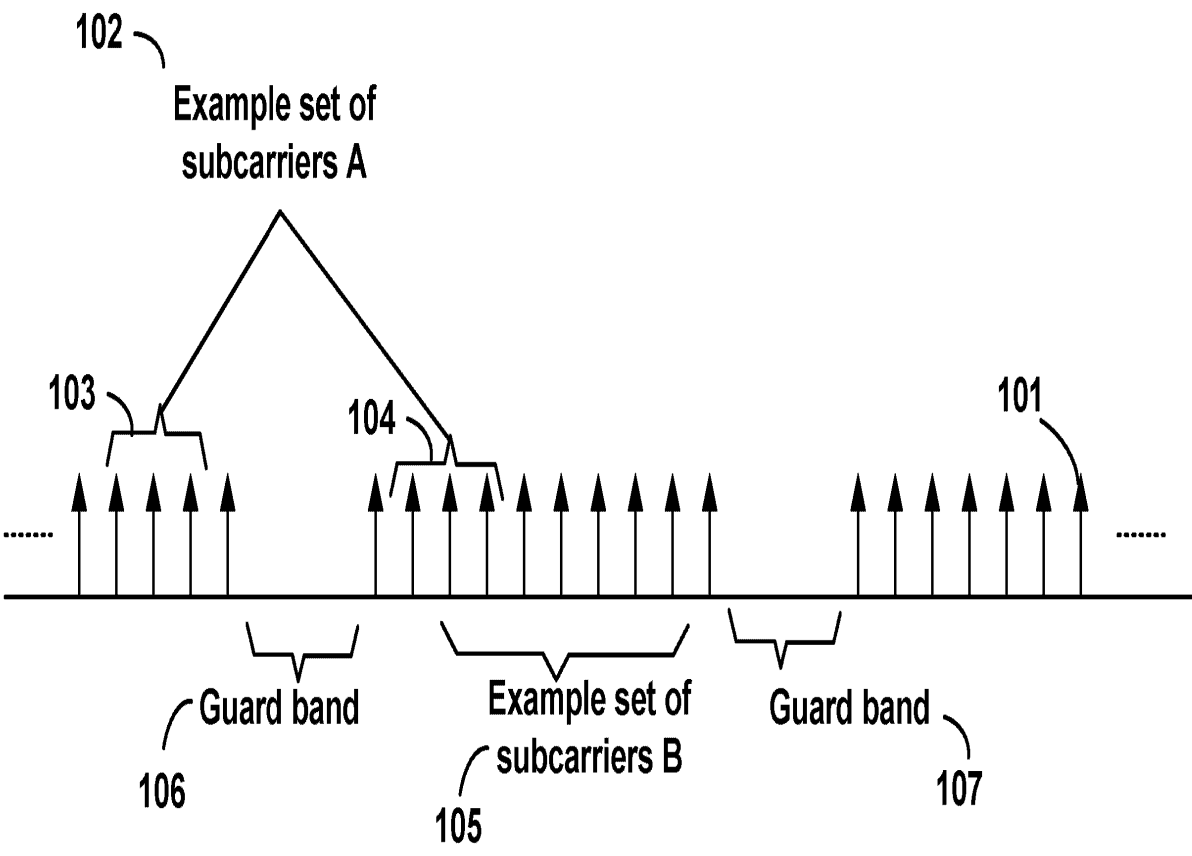


FIG. 1

+

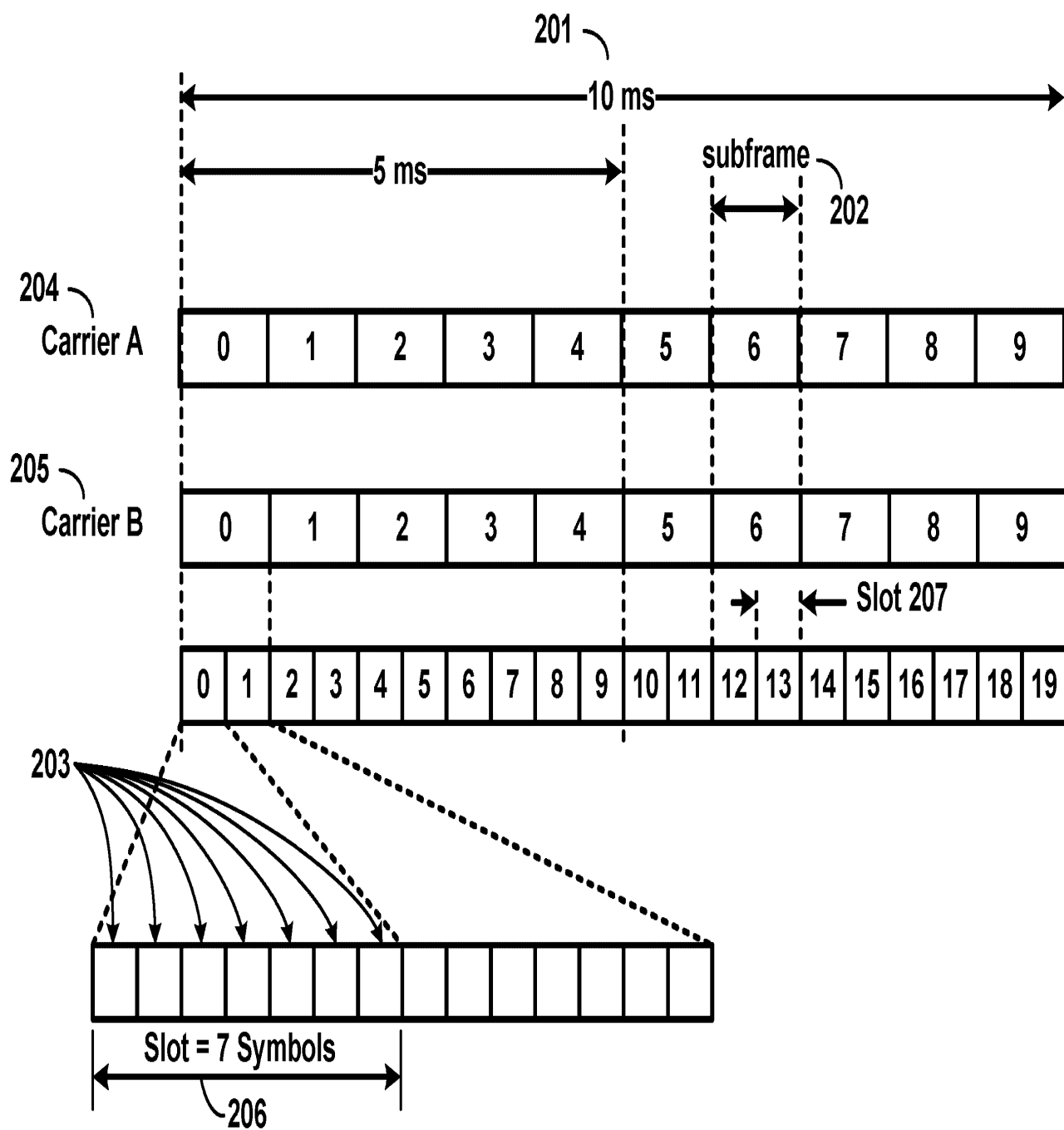


FIG. 2

+

+

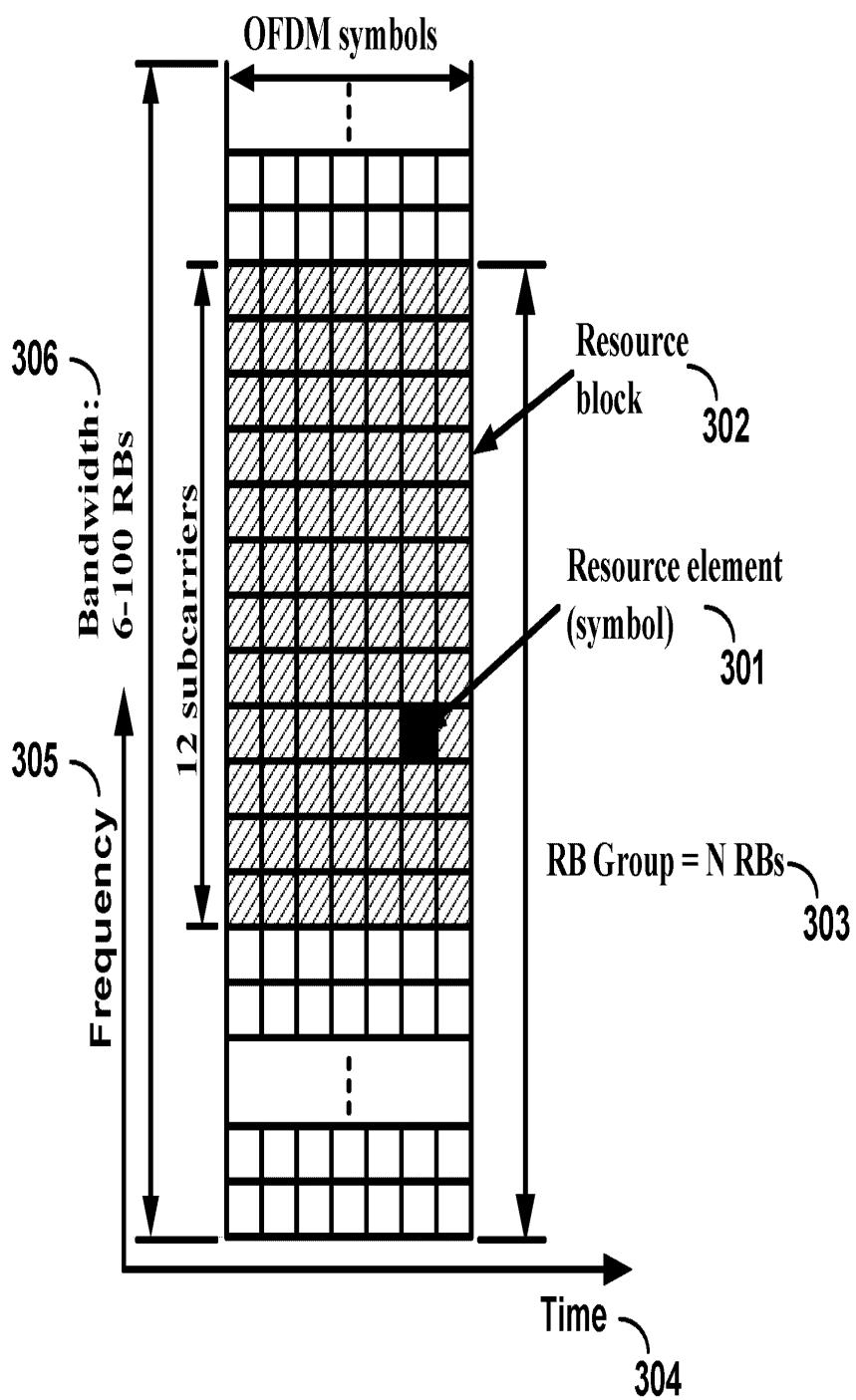
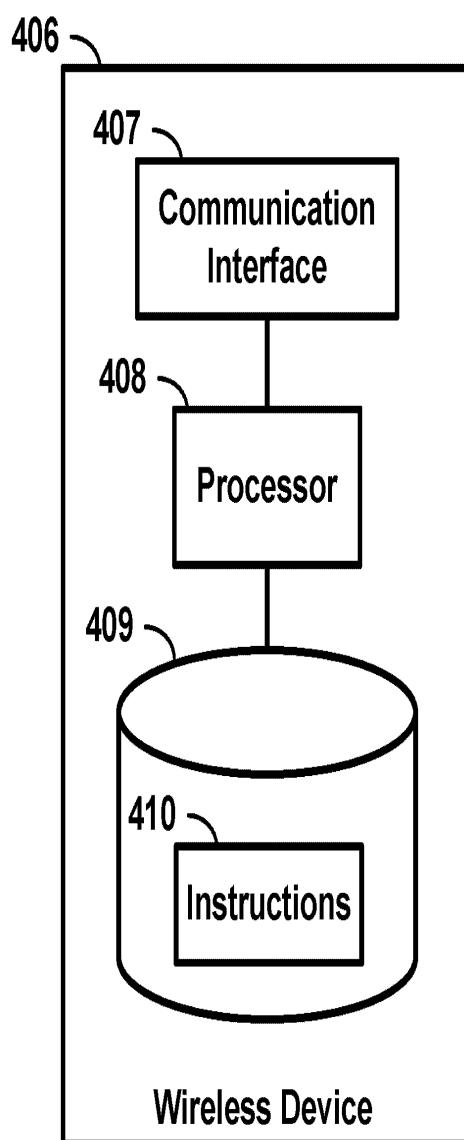
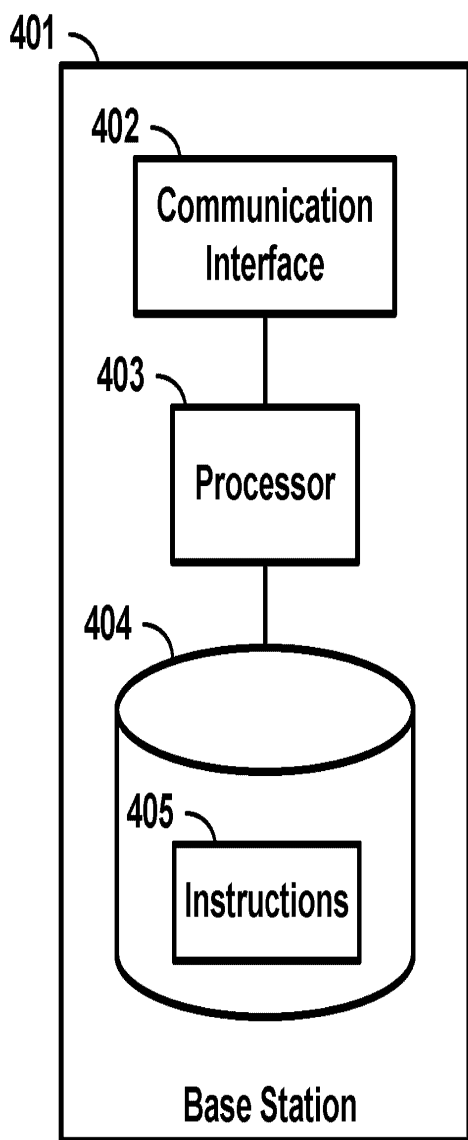


FIG. 3

+

+

400 ↘



4/12

Inventor: Esmael H. Dinan

FIG. 4

+

+

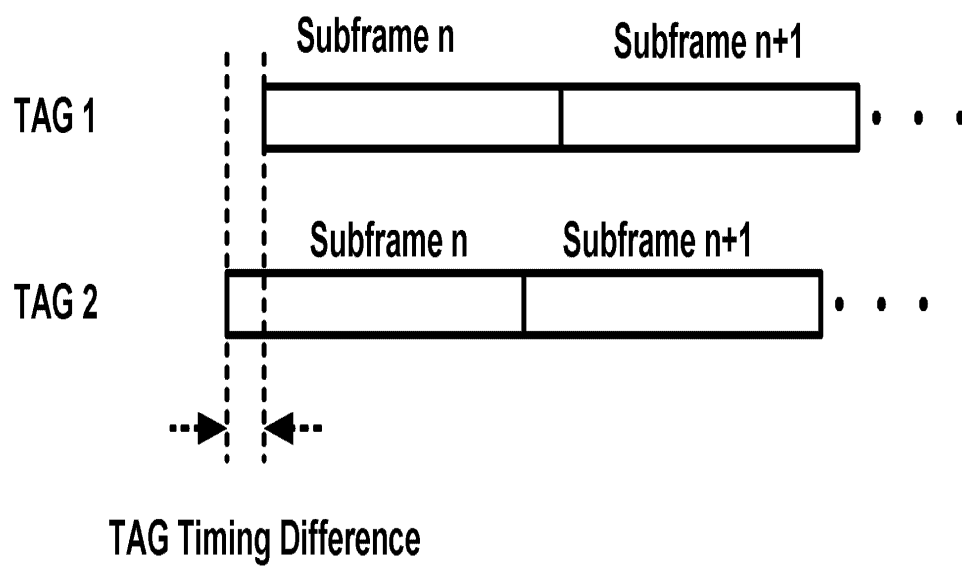


FIG. 5

+

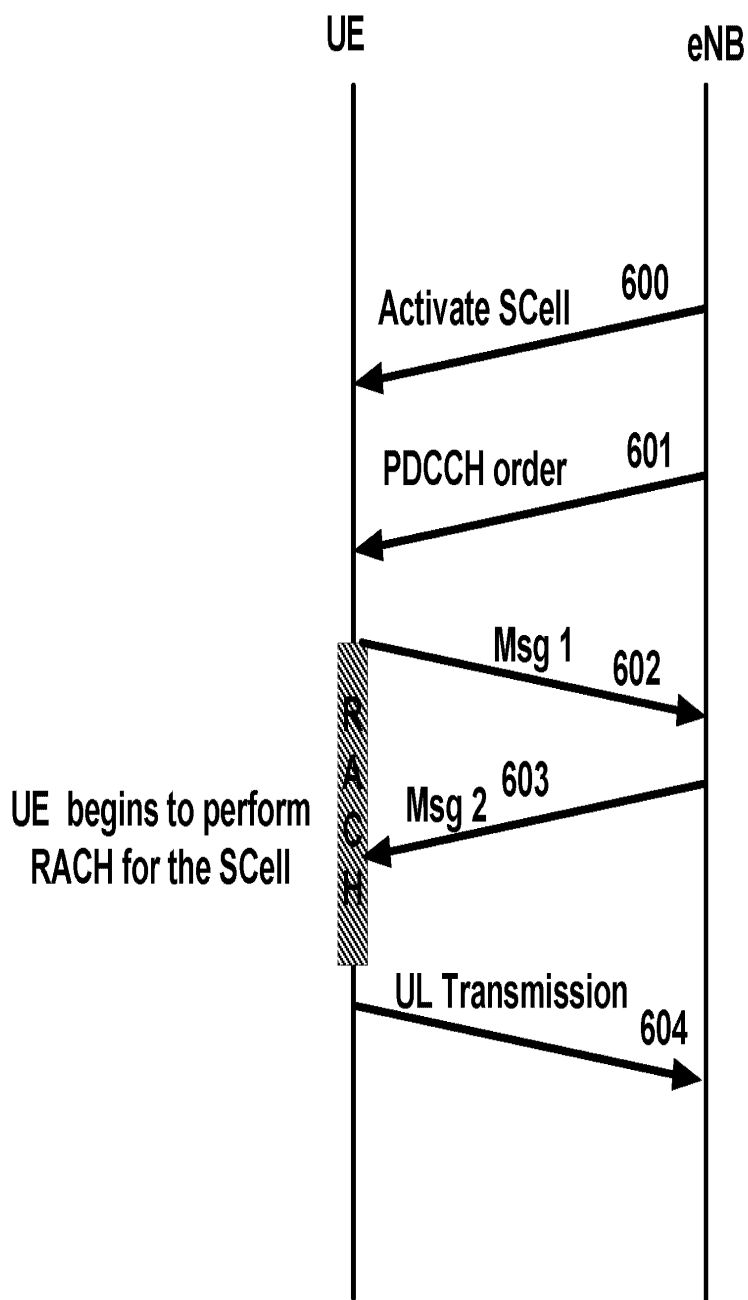
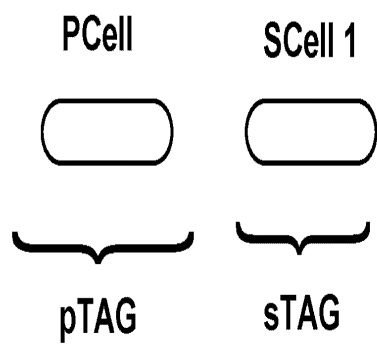
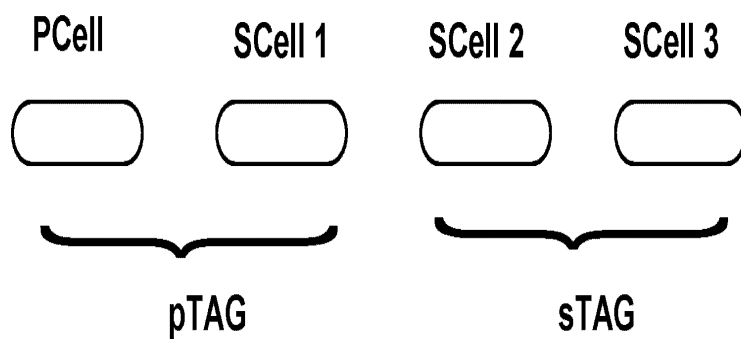


FIG. 6

Example 1:



Example 2:



Example 3:

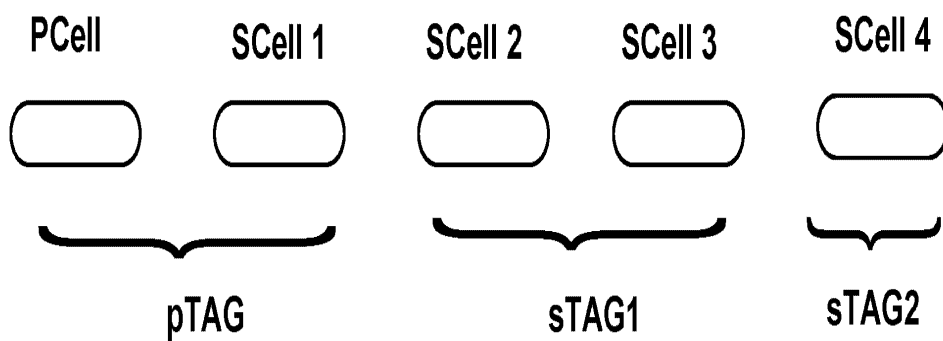


FIG. 7

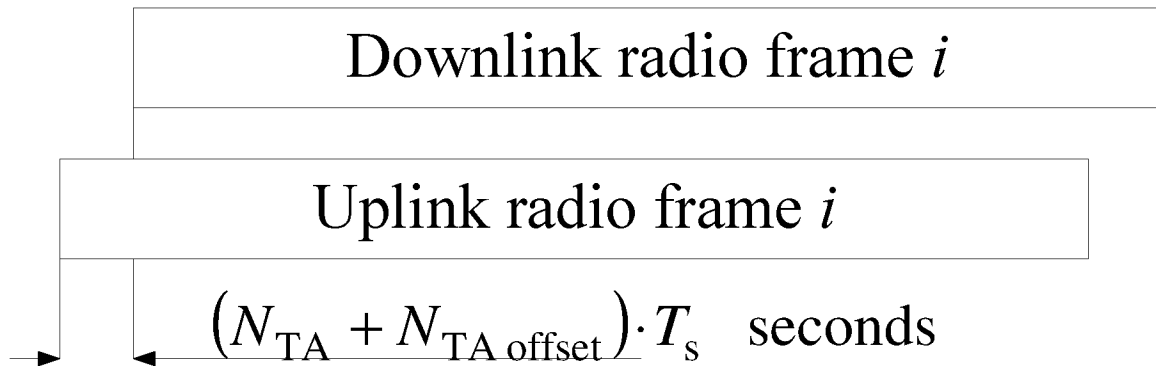


FIG. 8



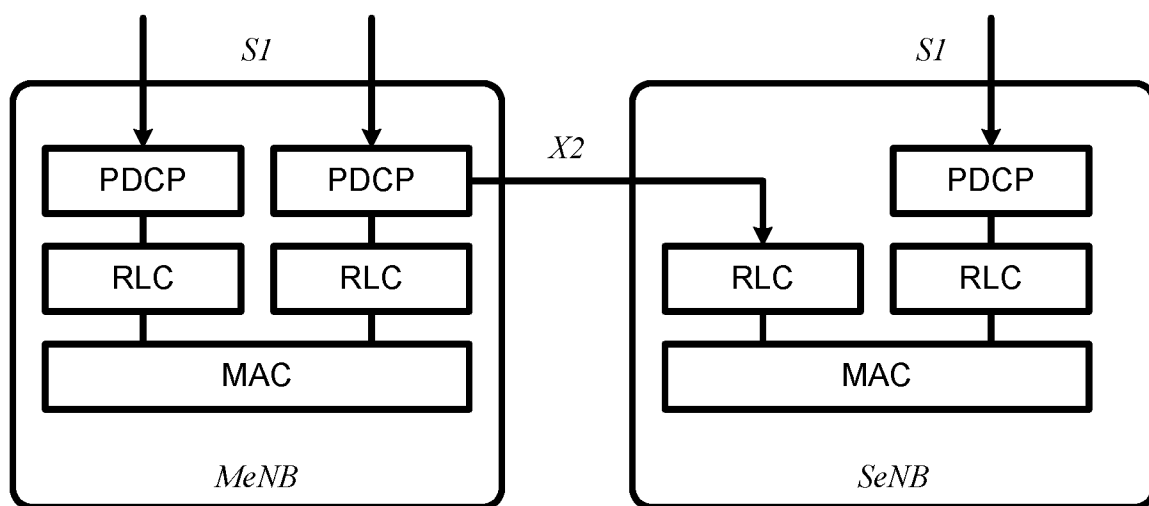


FIG. 9

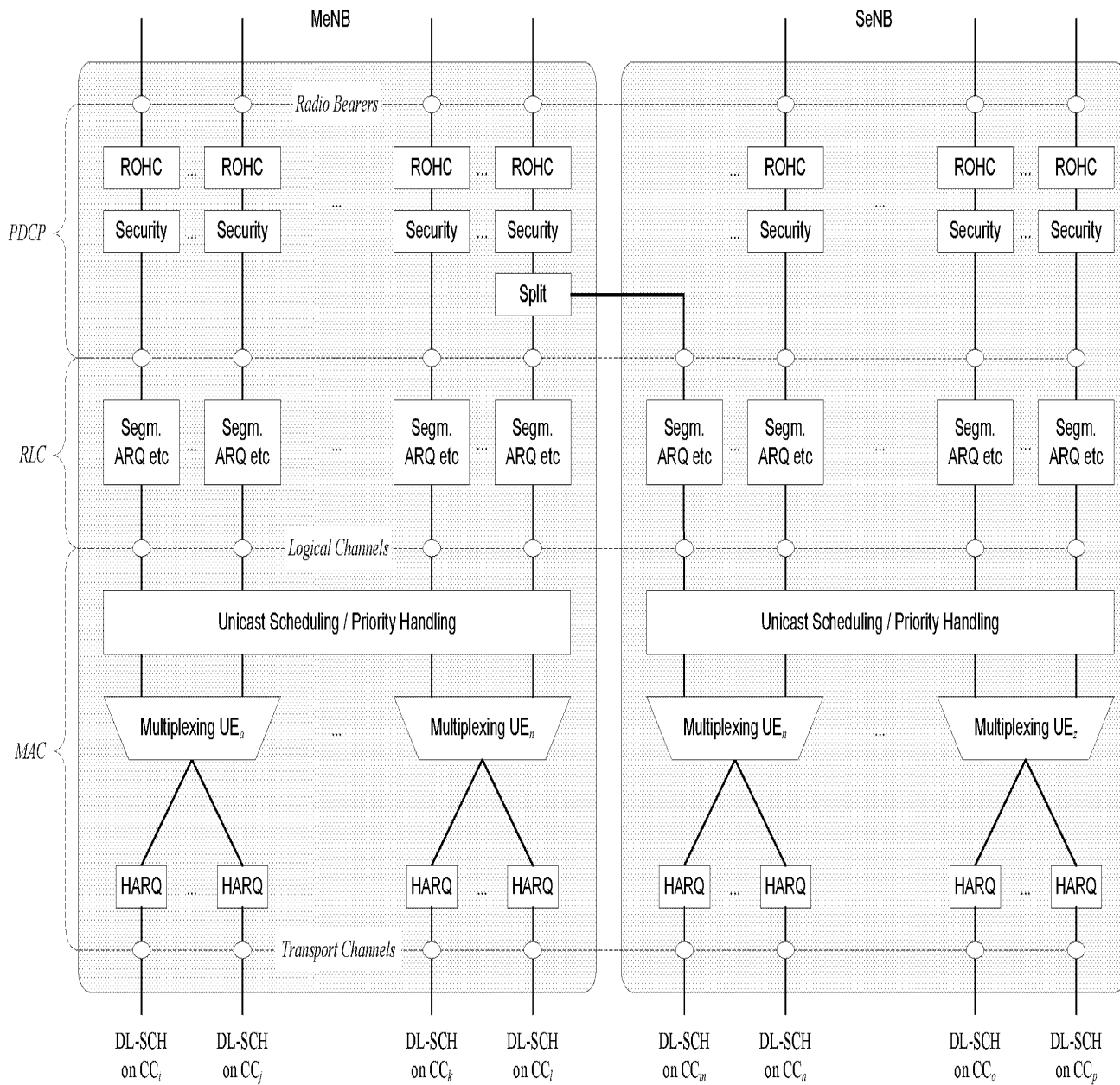


FIG. 10



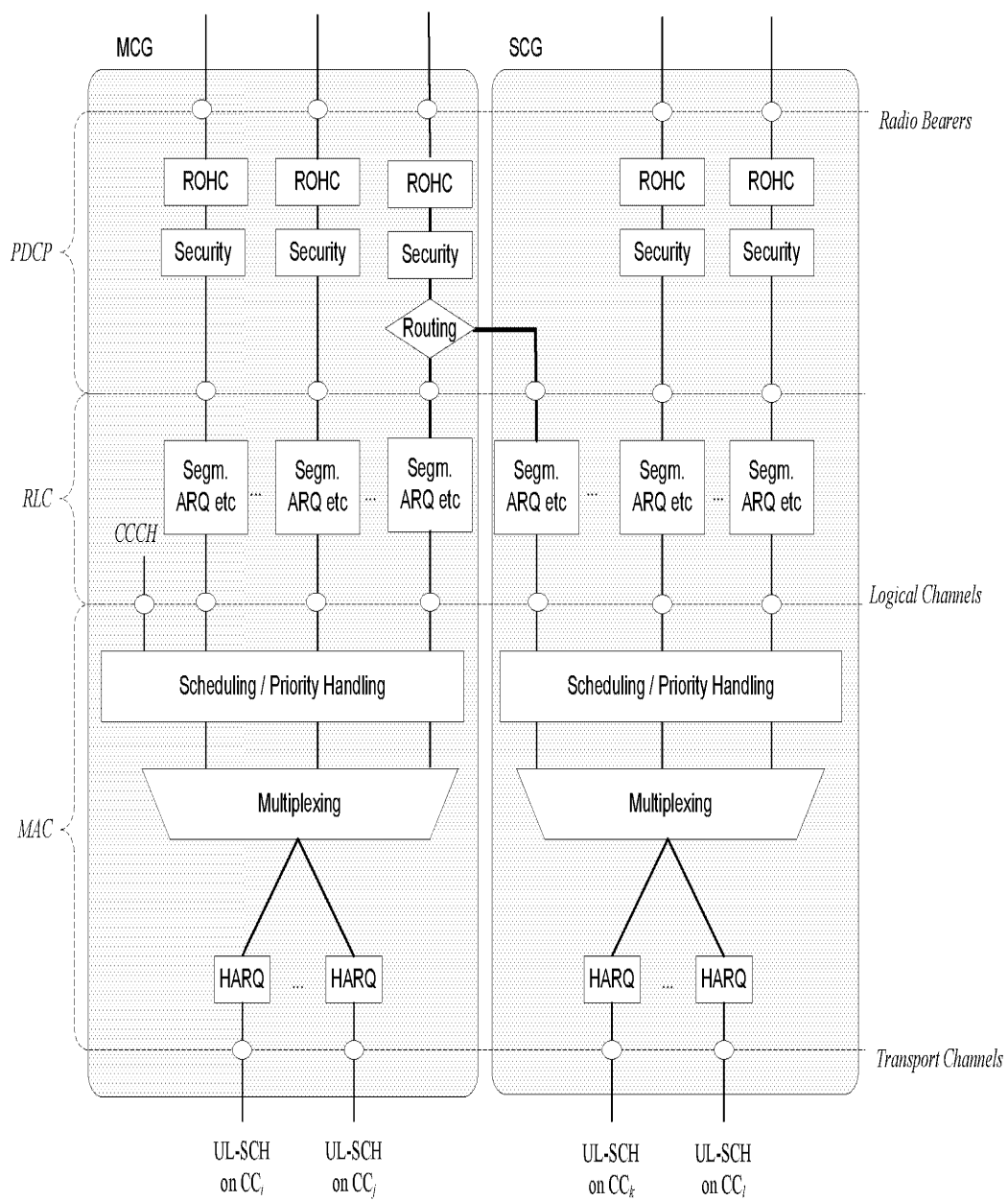


FIG. 11

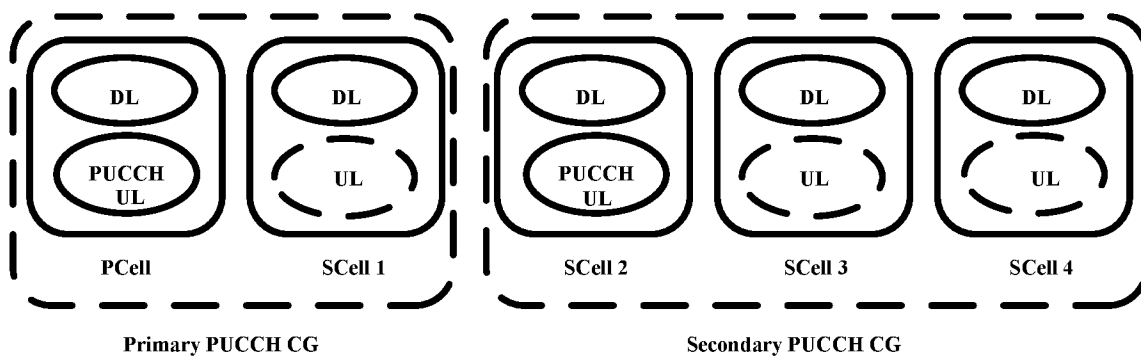


FIG. 12



BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

- [0001] Examples of several of the various embodiments of the present invention are described herein with reference to the drawings, in which:
- [0002] FIG. 1 is a diagram depicting example sets of OFDM subcarriers as per an aspect of an embodiment of the present invention;
- [0003] FIG. 2 is a diagram depicting an example transmission time and reception time for two carriers in a carrier group as per an aspect of an embodiment of the present invention;
- [0004] FIG. 3 is a diagram depicting OFDM radio resources as per an aspect of an embodiment of the present invention;
- [0005] FIG. 4 is a block diagram of a base station and a wireless device as per an aspect of an embodiment of the present invention;
- [0006] FIG. 5 is a diagram depicting uplink transmission timing of one or more cells in a first timing advance group (TAG) and a second TAG as per an aspect of an embodiment of the present invention;
- [0007] FIG. 6 is an example message flow in a random access process in a secondary TAG as per an aspect of an embodiment of the present invention;
- [0008] FIG. 7 shows example TAG configurations as per an aspect of an embodiment of the present invention;
- [0009] FIG. 8 is an example diagram illustrating timing of uplink and downlink radio frames;
- [0010] FIG. 9 is an example diagram illustrating Radio Protocol Architecture for Dual Connectivity;
- [0011] FIG. 10 is an example diagram Layer 2 Structure for DL with CA and DC configured as per an aspect of an embodiment of the present invention; and
- [0012] FIG. 11 is an example diagram Layer 2 Structure for UL with CA and DC configured as per an aspect of an embodiment of the present invention; and
- [0013] FIG. 12 is an example grouping of cells into PUCCH CGs as per an aspect of an embodiment of the present invention.

[0014]

DETAILED DESCRIPTION OF EMBODIMENTS

- [0015] Example embodiments of the present invention enable operation of carrier aggregation. Embodiments of the technology disclosed herein may be employed in the technical field of multicarrier communication systems.
- [0016] Example embodiments of the invention may be implemented using various physical layer modulation and transmission mechanisms. Example transmission mechanisms may include, but are not limited to: CDMA (code division multiple access), OFDM (orthogonal frequency division multiplexing), TDMA (time division multiple access), Wavelet technologies, and/or the like. Hybrid transmission mechanisms such as TDMA/CDMA, and OFDM/CDMA may also be employed. Various modulation schemes may be applied for signal transmission in the physical layer. Examples of modulation schemes include, but are not limited to: phase, amplitude, code, a combination of these, and/or the like. An example radio transmission method may implement QAM (quadrature amplitude modulation) using BPSK (binary phase shift keying), QPSK (quadrature phase shift keying), 16-QAM, 64-QAM, 256-QAM, and/or the like. Physical radio transmission may be enhanced

by dynamically or semi-dynamically changing the modulation and coding scheme depending on transmission requirements and radio conditions.

[0017] FIG. 1 is a diagram depicting example sets of OFDM subcarriers as per an aspect of an embodiment of the present invention. As illustrated in this example, arrow(s) in the diagram may depict a subcarrier in a multicarrier OFDM system. The OFDM system may use technology such as OFDM technology, SC-OFDM (single carrier-OFDM) technology, or the like. For example, arrow 101 shows a subcarrier transmitting information symbols. FIG. 1 is for illustration purposes, and a typical multicarrier OFDM system may include more subcarriers in a carrier. For example, the number of subcarriers in a carrier may be in the range of 10 to 10,000 subcarriers. FIG. 1 shows two guard bands 106 and 107 in a transmission band. As illustrated in FIG. 1, guard band 106 is between subcarriers 103 and subcarriers 104. The example set of subcarriers A 102 includes subcarriers 103 and subcarriers 104. FIG. 1 also illustrates an example set of subcarriers B 105. As illustrated, there is no guard band between any two subcarriers in the example set of subcarriers B 105. Carriers in a multicarrier OFDM communication system may be contiguous carriers, non-contiguous carriers, or a combination of both contiguous and non-contiguous carriers.

[0018] FIG. 2 is a diagram depicting an example transmission time and reception time for two carriers as per an aspect of an embodiment of the present invention. A multicarrier OFDM communication system may include one or more carriers, for example, ranging from 1 to 10 carriers. Carrier A 204 and carrier B 205 may have the same or different timing structures. Although FIG. 2 shows two synchronized carriers, carrier A 204 and carrier B 205 may or may not be synchronized with each other. Different radio frame structures may be supported for FDD (frequency division duplex) and TDD (time division duplex) duplex mechanisms. FIG. 2 shows an example FDD frame timing. Downlink and uplink transmissions may be organized into radio frames 201. In this example, radio frame duration is 10 msec. Other frame durations, for example, in the range of 1 to 100 msec may also be supported. In this example, each 10 ms radio frame 201 may be divided into ten equally sized sub-frames 202. Other subframe durations such as including 0.5 msec, 1 msec, 2 msec, and 5 msec may also be supported. Sub-frame(s) may consist of two or more slots 206. For the example of FDD, 10 subframes may be available for downlink transmission and 10 subframes may be available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions may be separated in the frequency domain. Slot(s) may include a plurality of OFDM symbols 203. The number of OFDM symbols 203 in a slot 206 may depend on the cyclic prefix length and subcarrier spacing.

[0019] FIG. 3 is a diagram depicting OFDM radio resources as per an aspect of an embodiment of the present invention. The resource grid structure in time 304 and frequency 305 is illustrated in FIG. 3. The quantity of downlink subcarriers or resource blocks (RB) (in this example 6 to 100 RBs) may depend, at least in part, on the downlink transmission bandwidth 306 configured in the cell. The smallest radio resource unit may be called a resource element (e.g. 301). Resource elements may be grouped into resource blocks (e.g. 302). Resource blocks may be grouped into larger radio resources called Resource Block Groups (RBG) (e.g. 303). The transmitted signal in slot 206 may be described by one or several resource grids of a plurality of subcarriers and a plurality of OFDM symbols. Resource blocks may be used to describe the mapping of certain physical channels to resource elements. Other pre-defined groupings of physical resource elements may be implemented in the system depending on the radio technology. For example, 24 subcarriers may be grouped

as a radio block for a duration of 5 msec. In an illustrative example, a resource block may correspond to one slot in the time domain and 180 kHz in the frequency domain (for 15 KHz subcarrier bandwidth and 12 subcarriers).

[0020] FIG. 4 is an example block diagram of a base station 401 and a wireless device 406, as per an aspect of an embodiment of the present invention. A communication network 400 may include at least one base station 401 and at least one wireless device 406. The base station 401 may include at least one communication interface 402, at least one processor 403, and at least one set of program code instructions 405 stored in non-transitory memory 404 and executable by the at least one processor 403. The wireless device 406 may include at least one communication interface 407, at least one processor 408, and at least one set of program code instructions 410 stored in non-transitory memory 409 and executable by the at least one processor 408. Communication interface 402 in base station 401 may be configured to engage in communication with communication interface 407 in wireless device 406 via a communication path that includes at least one wireless link 411. Wireless link 411 may be a bi-directional link. Communication interface 407 in wireless device 406 may also be configured to engage in a communication with communication interface 402 in base station 401. Base station 401 and wireless device 406 may be configured to send and receive data over wireless link 411 using multiple frequency carriers. According to some of the various aspects of embodiments, transceiver(s) may be employed. A transceiver is a device that includes both a transmitter and receiver. Transceivers may be employed in devices such as wireless devices, base stations, relay nodes, and/or the like. Example embodiments for radio technology implemented in communication interface 402, 407 and wireless link 411 are illustrated are FIG. 1, FIG. 2, and FIG. 3. and associated text.

[0021] An interface may be a hardware interface, a firmware interface, a software interface, and/or a combination thereof. The hardware interface may include connectors, wires, electronic devices such as drivers, amplifiers, and/or the like. A software interface may include code stored in a memory device to implement protocol(s), protocol layers, communication drivers, device drivers, combinations thereof, and/or the like. A firmware interface may include a combination of embedded hardware and code stored in and/or in communication with a memory device to implement connections, electronic device operations, protocol(s), protocol layers, communication drivers, device drivers, hardware operations, combinations thereof, and/or the like.

[0022] The term configured may relate to the capacity of a device whether the device is in an operational or non-operational state. Configured may also refer to specific settings in a device that effect the operational characteristics of the device whether the device is in an operational or non-operational state. In other words, the hardware, software, firmware, registers, memory values, and/or the like may be “configured” within a device, whether the device is in an operational or nonoperational state, to provide the device with specific characteristics. Terms such as “a control message to cause in a device” may mean that a control message has parameters that may be used to configure specific characteristics in the device, whether the device is in an operational or non-operational state.

[0023] According to some of the various aspects of embodiments, an LTE network may include many base stations, providing a user plane (PDCP: packet data convergence protocol/RLC: radio link control/MAC: media access control/PHY: physical) and control plane (RRC: radio resource control) protocol terminations towards the wireless device. The base station(s) may be interconnected with other base station(s) by means of an X2 interface.

The base stations may also be connected by means of an S1 interface to an EPC (Evolved Packet Core). For example, the base stations may be interconnected to the MME (Mobility Management Entity) by means of the S1-MME interface and to the Serving Gateway (S-GW) by means of the S1-U interface. The S1 interface may support a many-to-many relation between MMEs / Serving Gateways and base stations. A base station may include many sectors for example: 1, 2, 3, 4, or 6 sectors. A base station may include many cells, for example, ranging from 1 to 50 cells or more. A cell may be categorized, for example, as a primary cell or secondary cell. When carrier aggregation is configured, a wireless device may have one RRC connection with the network. At RRC connection establishment/re-establishment/handover, one serving cell may provide the NAS (non-access stratum) mobility information (e.g. TAI-tracking area identifier), and at RRC connection re-establishment/handover, one serving cell may provide the security input. This cell may be referred to as the Primary Cell (PCell). In the downlink, the carrier corresponding to the PCell may be the Downlink Primary Component Carrier (DL PCC), while in the uplink, it may be the Uplink Primary Component Carrier (UL PCC). Depending on wireless device capabilities, Secondary Cells (SCells) may be configured to form together with the PCell a set of serving cells. In the downlink, the carrier corresponding to an SCell may be a Downlink Secondary Component Carrier (DL SCC), while in the uplink, it may be an Uplink Secondary Component Carrier (UL SCC). An SCell may or may not have an uplink carrier.

[0024] A cell, comprising a downlink carrier and optionally an uplink carrier, is assigned a physical cell ID and a cell index. A carrier (downlink or uplink) belongs to only one cell, the cell ID or Cell index may also identify the downlink carrier or uplink carrier of the cell (depending on the context it is used). In the specification, cell ID may be equally referred to a carrier ID, and cell index may be referred to carrier index. In implementation, the physical cell ID or cell index may be assigned to a cell. Cell ID may be determined using the synchronization signal transmitted on a downlink carrier. Cell index may be determined using RRC messages. For example, when the specification refers to a first physical cell ID for a first downlink carrier, it may mean the first physical cell ID is for a cell comprising the first downlink carrier. The same concept may apply to, for example, carrier activation. When the specification indicates that a first carrier is activated, it equally means that the cell comprising the first carrier is activated.

[0025] Embodiments may be configured to operate as needed. The disclosed mechanism may be performed when certain criteria are met, for example, in wireless device, base station, radio environment, network, a combination of the above, and/or the like. Example criteria may be based, at least in part, on for example, traffic load, initial system set up, packet sizes, traffic characteristics, a combination of the above, and/or the like. When the one or more criteria are met, the example embodiments may be applied. Therefore, it may be possible to implement example embodiments that selectively implement disclosed protocols.

[0026] Example embodiments of the invention may enable operation of multiple timing advance groups. Other example embodiments may comprise a non-transitory tangible computer readable media comprising instructions executable by one or more processors to cause operation of multiple timing advance groups. Yet other example embodiments may comprise an article of manufacture that comprises a non-transitory tangible computer readable machine-accessible medium having instructions encoded thereon for enabling programmable hardware to cause a device (e.g. wireless communicator, UE, base station, etc.) to enable operation of multiple timing advance groups. The device may include processors, memory,

interfaces, and/or the like. Other example embodiments may comprise communication networks comprising devices such as base stations, wireless devices (or user equipment: UE), servers, switches, antennas, and/or the like.

[0027] According to some of the various aspects of embodiments, serving cells having an uplink to which the same time alignment (TA) applies may be grouped in a TA group (TAG). Serving cells in one TAG may use the same timing reference. For a given TAG, a user equipment (UE) may use one downlink carrier as the timing reference at a given time. The UE may use a downlink carrier in a TAG as the timing reference for that TAG. For a given TAG, a UE may synchronize uplink subframe and frame transmission timing of the uplink carriers belonging to the same TAG. According to some of the various aspects of embodiments, serving cells having an uplink to which the same TA applies may correspond to the serving cells hosted by the same receiver. A TA group may comprise at least one serving cell with a configured uplink. A UE supporting multiple TAs may support two or more TA groups. One TA group may contain the PCell and may be called a primary TAG (pTAG). In a multiple TAG configuration, at least one TA group may not contain the PCell and may be called a secondary TAG (sTAG). Carriers within the same TA group may use the same TA value and the same timing reference.

[0028] FIG. 5 is a diagram depicting uplink transmission timing of one or more cells in a first timing advance group (TAG1) and a second TAG (TAG2) as per an aspect of an embodiment of the present invention. TAG1 may include one or more cells, TAG2 may also include one or more cells. TAG timing difference in FIG. 5 may be the difference in UE uplink transmission timing for uplink carriers in TAG1 and TAG2. The timing difference may range between, for example, sub micro-seconds to about 30 micro-seconds.

[0029] FIG. 7 shows example TAG configurations as per an aspect of an embodiment of the present invention. In Example 1, pTAG include PCell, and sTAG includes SCell1. In Example 2, pTAG includes PCell and SCell1, and sTAG includes SCell2 and SCell3. In Example 3, pTAG includes PCell and SCell1, and sTAG1 includes SCell2 and SCell3, and sTAG2 includes SCell4. Up to four TAGs may be supported and other example TAG configurations may also be provided. In many examples of this disclosure, example mechanisms are described for a pTAG and an sTAG. The operation with one example sTAG is described, and the same operation may be applicable to other sTAGs. The example mechanisms may be applied to configurations with multiple sTAGs.

[0030] According to some of the various aspects of embodiments, TA maintenance, pathloss reference handling and the timing reference for pTAG may follow LTE release 10 principles. The UE may need to measure downlink pathloss to calculate the uplink transmit power. The pathloss reference may be used for uplink power control and/or transmission of random access preamble(s). A UE may measure downlink pathloss using the signals received on the pathloss reference cell. For SCell(s) in a pTAG, the choice of pathloss reference for cells may be selected from and be limited to the following two options: a) the downlink SCell linked to an uplink SCell using the system information block 2 (SIB2), and b) the downlink pCell. The pathloss reference for SCells in pTAG may be configurable using RRC message(s) as a part of SCell initial configuration and/or reconfiguration. According to some of the various aspects of embodiments, PhysicalConfigDedicatedSCell information element (IE) of an SCell configuration may include the pathloss reference SCell (downlink carrier) for an SCell in pTAG. The downlink SCell linked to an uplink SCell using the system information block 2 (SIB2) may be referred to as the SIB2 linked downlink of the SCell. Different TAGs

may operate in different bands. For an uplink carrier in an sTAG, the pathloss reference may be only configurable to the downlink SCell linked to an uplink SCell using the system information block 2 (SIB2) of the SCell.

[0031] To obtain initial uplink (UL) time alignment for an sTAG, eNB may initiate an RA procedure. In an sTAG, a UE may use one of any activated SCells from this sTAG as a timing reference cell. In an example embodiment, the timing reference for SCells in an sTAG may be the SIB2 linked downlink of the SCell on which the preamble for the latest RA procedure was sent. There may be one timing reference and one time alignment timer (TAT) per TA group. TAT for TAGs may be configured with different values. When the TAT associated with the pTAG expires: all TATs may be considered as expired, the UE may flush all HARQ buffers of all serving cells, the UE may clear any configured downlink assignment/uplink grants, and the RRC in the UE may release PUCCH/SRS for all configured serving cells. When the pTAG TAT is not running, an sTAG TAT may not be running. When the TAT associated with sTAG expires: a) SRS transmissions may be stopped on the corresponding SCells, b) SRS RRC configuration may be released, c) CSI reporting configuration for the corresponding SCells may be maintained, and/or d) the MAC in the UE may flush the uplink HARQ buffers of the corresponding SCells.

[0032] Upon deactivation of the last SCell in an sTAG, the UE may not stop TAT of the sTAG. In an implementation, upon removal of the last SCell in an sTAG, TAT of the TA group may not be running. RA procedures in parallel may not be supported for a UE. If a new RA procedure is requested (either by UE or network) while another RA procedure is already ongoing, it may be up to the UE implementation whether to continue with the ongoing procedure or start with the new procedure. The eNB may initiate the RA procedure via a PDCCH order for an activated SCell. This PDCCH order may be sent on the scheduling cell of this SCell. When cross carrier scheduling is configured for a cell, the scheduling cell may be different than the cell that is employed for preamble transmission, and the PDCCH order may include the SCell index. At least a non-contention based RA procedure may be supported for SCell(s) assigned to sTAG(s).

[0033] FIG. 6 is an example message flow in a random access process in a secondary TAG as per an aspect of an embodiment of the present invention. eNB transmits an activation command 600 to activate an SCell. A preamble 602 (Msg1) may be sent by a UE in response to the PDCCH order 601 on an SCell belonging to an sTAG. In an example embodiment, preamble transmission for SCells may be controlled by the network using PDCCH format 1A. Msg2 message 603 (RAR: random access response) in response to the preamble transmission on SCell may be addressed to RA-RNTI in PCell common search space (CSS). Uplink packets 604 may be transmitted on the SCell, in which the preamble was transmitted.

[0034] According to some of the various aspects of embodiments, initial timing alignment may be achieved through a random access procedure. This may involve the UE transmitting a random access preamble and the eNB responding with an initial TA command NTA (amount of timing advance) within the random access response window. The start of the random access preamble may be aligned with the start of the corresponding uplink subframe at the UE assuming NTA=0. The eNB may estimate the uplink timing from the random access preamble transmitted by the UE. The TA command may be derived by the eNB based on the estimation of the difference between the desired UL timing and the actual UL timing. The UE may determine the initial uplink transmission timing relative to the corresponding downlink of the sTAG on which the preamble is transmitted.

[0035] A base station may communicate with a mix of wireless devices. Wireless devices may support multiple technologies, or multiple releases of the same technology, have some specific capability depending on the wireless device category and/or capability. A base station may comprise multiple sectors. When this disclosure refers to a base station communicating with a plurality of wireless devices, this disclosure may refer to a subset of the total wireless devices in the coverage area. This disclosure may refer to, for example, a plurality of wireless devices of a given LTE release with a given capability and in a given sector of the base station. The plurality of wireless devices in this disclosure may refer to a selected plurality of wireless devices, and/or a subset of total wireless devices in the coverage area, which perform according to the disclosed methods, and/or the like. There may be many wireless devices in the coverage area that may not comply with the disclosed methods, for example, because those wireless devices perform based on older releases of LTE technology. A time alignment command MAC control element may be a unicast MAC command transmitted to a wireless device.

[0036] According to some of the various aspects of various embodiments, the base station or wireless device may group cells into a plurality of cell groups. The term “cell group” may refer to a timing advance group (TAG) or a timing alignment group or a time alignment group. Time alignment command may also be referred to timing advance command. A cell group may include at least one cell. A MAC TA command may correspond to a TAG. A cell group may explicitly or implicitly be identified by a TAG index. Cells in the same band may belong to the same cell group. A first cell’s frame timing may be tied to a second cell’s frame timing in a TAG. When a time alignment command is received for the TAG, the frame timing of both first cell and second cell may be adjusted. Base station(s) may provide TAG configuration information to the wireless device(s) by RRC configuration message(s).

[0037] The mapping of a serving cell to a TAG may be configured by the serving eNB with RRC signaling. The mechanism for TAG configuration and reconfiguration may be based on RRC signaling. According to some of the various aspects of embodiments, when an eNB performs SCell addition configuration, the related TAG configuration may be configured for the SCell. In an example embodiment, eNB may modify the TAG configuration of an SCell by removing (releasing) the SCell and adding(configuring) a new SCell (with the same physical cell ID and frequency) with an updated TAG ID. The new SCell with the updated TAG ID may be initially inactive subsequent to being assigned the updated TAG ID. eNB may activate the updated new SCell and then start scheduling packets on the activated SCell. In an example implementation, it may not be possible to change the TAG associated with an SCell, but rather, the SCell may need to be removed and a new SCell may need to be added with another TAG. For example if there is a need to move an SCell from an sTAG to a pTAG, at least one RRC message, for example, at least one RRC reconfiguration message, may be send to the UE to reconfigure TAG configurations by releasing the SCell and then configuring the SCell as a part of pTAG (when an SCell is added/configured without a TAG index, the SCell is explicitly assigned to pTAG). The PCell may not change its TA group and may always be a member of the pTAG.

[0038] An eNB may perform initial configuration based on initial configuration parameters received from a network node (for example a management platform), an initial eNB configuration, a UE location, a UE type, UE CSI feedback, UE uplink transmissions (for example, data, SRS, and/or the like), a combination of the above, and/or the like. For

example, initial configuration may be based on UE channel state measurements or received signal timing. For example, depending on the signal strength received from a UE on various SCells downlink carrier or by determination of UE being in a repeater coverage area, or a combination of both, an eNB may determine the initial configuration of sTAGs and membership of SCells to sTAGs.

[0039] In an example implementation, the TA value of a serving cell may change, for example due to UE's mobility from a macro-cell to a repeater or an RRH (remote radio head) coverage area. The signal delay for that SCell may become different from the original value and different from other serving cells in the same TAG. In this scenario, eNB may re-configure this TA-changed serving cell to another existing TAG. Or alternatively, the eNB may create a new TAG for the SCell based on the updated TA value. The TA value may be derived, for example, through eNB measurement(s) of signal reception timing, a RA mechanism, or other standard or proprietary processes. An eNB may realize that the TA value of a serving cell is no longer consistent with its current TAG. There may be many other scenarios which require eNB to reconfigure TAGs. During reconfiguration, the eNB may need to move the reference SCell belonging to an sTAG to another TAG. In this scenario, the sTAG would require a new reference SCell. In an example embodiment, the UE may select an active SCell in the sTAG as the reference timing SCell.

[0040] eNB may consider UE's capability in configuring multiple TAGs for a UE. UE may be configured with a configuration that is compatible with UE capability. Multiple TAG capability may be an optional feature and per band combination Multiple TAG capability may be introduced. UE may transmit its multiple TAG capability to eNB via an RRC message and eNB may consider UE capability in configuring TAG configuration(s).

[0041] The purpose of an RRC connection reconfiguration procedure may be to modify an RRC connection, (e.g. to establish, modify and/or release RBs, to perform handover, to setup, modify, and/or release measurements, to add, modify, and/or release SCells). If the received RRC Connection Reconfiguration message includes the sCellToReleaseList, the UE may perform an SCell release. If the received RRC Connection Reconfiguration message includes the sCellToAddModList, the UE may perform SCell additions or modification.

[0042] The parameters related to SCell random access channel may be common to all UEs. For example PRACH configuration (RACH resources, configuration parameters, RAR window) for the SCell may be common to UEs. RACH resource parameters may include prach-configuration index, and/or prach-frequency offset. SCell RACH common configuration parameters may also include power: power ramping parameter(s) for preamble transmission; and max number of preamble transmission parameter. It is more efficient to use common parameters for RACH configuration, since different UEs will share the same random access channel.

[0043] eNB may transmit at least one RRC message to configure PCell, SCell(s) and RACH, and TAG configuration parameters. MAC-MainConfig may include a timeAlignmentTimerDedicated IE to indicate time alignment timer value for the pTAG. MAC-MainConfig may further include an IE including a sequence of at least one (sTAG ID, and TAT value) to configure time alignment timer values for sTAGs. In an example, a first RRC message may configure TAT value for pTAG, a second RRC message may configure TAT value for sTAG1, and a third RRC message may configure TAT value for sTAG2. There is no need to include all the TAT configurations in a single RRC message. In an example embodiment they may be included in one or two RRC messages. The IE including a sequence

of at least one (sTAG ID, and TAT) value may also be used to update the TAT value of an existing sTAG to an updated TAT value. The at least one RRC message may also include sCellToAddModList including at least one SCell configuration parameters. The radioResourceConfigDedicatedSCell (dedicated radio configuration IEs) in sCellToAddModList may include an SCell MAC configuration comprising TAG ID for the corresponding SCell added or modified. The radioResourceConfigDedicatedSCell may also include pathloss reference configuration for an SCell. If TAG ID is not included in SCell configuration, the SCell is assigned to the pTAG. In other word, a TAG ID may not be included in radioResourceConfigDedicatedSCell for SCells assigned to pTAG. The radioResourceConfigCommonSCell (common radio configuration IEs) in sCellToAddModList may include RACH resource configuration parameters, preamble transmission power control parameters, and other preamble transmission parameter(s). At the least one RRC message configures PCell, SCell, RACH resources, and/or SRS transmissions and may assign each SCell to a TAG (implicitly for pTAG or explicitly for sTAG). PCell is always assigned to the pTAG.

[0044] According to some of the various aspects of embodiments, a base station may transmit at least one control message to a wireless device in a plurality of wireless devices. The at least one control message is for example, RRC connection reconfiguration message, RRC connection establishment message, RRC connection re-establishment message, and/or other control messages configuring or reconfiguring radio interface, and/or the like. The at least one control message may be configured to cause, in the wireless device, configuration of at least: I) a plurality of cells. Each cell may comprise a downlink carrier and zero or one uplink carrier. The configuration may assign a cell group index to a cell in the plurality of cells. The cell group index may identify one of a plurality of cell groups. A cell group in the plurality of cell groups may comprise a subset of the plurality of cells. The subset may comprise a reference cell with a reference downlink carrier and a reference uplink carrier. Uplink transmissions by the wireless device in the cell group may employ the reference cell (the primary cell in pTAG and a secondary cell in an sTAG). The wireless device may employ a synchronization signal transmitted on the reference downlink carrier as timing reference to determine a timing of the uplink transmissions. The synchronization signal for example may be a) primary/secondary synchronization signal, b) reference signal(s), and/or c) a combination of a) and b). II) a time alignment timer for each cell group in the plurality of cell groups; and/or III) an activation timer for each configured secondary cell.

[0045] The base station may transmit a plurality of timing advance commands. Each timing advance command may comprise: a time adjustment value, and a cell group index. A time alignment timer may start or may restart when the wireless device receives a timing advance command to adjust uplink transmission timing on a cell group identified by the cell group index. A cell group may be considered out-of-sync, by the wireless device, when the associated time alignment timer expires or is not running. The cell group may be considered in-sync when the associated time alignment timer is running.

[0046] The timing advance command may causes substantial alignment of reception timing of uplink signals in frames and subframes of all activated uplink carriers in the cell group at the base station. The time alignment timer value may be configured as one of a finite set of predetermined values. For example, the finite set of predetermined values may be eight. Each time alignment timer value may be encoded employing three bits. TAG TAT may be a dedicated time alignment timer value and is transmitted by the base station to the wireless

device. TAG TAT may be configured to cause configuration of time alignment timer value for each time alignment group. The IE TAG TAT may be used to control how long the UE is considered uplink time aligned. It corresponds to the timer for time alignment for each cell group. Its value may be in number of sub-frames. For example, value sf500 corresponds to 500 sub-frames, sf750 corresponds to 750 sub-frames and so on. An uplink time alignment is common for all serving cells belonging to the same cell group. In an example embodiment, the IE TAG TAT may be defined as: TAG TAT::= SEQUENCE{TAG ID, ENUMERATED {sf500, sf750, sf1280, sf1920, sf2560, sf5120, sf10240, infinity}}. Time alignment timer for pTAG may be indicated in a separate IE and may not be included in the sequence.

[0047] In an example, TimeAlignmentTimerDedicated IE may be sf500, and then TAG TAT may be {1, sf500; 2, sf2560; 3, sf500}. In the example, time alignment timer for the pTAG is configured separately and is not included in the sequence. In the examples, TAG0 (pTAG) time alignment timer value is 500 subframes (500 m-sec), TAG1 (sTAG) time alignment timer value is 500 subframes, TAG2 time alignment timer value is 2560 subframes, and TAG3 time alignment timer value is 500 subframes. This is for example purposes only. In this example a TAG may take one of 8 predefined values. In a different embodiment, the enumerated values could take other values.

[0048] Dual Connectivity

[0049] Dual connectivity has been introduced in LTE Release-12. E-UTRAN may support Dual Connectivity (DC) operation whereby a multiple RX/TX UE in RRC_CONNECTED is configured to utilise radio resources provided by two distinct schedulers, located in two eNBs connected via a non-ideal backhaul over the X2 interface. eNBs involved in DC for a certain UE may assume two different roles: an eNB may either act as an MeNB or as an SeNB. In DC a UE may be connected to one MeNB and one SeNB. Mechanisms implemented in DC may be extended to cover more than two eNBs.

[0050] In DC, the radio protocol architecture that a particular bearer uses may depend on how the bearer is setup. Three alternatives may exist, MCG bearer, SCG bearer and split bearer. Those three alternatives are depicted on Figure 9 below. RRC is located in MeNB and SRBs are always configured as MCG bearer type and therefore only use the radio resources of the MeNB. DC may also be described as having at least one bearer configured to use radio resources provided by the SeNB.

[0051] In case of DC, the UE may be configured with two MAC entities: one MAC entity for MeNB and one MAC entity for SeNB. Figure 10 below describes the layer 2 structure for the downlink when both CA and DC are configured. In order to simplify the figure, the BCH, PCH, MCH and corresponding logical channels are not included. UEn is shown as having DC configured.

[0052] Figure 11 below describes the layer 2 structure for the uplink when both CA and DC are configured. SRBs may be handled by the MeNB and as a result, CCCH is only shown for the MeNB. For a split bearer, UE may be configured over which link the UE transmits UL PDCP PDUs by the MeNB. On the link which is not responsible for UL PDCP PDUs transmission, the RLC layer may transmits corresponding ARQ feedback for the downlink data.

[0053] In DC, the configured set of serving cells for a UE may comprise of two subsets: the Master Cell Group (MCG) containing the serving cells of the MeNB, and the Secondary Cell Group (SCG) containing the serving cells of the SeNB. For SCG, one or more of the following principles may be applied:

- At least one cell in SCG has a configured UL CC and one of them, named PSCell, is configured with PUCCH resources;
- When SCG is configured, there is at least one SCG bearer or one Split bearer;
- Upon detection of a physical layer problem or a random access problem on PSCell, or the maximum number of RLC retransmissions has been reached associated with the SCG, or upon detection of an access problem on PSCell (T307 expiry) during SCG addition or SCG change:
 - RRC connection Re-establishment procedure is not triggered;
 - All UL transmissions towards all cells of the SCG are stopped;
 - MeNB is informed by the UE of SCG failure type.
 - For split bearer, the DL data transfer over the MeNB is maintained.
- Only the RLC AM bearer can be configured for the split bearer;
- Like PCell, PSCell cannot be de-activated;
- PSCell can be changed with SCG change (e.g. with security key change and RACH procedure);
- Neither direct bearer type change between Split bearer and SCG bearer nor simultaneous configuration of SCG and Split bearer are supported.

[0054] With respect to the interaction between MeNB and SeNB, one or more of the following principles may be applied:

- The MeNB maintains the RRM measurement configuration of the UE and may, e.g. based on received measurement reports or traffic conditions or bearer types, decide to ask a SeNB to provide additional resources (serving cells) for a UE.
- Upon receiving the request from the MeNB, a SeNB may create the container that will result in the configuration of additional serving cells for the UE (or decide that it has no resource available to do so).
- For UE capability coordination, the MeNB provides (part of) the AS configuration and the UE capabilities to the SeNB.
- The MeNB and the SeNB exchange information about UE configuration by means of RRC containers (inter-node messages) carried in X2 messages.
- The SeNB may initiate a reconfiguration of its existing serving cells (e.g., PUCCH towards the SeNB).
- The SeNB decides which cell is the PSCell within the SCG.
- The MeNB does not change the content of the RRC configuration provided by the SeNB.
- In the case of the SCG addition and SCG SCell addition, the MeNB may provide the latest measurement results for the SCG cell(s).

- Both MeNB and SeNB know the SFN and subframe offset of each other by OAM, e.g., for the purpose of DRX alignment and identification of measurement gap.

[0055] When adding a new SCG SCell, dedicated RRC signalling is used for sending all required system information of the cell as for CA, except for the SFN acquired from MIB of the PCell of SCG.

[0056] PUCCH Cell Groups

[0057] In LTE Release-10 and Release-11 CA, PUCCH is only transmitted on the PCell. In LTE-Release 12 and earlier, a UE may transmit PUCCH information on one cell (PCell) to a given eNB. DC is introduced in Release 12 as described in the previous section.

[0058] As the number of CA capable UEs and also the number of aggregated carriers increase, the number of PUCCHs and also the PUCCH payload size may increase. Accommodating the PUCCH transmissions on the PCell may lead to high PUCCH load on the PCell. PUCCH on SCell may be introduced to offload the PUCCH resource from the PCell. It may be advantageous to configure more than one PUCCH for example, a PUCCH on PCell and another PUCCH on an SCell. In the example embodiments of the invention, one, two or more cells may be configured with PUCCH resources for transmitting CSI/ACK/NACK to a base station. Cells may be grouped into multiple groups, and one or more cell within a group may be configured with PUCCH. In an example configuration, one SCell may belong to one PUCCH cell group. The SCells with a configured PUCCH transmitted to a base station may be called PUCCH SCell, and a cell group with a common PUCCH resource transmitted to the same base station may be called a PUCCH cell group (CG).

[0059] In Release-12, PUCCH can be configured on PCell and PSCell, but cannot be configured on other SCells. In an example embodiment, a UE may transmit a message indicating that the UE supports PUCCH configuration on PCell and SCell, Such an indication may be separate from the indication of the support of dual connectivity by the UE. In an example, embodiment a UE may support both DC and PUCCH CGs. In an example embodiment, either DC or PUCCH CGs may be configured but not both. In another example embodiment, more complicated configurations comprising both DC and PUCCH may be supported.

[0060] When UE is capable of PUCCH CG configuration, and if a UE indicates that it supports simultaneous PUCCH/PUSCH transmission capability, it may imply that the UE supports simultaneous PUCCH/PUSCH transmission on both PCell and SCell. When multiple PUCCH CGs are configured, a PUCCH may be configured or not configured with simultaneous PUCCH/PUSCH transmission.

[0061] In an example embodiment, PUCCH transmission to a base station on two serving cells may be realized as shown in Figure 12. A first group of cells may employ PUCCH on the PCell and may be called PUCCH cell group 1 or a primary PUCCH CG. A second group of cells may employ PUCCH on an SCell and may be called PUCCH cell group 2 or a secondary PUCCH CG. One, two or more PUCCH CGs may be configured. In an example, cells may be grouped into two PUCCH CGs, and each PUCCH CG may include a cell with PUCCH resources. PCell may provide PUCCH resources for the primary PUCCH CG and an SCell in the secondary PUCCH CG may provide PUCCH resources for the cells in the secondary PUCCH CG. In an example embodiment, no cross-carrier scheduling between cells in different PUCCH cell groups may be configured. When cross-carrier scheduling between cells in different PUCCH CGs is not configured, ACK/NACK on PHICH channel may be

limited within PUCCH CG. Both downlink and uplink scheduling activity may be separate between cells belonging to different PUCCH CGs.

[0062] PUCCH on an SCell may carry HARQ-ACK and CSI information. At least PCell may be configured with PUCCH resources. In an example embodiment, RRC parameters for SCell PUCCH Power Control for PUCCH on SCell may be different from those of PCell PUCCH. Transmit Power Control command for PUCCH on SCell may be transmitted in DCI(s) on the SCell carrying the PUCCH.

[0063] UE procedures on PUCCH transmission may be different and/or independent between cell groups. For example, determination of DL HARQ-ACK timing, PUCCH resource determination for HARQ-ACK and/or CSI, Higher-layer configuration of simultaneous HARQ-ACK + CSI on PUCCH, Higher-layer configuration of simultaneous HARQ-ACK + SRS in one subframe may be configured differently for PUCCH PCell and PUCCH SCell.

[0064] The following terminologies may be defined:

[0065] PUCCH Cell Group: A group of serving cells that is configured by RRC and use the same serving cell in the group for transmission of PUCCH.

[0066] Primary PUCCH Cell Group: PUCCH Cell Group containing the PCell.

[0067] Secondary PUCCH Cell Group: PUCCH Cell Group not containing the PCell.

[0068] In an example embodiment, an SCell may belong to one PUCCH cell group. When one SCell belongs to a PUCCH CG, ACK/NACK or CSI for that SCell may be transmitted over the PUCCH in that PUCCH CG (over PUCCH SCell or PUCCH PCell). PUCCH on SCell may reduce PUCCH load on PCell. PUCCH SCell may be employed for UCI transmission of SCells in the corresponding PUCCH CG.

[0069] In an example embodiment, a flexible PUCCH configuration in which the control signalling is sent on one, two or more PUCCHs may be possible. Beside the PCell, it may be possible to configure a selected number of SCells for PUCCH transmission, here called PUCCH SCells. The control signalling information conveyed in a certain PUCCH SCell may be related to a set of SCells in the corresponding PUCCH CG that are configured by the network via RRC signalling.

[0070] The PUCCH control signalling carried by the PUCCH channel may be distributed between PCell and SCells for off-loading or robustness purposes. By enabling PUCCH in SCell, it may be possible to distribute the overall CSI reports for a given UE between PCell and a selected number of SCells (i.e. PUCCH SCells) thereby limiting PUCCH CSI resource consumption by a given UE on a certain cell. It may be possible to map CSI reports for a certain SCell to a selected PUCCH SCell. An SCell is assigned a certain periodicity and time-offset for transmission of control information. Periodic CSI for a serving cell may be mapped on a PUCCH (on the PCell or on a PUCCH-SCell) via RRC signalling. The possibility to distributing CSI reports, HARQ feedbacks, and /or Scheduling Requests across PUCCH SCells may provide flexibility and capacity improvements. HARQ feedbacks for a serving cell may be mapped on a PUCCH (on the PCell or on a PUCCH SCell) via RRC signalling.

[0071] Carrier aggregation, in which two or more CCs are aggregated at a single UE, was introduced in 3GPP Rel-10 in order to support wider transmission bandwidths (e.g. up to 100MHz) and spectrum aggregation. Accordingly, a terminal may simultaneously receive or transmit one or multiple component carriers depending on its capabilities. According to Rel-10, CCs supported by a single eNB may be Rel-8 compatible (providing backward compatibility).

[0072] Aggregated CCs at a UE may be classified under two categories as primary component carrier (PCC)/primary serving cell (PCell) and secondary component carrier (SCC)/secondary serving cell (SCell). Symmetric (no. of DL CCs = no. of UL CCs) as well as asymmetric (no. of DL CCs > no. of UL CCs) configurations such that number of DL CCs is greater than or equal to number of UL CCs may be supported. In legacy CA mechanism, a UE may be configured with only one PCell and up to 4 SCells. PCell may handle RRC and NAS procedures and performs configuration of SCells. UE monitors system information on PCell and performs both contention and contention-free random access on it (in Rel-11 contention-free random access may be allowed in SCell as well). In prior releases, PUCCH may be transmitted on the PCell; thus HARQ-ACK and CSI reporting of activated cells may be transmitted on PCell PUCCH.

[0073] In example embodiments of the invention, PUCCH transmission may be configured on PCell as well as one SCell in CA. SCell PUCCH may be realised using the concept of PUCCH Cell Groups (PUCCH CG), where aggregated cells are grouped in to two or more PUCCH CGs. One cell from a PUCCH CG may be configured to carry PUCCH. More than 5 carriers may be configured. In the example embodiments up to n carriers may be aggregated. For example, n may be 16, 32, or 64. Some CCs may have non-backward compatible configurations supporting only advanced UEs. In an example embodiment, one SCell PUCCH (e.g. two PUCCH CGs). In another example embodiment, using PUCCH CG concept with multiple (more than one) SCells carrying PUCCH (e.g., there can be more than two PUCCH CGs).

[0074] Example Physical and MAC Layer Embodiment

[0075] The following paragraphs describe an example radio architecture for an example embodiment. The radio architecture may not be limited to the following examples, and other variations according to other radio technologies, such as WiFi, WiMAX, UMTS, etc may be implemented.

[0076] The figure below shows the protocol stack for an example user-plane, where PDCP, RLC and MAC sublayers (terminated in eNB on the network side) perform the functions listed for the user plane, e.g. header compression, ciphering, scheduling, ARQ and HARQ.

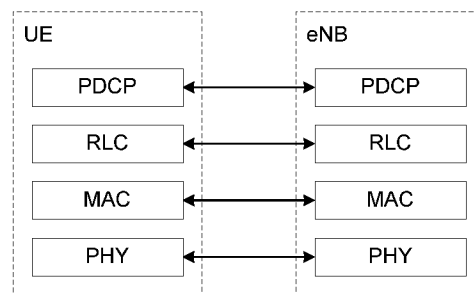


Figure: User-plane protocol stack

[0077] The figure below shows an example protocol stack for the control-plane. Some example functions of different components are described below:

- PDCP sublayer (terminated in eNB on the network side) performs the functions listed for the control plane, e.g. ciphering and integrity protection;

- RLC and MAC sublayers (terminated in eNB on the network side) perform similar functions as for the user plane;
- RRC (terminated in eNB on the network side) performs the functions, e.g.:
 - Broadcast;
 - Paging;
 - RRC connection management;
 - RB control;
 - Mobility functions; and/or
 - UE measurement reporting and control.
- NAS control protocol (terminated in MME on the network side) performs the functions, e.g.:
 - EPS bearer management;
 - Authentication;
 - ECM-IDLE mobility handling;
 - Paging origination in ECM-IDLE; and/or
 - Security control.

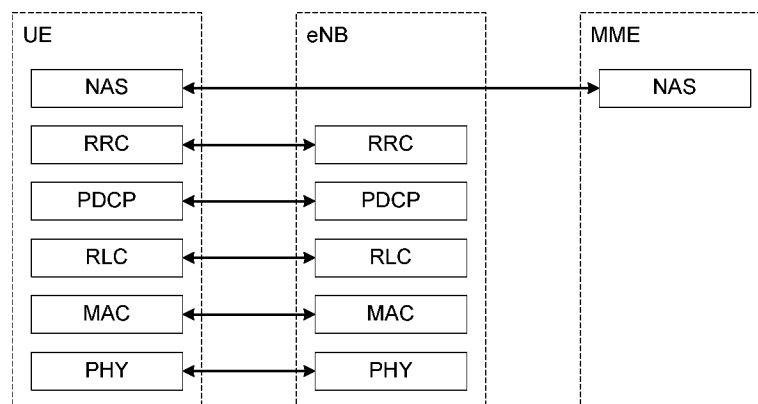


Figure: Control-plane protocol stack

[0078] Uplink Transmissions

[0079] The baseband signal representing the physical uplink shared channel may perform the following processes. These functions are for example and other modulation and coding mechanisms may be implemented.

- scrambling
- modulation of scrambled bits to generate complex-valued symbols

- mapping of the complex-valued modulation symbols onto one or several transmission layers
- transform precoding to generate complex-valued symbols
- precoding of the complex-valued symbols
- mapping of precoded complex-valued symbols to resource elements
- generation of complex-valued time-domain SC-FDMA signal for each antenna port

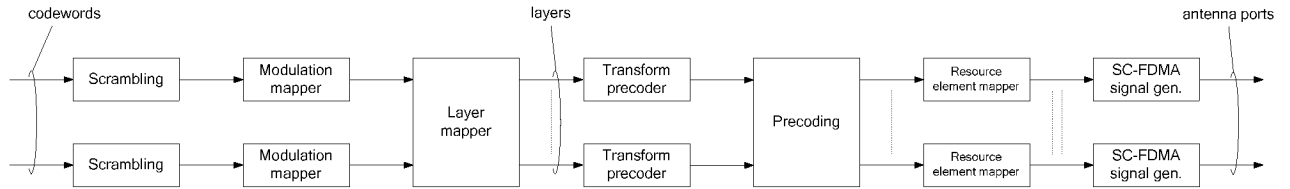


Figure: Overview of uplink physical channel

[0080] Example modulation and upconversion to the carrier frequency of the complex-valued SC-FDMA baseband signal for each antenna port or the complex-valued PRACH baseband signal is shown in Figure below. The filtering may be required prior to transmission.

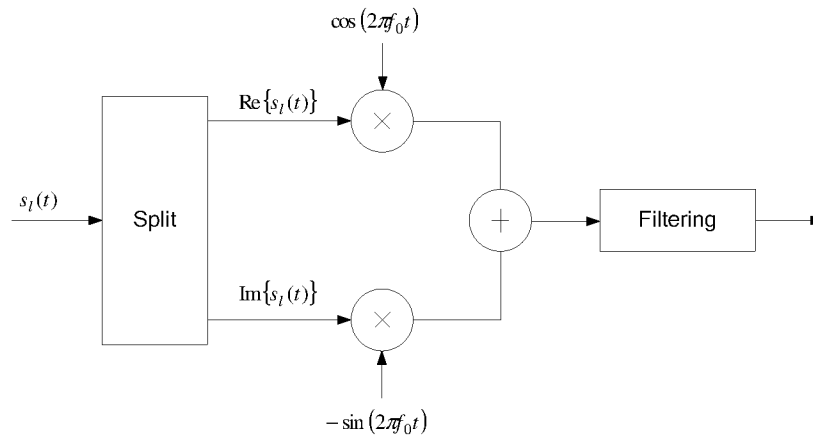


Figure: Uplink modulation

[0081] Example structure for Downlink Transmissions is shown below.

[0082] The baseband signal representing a downlink physical channel may perform the following processes. These functions are for example and other modulation and coding mechanisms may be implemented.

- scrambling of coded bits in each of the codewords to be transmitted on a physical channel
- modulation of scrambled bits to generate complex-valued modulation symbols

- mapping of the complex-valued modulation symbols onto one or several transmission layers
- precoding of the complex-valued modulation symbols on each layer for transmission on the antenna ports
- mapping of complex-valued modulation symbols for each antenna port to resource elements
- generation of complex-valued time-domain OFDM signal for each antenna port

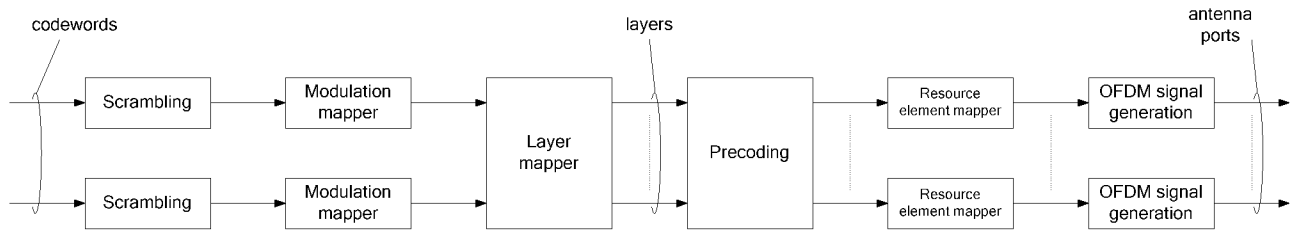


Figure : Overview of downlink physical channel

[0083] Modulation and upconversion

[0084] Example modulation and upconversion to the carrier frequency of the complex-valued OFDM baseband signal for each antenna port is shown in Figure below. The filtering may be required prior to transmission.

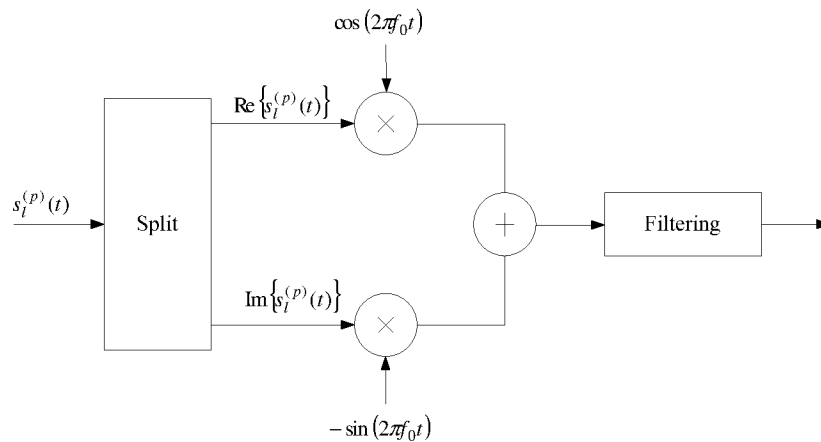


Figure: Downlink modulation

[0085] MAC Introduction

[0086] Example MAC architecture and the MAC entity is described here. Functionality specified for the UE similarly applies to the RN for functionality necessary for the RN. There is also functionality which is only applicable to the RN, in which case the specification denotes the RN instead of the UE. RN-specific behaviour may not be applicable to the UE. For

TDD operation, UE behaviour may follow the TDD UL/DL configuration indicated by tdd-Config.

[0087] E-UTRA may include two MAC entities; one in the UE and one in the E-UTRAN. These MAC entities may handle some or all of the following example transport channels:

- Broadcast Channel (BCH);
- Downlink Shared Channel(s) (DL-SCH);
- Paging Channel (PCH);
- Uplink Shared Channel(s) (UL-SCH);
- Random Access Channel(s) (RACH);
- Multicast Channel(s) (MCH).

[0088] The RN **may** include both types of MAC entities; one type for communication with UEs and one type for communication with the E-UTRAN.

[0089] In Dual Connectivity, two MAC entities may be configured in the UE: one for the MCG and one for the SCG. A MAC entity may be configured by RRC with a serving cell supporting PUCCH transmission and contention based Random Access. A Timing Advance Group containing the SpCell of a MAC entity is referred to as pTAG, whereas the term sTAG refers to other TAGs.

[0090] The timers and parameters used in a MAC entity are configured independently if not otherwise indicated.

[0091] If the MAC entity is configured with one or more SCells, there may multiple DL-SCH and there may be multiple UL-SCH and RACH per MAC entity; one DL-SCH and UL-SCH on the SpCell, one DL-SCH, zero or one UL-SCH and zero or one RACH for an SCell.

[0092] Figure below illustrates one example possible structure for the UE side MAC entity when SCG is not configured, and it should not restrict implementation.

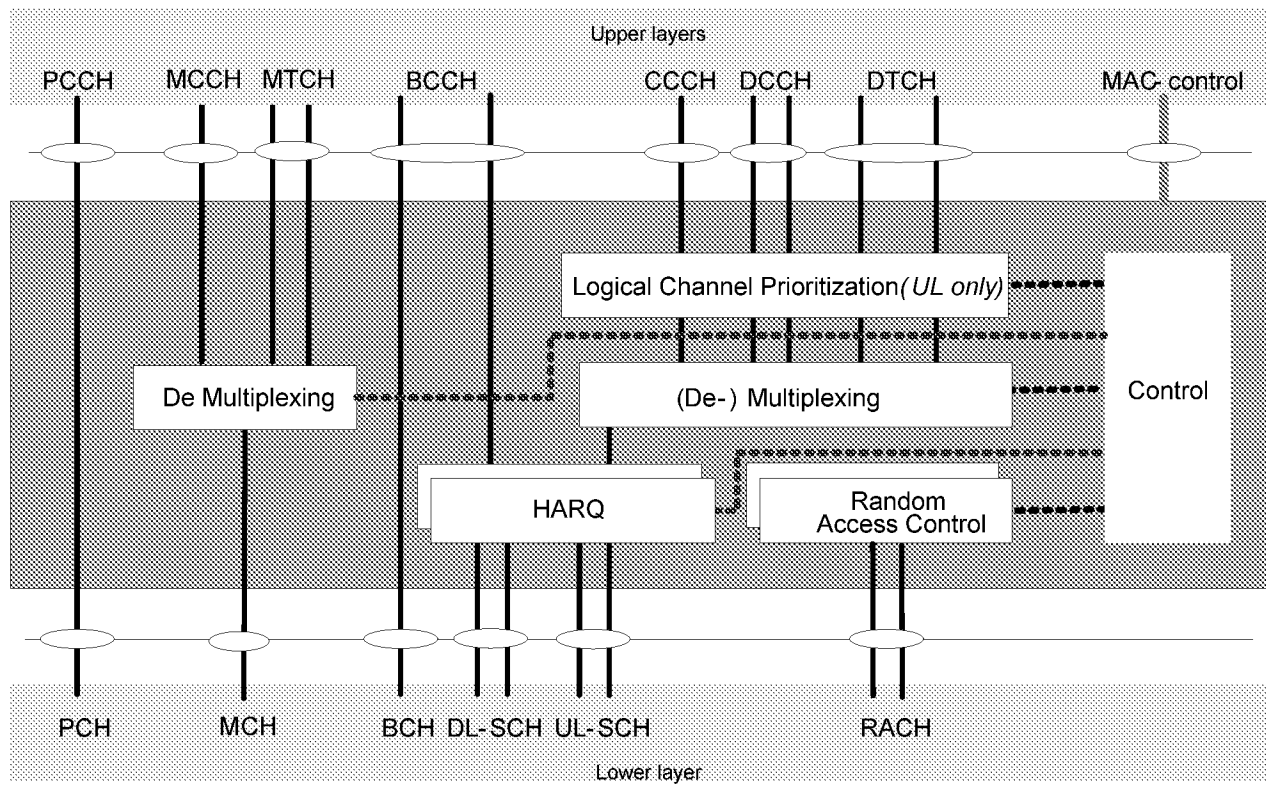


Figure: MAC structure overview, UE side

[0093] Figure below illustrates one possible structure for the UE side MAC entities when MCG and SCG are configured, and it should not restrict implementation. MBMS reception is excluded from this figure for simplicity.

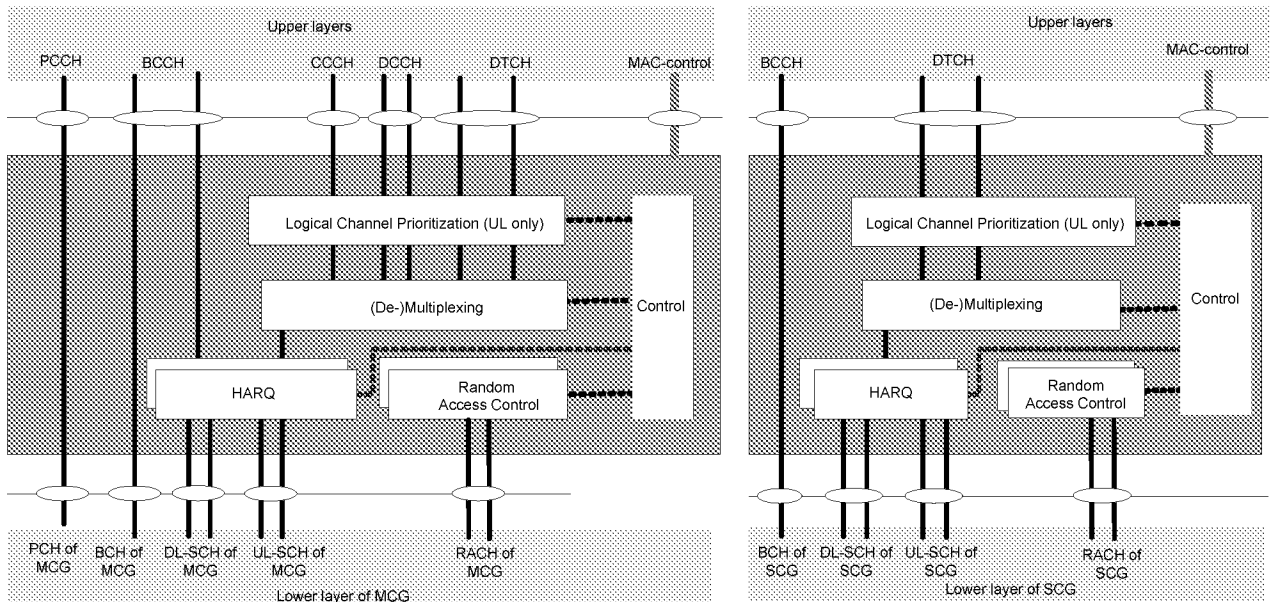


Figure: MAC structure overview with two MAC entities, UE side

[0094] Example Services provided to upper layers are data transfer and radio resource allocation. The physical layer may provide the some or all of following example services to MAC:

- data transfer services;
- signalling of HARQ feedback;
- signalling of Scheduling Request;
- measurements (e.g. Channel Quality Indication (CQI)).

[0095] The access to the data transfer services is through the use of transport channels. The some or all of the following example functions are supported by MAC sublayer:

- mapping between logical channels and transport channels;
- multiplexing of MAC SDUs from one or different logical channels onto transport blocks (TB) to be delivered to the physical layer on transport channels;
- demultiplexing of MAC SDUs from one or different logical channels from transport blocks (TB) delivered from the physical layer on transport channels;
- scheduling information reporting;
- error correction through HARQ;
- priority handling between UEs by means of dynamic scheduling;
- priority handling between logical channels of one MAC entity;

- Logical Channel prioritisation;
- transport format selection.

Acronyms:

MCG	Master Cell Group
MeNB	Master eNB
SeNB	Secondary eNB
SCG	Secondary Cell Group
SRB	Signaling Radio Bearer
DC	Dual Connectivity
CA	Carrier Aggregation
PSCell	Primary SCell
PUCCH	Physical Uplink Control Channel
CSI	Channel State Information
RRC	Radio Resource Control
SCell	Secondary Cell
PCell	Primary Cell
UE	User Equipment
CG	Cell Group
MAC	Media Access Control
PHICH	Physical Hybrid Indicator Channel
DCI	Downlink Control Information

Example LTE based V2X services

Example LTE based V2X services may be:

- V2V or vehicle-to-vehicle: LTE based
 - o direct communication between 2 or more vehicles. In one example embodiment this communication may be one-to-one. In one example embodiment this communication may be one-to-many. Following figure shows only the example embodiment when the communication is one-to-one.

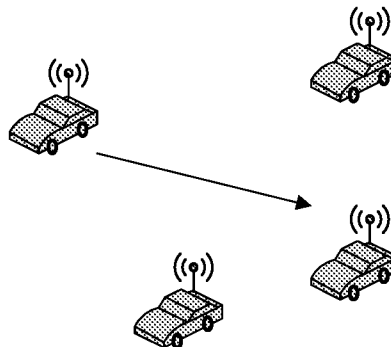


FIG. 1

- o via network communication between 2 or more vehicles. In one example embodiment this communication may be one-to-one. In one example embodiment this communication may be one-

to-many. Following figure shows only the example embodiment when the communication is one-to-many.

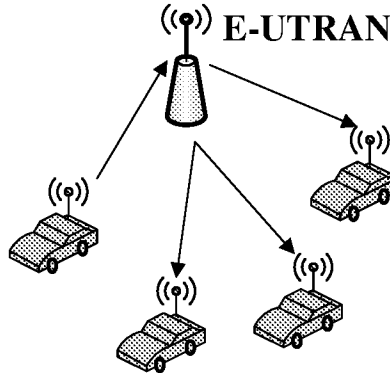


FIG. 2

- V2P or vehicle-to-pedestrian: LTE based
 - direct communications between vehicles and devices of mobile users. In one example embodiment this communication may be one-to-one as shown in section (A) of the following figure. In one example embodiment this communication may be one-to-many as shown in section (B) of the following figure.

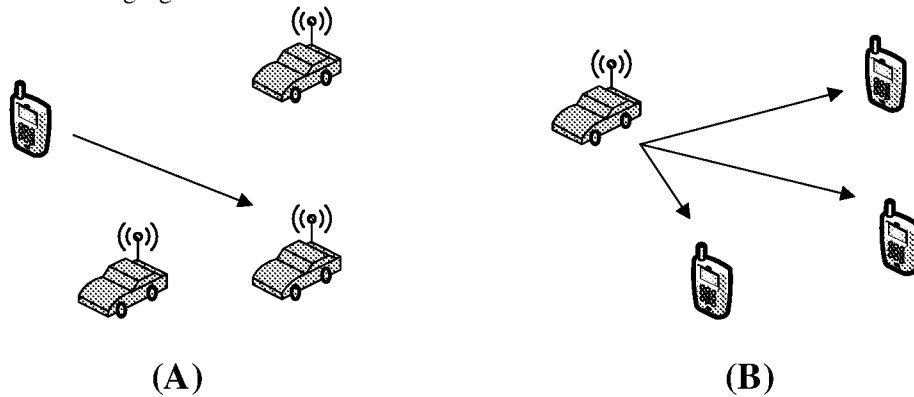


FIG. 3

- via network communications between vehicles and devices of mobile users. In one example embodiment this communication may be one-to-one as shown in section (A) of the following figure. In one example embodiment this communication may be one-to-many as shown in section (B) of the following figure.

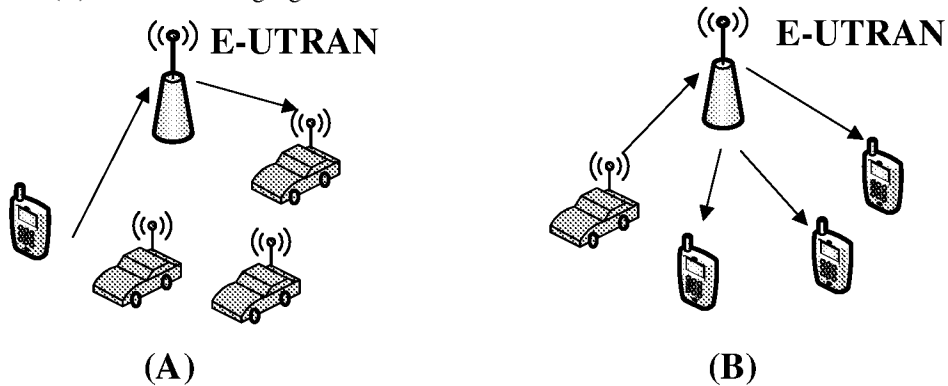


FIG. 4

- V2I/N or vehicle-to-infrastructure/network: LTE based communications between vehicles and roadside units (RSUs) or infrastructure.
 - o In one example embodiment RSU may be eNB-type RSU (infrastructure) as shown in the following figure. In one example embodiment, communications between the RSU/network and the vehicle may be one-to-one as shown in section (A) in the following figure and in one example embodiment the communications between the RSU/network and the vehicle may be one-to-many.

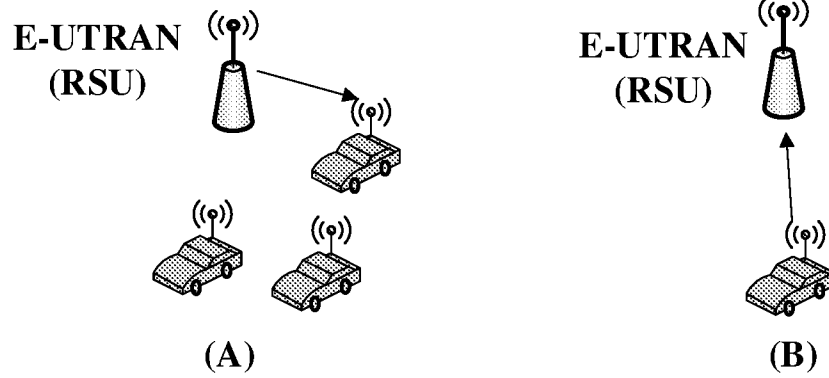


FIG. 5

- o In one example embodiment RSU may be UE-type RSU and relay the UE to the network as shown in the following figure. In one example embodiment, communications between the RSU and the vehicle may be one-to-one as shown in section (A) in the following figure and in one example embodiment the communications between the RSU and the vehicle may be one-to-many as shown in section (B) of the following figure.

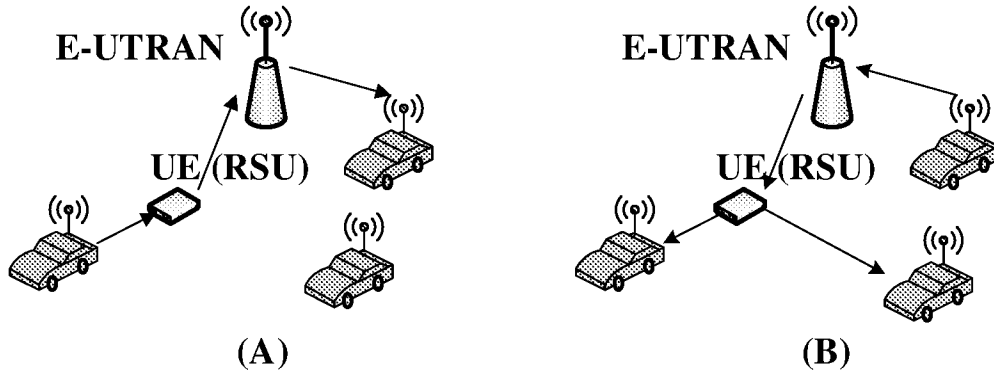


FIG. 6

- Other combinations, LET based
 - o V2I/V or vehicle-to-infrastructure/vehicle:
 - In one example embodiment RSU may be UE-type RSU and relay the vehicle to another vehicle as shown in the following figure. In one example embodiment, communications between the RSU and the vehicle may be one-to-one as shown in section (A) in the following figure and in one example embodiment the communications between the RSU and the vehicle may be one-to-many as shown in section (B) of the following figure.

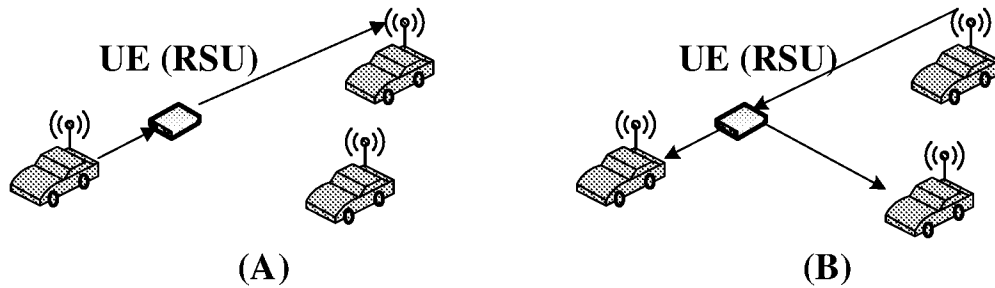


FIG. 7

- V2I/P or vehicle-to-infrastructure/pedestrian:
In one example embodiment RSU may be UE-type RSU and relay the vehicle to pedestrians as shown in the following figure. In one example embodiment, communications between the RSU and the vehicle may be one-to-one as shown in section (A) in the following figure and in one example embodiment the communications between the RSU and the vehicle may be one-to-many as shown in section (B) of the following figure.

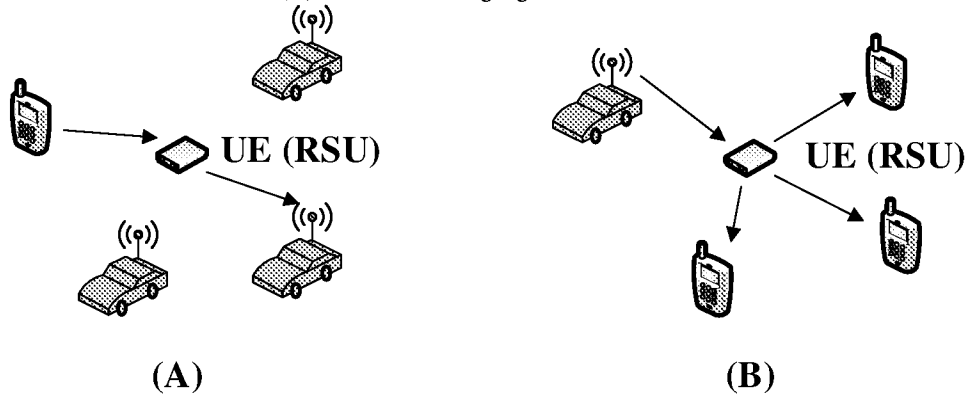


FIG. 8

Example V2X Architecture

In one example embodiment the architecture of V2X may be as shown in FIG. 9. In example network diagrams of the specification, some of the interfaces and/or network nodes may be considered optional and not all interfaces and/or nodes have to be implemented.

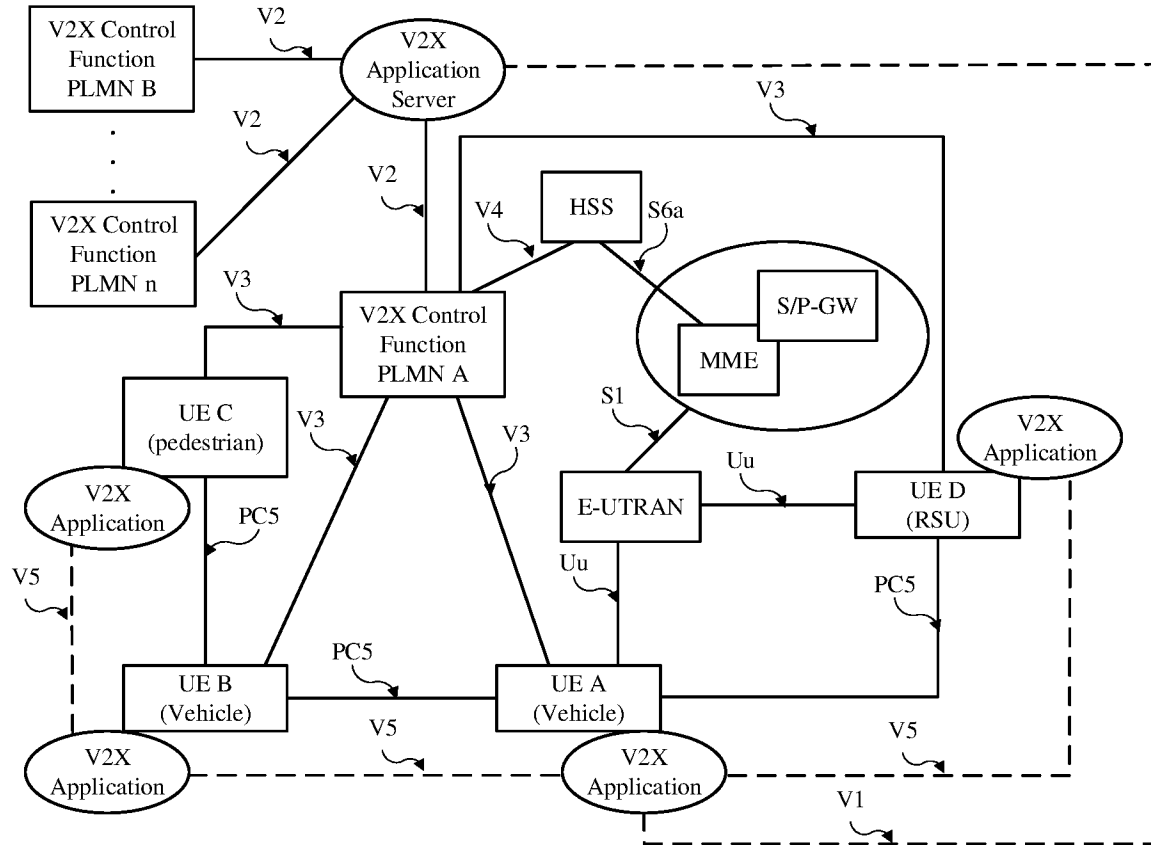


FIG. 9

where,

MME = mobility management entity,

HSS = home subscriber server

PLMN = public land mobile network

E-UTRAN = evolved universal terrestrial access network

UE = user equipment

S-GW = serving gateway

P-GW = public directory number gateway.

In one example embodiment, user equipment (UE) with the application V2X may be a pedestrian and may get credentials from V2X application server (AS) and V2X control function for discovery procedure on PC5. In one example embodiment, user equipment (UE) with the application V2X may be a vehicle and may get credentials from V2X application server (AS) and V2X control function for discovery procedure on PCF. In one example embodiment, user equipment (UE) with the application V2X may be a RSU and may get credentials from V2X application server (AS) and V2X control function for discovery procedure on PC5.

In one example embodiment, the first UE with the application V2X may communicate with the second UE with the application V2X by means for accessing the V2X control function and V2X AS. In one example embodiment, the first UE with the application V2X may communicate with the second UE with the application V2X by means for using PC5 interface. In one example embodiment, the first UE with the application V2X may communicate with the second UE with the application V2X by means for accessing the V2X control function and V2X AS through a third UE with the application V2X. In one example embodiment, the first UE with the application V2X may communicate with the second UE with the application V2X through the third UE with application V2X by means for first accessing the V2X control function and the V2X AS to access the third UE with the application V2X. In one example embodiment, the first UE with application V2X may communicate with the second UE with the application V2X through the third UE with the application V2X.

Provisional Application for Patent Cover Sheet

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c)

Inventor(s)

Inventor 1

Remove

Given Name

Middle Name

Family Name

City

State

Country j

Alireza

Babaei

Ashburn

VA

US

Inventor 2

Remove

Given Name

Middle Name

Family Name

City

State

Country j

Esmael

Hejazi

Dinan

Herndon

VA

US

All Inventors Must Be Listed – Additional Inventor Information blocks may be generated within this form by selecting the **Add** button.

Add

Title of Invention

MAC Configuration in a Wireless Network

Attorney Docket Number (if applicable)

16-1098P

Correspondence Address

Direct all correspondence to (select one):

☒ The address corresponding to Customer Number

☐ Firm or Individual Name

Customer Number

92629

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are:

Entity Status

Applicant claims small entity status under 37 CFR 1.27

- ☒ Yes, applicant qualifies for small entity status under 37 CFR 1.27
☐ No

Warning

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

Signature

Please see 37 CFR 1.4(d) for the form of the signature.

Signature	/Esmael Dinan, Reg. No 64,478/		Date (YYYY-MM-DD)	2016-11-14
First Name	Esmael	Last Name	Dinan	Registration Number (If appropriate)
				64478

This collection of information is required by 37 CFR 1.51. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **This form can only be used when in conjunction with EFS-Web. If this form is mailed to the USPTO, it may cause delays in handling the provisional application.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that : (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

In an example, the IE *MAC-MainConfig* may be used to specify the MAC main configuration for signalling and data radio bearers. The MAC main configuration parameters may be configured independently per Cell Group (e.g., MCG or SCG), unless explicitly specified otherwise. Example *MAC-MainConfig* information element is shown below. New fields may be added in example embodiments.

```

-- ASN1START
MAC-MainConfig ::=
    ul-SCH-Config
        maxHARQ-Tx
        periodicBSR-Timer
        retxBSR-Timer
        ttiBundling
    }
    drx-Config
    timeAlignmentTimerDedicated
    phr-Config
        release
        setup
            periodicPHR-Timer
            prohibitPHR-Timer
            dl-PathlossChange
        }
    ....
    [[ sr-ProhibitTimer-r9
    ]],
    [[ mac-MainConfig-v1020
        sCellDeactivationTimer-r10
        extendedBSR-Size-r10
        extendedPHR-r10
    ]],
    [[ stag-ToReleaseList-r11
        stag-ToAddModList-r11
        drx-Config-v1130
    ]],
    [[ e-HARQ-Pattern-r12
        dualConnectivityPHR
            release
            setup
                phr-ModeOtherCG-r12
            }
        logicalChannelSR-Config-r12
            release
            setup
                logicalChannelSR-ProhibitTimer-r12
            }
    ]],
    [[ drx-Config-v1310
        extendedPHR2-r13
        eDRX-Config-CycleStartOffset-r13
            release
            setup
                sf5120
                sf10240
            }
    ]],
SEQUENCE {
    SEQUENCE {
        ENUMERATED {
            n1, n2, n3, n4, n5, n6, n7, n8,
            n10, n12, n16, n20, n24, n28,
            spare2, spare1}
        PeriodicBSR-Timer-r12
        RetxBSR-Timer-r12,
        BOOLEAN
    }
    DRX-Config
    TimeAlignmentTimer,
    CHOICE {
        NULL,
        SEQUENCE {
            ENUMERATED {sf10, sf20, sf50, sf100, sf200,
                sf500, sf1000, infinity},
            ENUMERATED {sf0, sf10, sf20, sf50, sf100,
                sf200, sf500, sf1000},
            ENUMERATED {dB1, dB3, dB6, infinity}
        }
    }
    OPTIONAL, -- Need ON
    INTEGER (0..7)
    OPTIONAL -- Need ON
    SEQUENCE {
        ENUMERATED {
            rf2, rf4, rf8, rf16, rf32, rf64, rf128,
            spare}
        ENUMERATED {setup}
        ENUMERATED {setup}
    }
    OPTIONAL -- Need ON
    STAG-ToReleaseList-r11
    STAG-ToAddModList-r11
    DRX-Config-v1130
    OPTIONAL -- Need ON
    BOOLEAN
    CHOICE {
        NULL,
        SEQUENCE {
            ENUMERATED {real, virtual}
        }
    }
    OPTIONAL, -- Need ON
    CHOICE {
        NULL,
        SEQUENCE {
            ENUMERATED {sf20, sf40, sf64, sf128,
                sf512, sf1024, sf2560, spare1}
        }
    }
    OPTIONAL -- Need ON
    DRX-Config-v1310
    BOOLEAN
    CHOICE {
        NULL,
        CHOICE {
            INTEGER(0..1),
            INTEGER(0..3)
        }
    }
    OPTIONAL -- Need ON
}
-- ASN1END

```

```

[[ drx-Config-r13
    release
    setup
    ]],
[[ skipUplinkTx-r14
    release
    setup
        skipUplinkTxSPS-r14
        skipUplinkTxDynamic-r14
    ]],
]

MAC-MainConfigSCell-r11 ::=
    stag-Id-r11
    ...
}

DRX-Config ::=
    release
    setup
        onDurationTimer

        drx-InactivityTimer

        drx-RetransmissionTimer

        longDRX-CycleStartOffset
            sf10
            sf20
            sf32
            sf40
            sf64
            sf80
            sf128
            sf160
            sf256
            sf320
            sf512
            sf640
            sf1024
            sf1280
            sf2048
            sf2560
        },
    shortDRX
        shortDRX-Cycle

        drxShortCycleTimer
    }
    OPTIONAL
}

CHOICE {
    NULL,
    DRX-Config-r13
    OPTIONAL -- Need ON
}

CHOICE {
    NULL,
    SEQUENCE {
        ENUMERATED {true} OPTIONAL, -- Need OR
        ENUMERATED {true} OPTIONAL -- Need OR
    }
    OPTIONAL -- Need ON
}

SEQUENCE {
    STAG-Id-r11 OPTIONAL, -- Need OP
}

CHOICE {
    NULL,
    SEQUENCE {
        ENUMERATED {
            psf1, psf2, psf3, psf4, psf5, psf6,
            psf8, psf10, psf20, psf30, psf40,
            psf50, psf60, psf80, psf100,
            psf200},
        ENUMERATED {
            psf1, psf2, psf3, psf4, psf5, psf6,
            psf8, psf10, psf20, psf30, psf40,
            psf50, psf60, psf80, psf100,
            psf200, psf300, psf500, psf750,
            psf1280, psf1920, psf2560, psf0-v1020,
            spare9, spare8, spare7, spare6,
            spare5, spare4, spare3, spare2,
            spare1},
        ENUMERATED {
            psf1, psf2, psf4, psf6, psf8, psf16,
            psf24, psf33},
        CHOICE {
            INTEGER(0..9),
            INTEGER(0..19),
            INTEGER(0..31),
            INTEGER(0..39),
            INTEGER(0..63),
            INTEGER(0..79),
            INTEGER(0..127),
            INTEGER(0..159),
            INTEGER(0..255),
            INTEGER(0..319),
            INTEGER(0..511),
            INTEGER(0..639),
            INTEGER(0..1023),
            INTEGER(0..1279),
            INTEGER(0..2047),
            INTEGER(0..2559)
        }
        SEQUENCE {
            ENUMERATED {
                sf2, sf5, sf8, sf10, sf16, sf20,
                sf32, sf40, sf64, sf80, sf128, sf160,
                sf256, sf320, sf512, sf640},
            INTEGER(1..16)
        }
    }
    OPTIONAL -- Need OR
}

DRX-Config-v1130 ::=
    drx-RetransmissionTimer-v1130
    longDRX-CycleStartOffset-v1130
}

SEQUENCE {
    ENUMERATED {psf0-v1130} OPTIONAL, --Need OR
    CHOICE {

```

```

        sf60-v1130                INTEGER(0..59),
        sf70-v1130                INTEGER(0..69)
    }
    shortDRX-Cycle-v1130          ENUMERATED {sf4-v1130} OPTIONAL, --Need OR
}
DRX-Config-v1310 ::=
    longDRX-CycleStartOffset-v1310 SEQUENCE {
        sf60-v1310                INTEGER(0..59)
    }
    OPTIONAL --Need OR
}

DRX-Config-r13 ::= SEQUENCE {
    onDurationTimer-v1310          ENUMERATED {psf300, psf400, psf500, psf600,
        psf800, psf1000, psf1200, psf1600}
        OPTIONAL, --Need OR
    drx-RetransmissionTimer-v1310 ENUMERATED {psf40, psf64, psf80, psf96, psf112,
        psf128, psf160, psf320}
        OPTIONAL, --Need OR
    drx-ULRetransmissionTimer-r13 psf16,
        psf24, psf33, psf40, psf64, psf80, psf96,
        psf112, psf128, psf160, psf320}
        OPTIONAL --Need OR
}

PeriodicBSR-Timer-r12 ::= ENUMERATED {
    sf5, sf10, sf16, sf20, sf32, sf40, sf64, sf80,
    sf128, sf160, sf320, sf640, sf1280, sf2560,
    infinity, spare1}

RetxBSR-Timer-r12 ::= ENUMERATED {
    sf320, sf640, sf1280, sf2560, sf5120,
    sf10240, spare2, spare1}

STAG-ToReleaseList-r11 ::= SEQUENCE (SIZE (1..maxSTAG-r11)) OF STAG-Id-r11
STAG-ToAddModList-r11 ::= SEQUENCE (SIZE (1..maxSTAG-r11)) OF STAG-ToAddMod-r11
STAG-ToAddMod-r11 ::= SEQUENCE {
    stag-Id-r11                    STAG-Id-r11,
    timeAlignmentTimerSTAG-r11    TimeAlignmentTimer,
    ...
}

STAG-Id-r11 ::= INTEGER (1..maxSTAG-r11)
-- ASN1STOP

```

In an example, dl-PathlossChange may indicate DL Pathloss Change and the change of the required power backoff due to power management (e.g., as allowed by P-MPRc) for PHR reporting. In an example, its value may be in dB. In an example, value dB1 may correspond to 1 dB, dB3 may correspond to 3 dB and so on. The same value may apply for each serving cell (although the associated functionality may be performed independently for each cell).

In an example, drx-Config may be used to configure DRX as specified. In an example, E-UTRAN may configure the values in DRX-Config-v1130 if the UE indicates support for IDC indication. In an example, E-UTRAN may configure drx-Config-v1130, drx-Config-v1310 and drx-Config-r13 if drx-Config (without suffix) is configured. In an example, E-UTRAN may configure drx-Config-r13 if UE supports CE or if the UE is configured with uplink of an LAA SCell.

In an example, drx-InactivityTimer may be a timer for DRX. In an example, its value may be in number of PDCCH sub-frames. In an example, the value psf0 may correspond to 0 PDCCH sub-frame, value psf1 may correspond to 1 PDCCH sub-frame, psf2 may correspond to 2 PDCCH sub-frames and so on.

In an example, drx-RetransmissionTimer may be a timer for DRX. In an example, its value may be in number of PDCCH sub-frames. In an example, the value psf0 may correspond to 0 PDCCH sub-frame, value psf1 may correspond to 1 PDCCH sub-frame, psf2 may correspond to 2 PDCCH sub-frames and so on. In an example, in case drx-RetransmissionTimer-v1130 or drx-RetransmissionTimer-v1310 is signalled, the UE may ignore drx-RetransmissionTimer (i.e. without suffix).

In an example, drx-ULRetransmissionTimer may be a timer for DRX. In an example, its value may be in number of PDCCH sub-frames. In an example, value psf0 may correspond to 0 PDCCH sub-frame, value psf1 may correspond to 1 PDCCH sub-frame, psf2 may correspond to 2 PDCCH sub-frames and so on.

In an example, drxShortCycleTimer may be a timer for DRX. In an example, its value may be in multiples of shortDRX-Cycle. In an example, a value of 1 may correspond to shortDRX-Cycle, a value of 2 may correspond to 2 * shortDRX-Cycle and so on.

In an example, dualConnectivityPHR may indicate if power headroom may be reported using Dual Connectivity Power Headroom Report MAC Control Element (value setup). In an example, if PHR functionality and dual connectivity are configured, E-UTRAN may configure the value setup for this field and configures phr-Config and dualConnectivityPHR for both CGs.

In an example, the value TRUE for e-HARQ-Pattern may indicate that enhanced HARQ pattern for TTI bundling is enabled for FDD. E-UTRAN may enable this field when ttiBundling is set to TRUE.

In an example, eDRX-Config-CycleStartOffset may indicate longDRX-Cycle and drxStartOffset. The value of longDRX-Cycle may be in number of sub-frames. The value of drxStartOffset, in number of subframes, may be indicated by the value of eDRX-Config-CycleStartOffset multiplied by 2560 plus the offset value configured in longDRX-CycleStartOffset. E-UTRAN may configure value setup when the value in longDRX-CycleStartOffset is sf2560.

In an example, if value setup is configured for extendedBSR-Sizes, the BSR index may indicate extended BSR size levels.

In an example, extendedPHR may indicate if power headroom may be reported using the Extended Power Headroom Report MAC control element (value setup). In an example, E-UTRAN may configure the value setup if more than one and up to eight Serving Cell(s) with uplink is configured and none of the serving cells with uplink configured has a servingCellIndex higher than seven and if PUCCH on SCell is not configured and if dual connectivity is not configured. In an example, E-UTRAN may configure extendedPHR if phr-Config is configured. The UE may release extendedPHR if phr-Config is released.

In an example, extendedPHR2 may indicate if power headroom may be reported using the Extended Power Headroom Report MAC Control Element (value setup). E-UTRAN may configure the value setup if any of the serving cells with uplink configured has a servingCellIndex higher than seven in case dual connectivity is not configured or if PUCCH SCell (with any number of serving cells with uplink configured) is configured. E-UTRAN configures extendedPHR2 only if phr-Config is configured. The UE shall release extendedPHR2 if phr-Config is released.

In an example, logicalChannelSR-ProhibitTimer may be a timer used to delay the transmission of an SR for logical channels enabled by logicalChannelSR-Prohibit. Value sf20 may correspond to 20 subframes, sf40 may correspond to 40 subframes, and so on.

In an example, longDRX-CycleStartOffset may be longDRX-Cycle and drxStartOffset unless eDRX-Config-CycleStartOffset is configured. In an example, the value of longDRX-Cycle may be in number of sub-frames. In an example, the value sf10 may correspond to 10 sub-frames, sf20 may correspond to 20 sub-frames and so on. In an example, if shortDRX-Cycle is configured, the value of longDRX-Cycle may be a multiple of the shortDRX-Cycle value. In an example, the value of drxStartOffset value may be in number of sub-frames. In case longDRX-CycleStartOffset-v1130 is signalled, the UE may ignore longDRX-CycleStartOffset (i.e. without suffix).

In an example, maxHARQ-Tx may be the maximum number of transmissions for UL HARQ.

In an example, onDurationTimer may be a timer for DRX. In an example, its value may be in number of PDCCH sub-frames. In an example, the value psf1 may correspond to 1 PDCCH sub-frame, psf2 may correspond to 2 PDCCH sub-frames and so on. In an example, in case onDurationTimer-v1310 is signalled, the UE may ignore onDurationTimer (i.e. without suffix).

In an example, periodicBSR-Timer may be a timer for BSR reporting. Its value may be in number of sub-frames. In an example, value sf10 may correspond to 10 sub-frames, sf20 may correspond to 20 sub-frames and so on.

In an example, periodicPHR-Timer may be a timer for PHR reporting. Its value may be in number of sub-frames. In an example, the value sf10 may correspond to 10 subframes, sf20 may correspond to 20 subframes and so on.

In an example, phr-ModeOtherCG may indicate the mode (i.e. real or virtual) used for the PHR of the activated cells that are part of the other Cell Group (i.e. MCG or SCG), when DC is configured.

In an example, prohibitPHR-Timer may be a timer for PHR reporting. Its value may be in number of sub-frames. In an example, the value sf0 may correspond to 0 subframes, sf100 may correspond to 100 subframes and so on.

In an example, retxBSR-Timer may be a timer for BSR reporting. Its value may be in number of sub-frames. The value sf640 may correspond to 640 sub-frames, value sf1280 may correspond to 1280 sub-frames and so on.

In an example, sCellDeactivationTimer may be a SCell deactivation timer. In an example, its value may be in number of radio frames. In an example, the value rf4 may correspond to 4 radio frames, value rf8 corresponds to 8 radio frames and so on. In an example E-UTRAN may configure the field if the UE is configured with one or more SCells other than the PSCell and PUCCH SCell. In an example, if the field is absent, the UE may delete any existing value for this field and assume the value to be set to infinity. The same value may apply for each SCell of a Cell Group (i.e. MCG or SCG) (although the associated functionality may be performed independently for each SCell). In an example, the field sCellDeactivationTimer may not apply for the PUCCH SCell.

In an example, shortDRX-Cycle may be a Short DRX cycle. Its value value may be in number of sub-frames. The value sf2 may correspond to 2 sub-frames, sf5 may correspond to 5 subframes and so on. In an example, in case shortDRX-Cycle-v1130 is signalled, the UE may ignore shortDRX-Cycle (i.e. without suffix). Short DRX cycle may not be configured for UEs in CE.

In an example, if skipUplinkTxDynamic is configured, the UE may skip UL transmissions for an uplink grant other than a configured uplink grant if no data is available for transmission in the UE buffer.

In an example, if skipUplinkTxSPS is configured, the UE may skip UL transmissions for a configured uplink grant if no data is available for transmission in the UE buffer. In an example, E-UTRAN may configure skipUplinkTxSPS when semiPersistSchedIntervalUL is shorter than sf10.

In an example, sr-ProhibitTimer may be a timer for SR transmission on PUCCH. Its value may be in number of SR period(s) of shortest SR period of any serving cell with PUCCH. Its value may be 0. The value 1 may correspond to one SR period, Value 2 may correspond to 2*SR periods and so on.

In an example, stag-Id may indicate the TAG of an SCell. In an example, it may uniquely identify the TAG within the scope of a Cell Group (i.e. MCG or SCG). If the field is not configured for an SCell (e.g. absent in MAC-MainConfigSCell), the SCell may be part of the PTAG.

In an example, stag-ToAddModList, stag-ToReleaseList may be used to configure one or more STAGs. In an example, E-UTRAN ensures that a STAG contains at least one SCell with configured uplink. If, due to SCell release a reconfiguration would result in an 'empty' TAG, E-UTRAN may include release of the concerned TAG.

In an example, timeAlignmentTimerSTAG may indicate the value of the time alignment timer for an STAG.

In an example, the value TRUE for ttiBundling may indicate that TTI bundling is enabled while FALSE may indicate that TTI bundling is disabled. In an example, TTI bundling may be enabled for FDD and for TDD for configurations 0, 1 and 6. In an example, the functionality may be performed independently per Cell Group (e.g., MCG or SCG). In an example, E-UTRAN may not configure TTI bundling for the SCG. In an example, for a TDD PCell, E-UTRAN may not simultaneously enable TTI bundling and semi-persistent scheduling in this release of specification. In an example, for a Cell Group, E-UTRAN may not simultaneously configure TTI bundling and SCells with configured uplink, and E-UTRAN may not simultaneously configure TTI bundling and eIMTA.

In an example, the IE *SPS-Config* may be used to specify the semi-persistent scheduling configuration. Example *SPS-Config* information element is shown below. New IE formats may be defined and additional fields may be added to support enhanced SPS mechanisms including e.g. up to 8 SPSs. Enhanced SPS-config IE may be implemented according to example embodiment to configure enhanced SPS according to example embodiments.

```
-- ASN1START

SPS-Config ::= SEQUENCE {
    semiPersistSchedC-RNTI          C-RNTI          OPTIONAL,      -- Need OR
    sps-ConfigDL                    SPS-ConfigDL      OPTIONAL,      -- Need ON
    sps-ConfigUL                    SPS-ConfigUL      OPTIONAL,      -- Need ON
}

SPS-ConfigDL ::= CHOICE {
    release                        NULL,
    setup                          SEQUENCE {
        semiPersistSchedIntervalDL  ENUMERATED {
            sf10, sf20, sf32, sf40, sf64, sf80,
            sf128, sf160, sf320, sf640, spare6,
            spare5, spare4, spare3, spare2,
            spare1},
        numberOfConfSPS-Processes    INTEGER (1..8),
        n1PUCCH-AN-PersistentList    N1PUCCH-AN-PersistentList,
        ...,
        [[ twoAntennaPortActivated-r10 CHOICE {
            release                        NULL,
            setup                          SEQUENCE {
                n1PUCCH-AN-PersistentListP1-r10 N1PUCCH-AN-PersistentList
            }
        }
    ]]
}
OPTIONAL -- Need ON

SPS-ConfigUL ::= CHOICE {
    release                        NULL,
    setup                          SEQUENCE {
        semiPersistSchedIntervalUL    ENUMERATED {
            sf10, sf20, sf32, sf40, sf64, sf80,
            sf128, sf160, sf320, sf640, sf1-v14xy,
            sf2-v14xy, sf3-v14xy, sf4-v14xy, sf5-v14xy,
            spare1},
        implicitReleaseAfter          ENUMERATED {e2, e3, e4, e8},
        p0-Persistent                  SEQUENCE {
            p0-NominalPUSCH-Persistent  INTEGER (-126..24),

```

```

        p0-UE-PUSCH-Persistent          INTEGER (-8..7)
    } OPTIONAL,                          -- Need OP
    twoIntervalsConfig                  ENUMERATED {true}      OPTIONAL, -- Cond TDD
    ...,
    [[ p0-PersistentSubframeSet2-r12     CHOICE {
        release                          NULL,
        setup                            SEQUENCE {
            p0-NominalPUSCH-PersistentSubframeSet2-r12  INTEGER (-126..24),
            p0-UE-PUSCH-PersistentSubframeSet2-r12      INTEGER (-8..7)
        }
    } OPTIONAL                          -- Need ON
    ]],
    [[ numberOfConfiguredSPS-Processes-r13  INTEGER (1..8)    OPTIONAL -- Need OR
    ]],
    ]
}

NIPUCCH-AN-PersistentList ::=          SEQUENCE (SIZE (1..4)) OF INTEGER (0..2047)

-- ASN1STOP

```

In an example, SPS configuration IE may be enhanced and multiple downlink or uplink SPS may be configured for a cell. In an example, multiple SPS RNTI may be configured when a plurality of SPS is configured. In an example, RRC may comprise an index identifying an SPS configuration for a cell. In an example, the DCI employing SPS RNTI and triggering an SPS may include the index of the SPS that is triggered (initialized) or released.

In an example, SPS configuration may include MCS employed for packet transmission of an SPS grant.

In an example, implicitReleaseAfter may be the number of empty transmissions before implicit release. In an example, the value e2 may correspond to 2 transmissions, e3 may correspond to 3 transmissions and so on. If skipUplinkTxSPS is configured, the UE may ignore this field.

In an example, n1PUCCH-AN-PersistentList, n1PUCCH-AN-PersistentListP1 may be List of parameter: $n_{\text{PUCCH}}^{(1,p)}$ for antenna port P0 and for antenna port P1 respectively. In an example, field n1-PUCCH-AN-PersistentListP1 may be applicable if the twoAntennaPortActivatedPUCCH-Format1a1b in PUCCH-ConfigDedicated-v1020 is set to true. Otherwise the field may not be configured.

In an example, numberOfConfSPS-Processes may be the number of configured HARQ processes for downlink Semi-Persistent Scheduling.

In an example, numberOfConfUISPS-Processes may be the number of configured HARQ processes for uplink Semi-Persistent Scheduling. In an example, E-UTRAN may configure this field for asynchronous UL HARQ. Otherwise it may not configure this field.

In an example, p0-NominalPUSCH-Persistent may be parameter: $P_{\text{O_NOMINAL_PUSCH}}^{(0)}$. In an example, its unit may be dBm with step 1. In an example, this field may be applicable for persistent scheduling. In an example, if choice setup is used and p0-Persistent is absent, the value of p0-NominalPUSCH for p0-NominalPUSCH-Persistent may be applied. In an example, if uplink power control subframe sets are configured by tpc-SubframeSet, this field may apply for uplink power control subframe set 1.

In an example, p0-NominalPUSCH-PersistentSubframeSet2 may be the Parameter: In an example, its unit may be dBm with step 1. In an example, this field may be applicable for persistent scheduling. In an example, if p0-PersistentSubframeSet2-r12 is not configured, the value of p0-NominalPUSCH-SubframeSet2-r12 for p0-NominalPUSCH-PersistentSubframeSet2 may be applied. In an example, E-UTRAN may configure this field if uplink power control subframe sets are configured by tpc-SubframeSet, in which case this field may apply for uplink power control subframe set 2.

In an example, p0-UE-PUSCH-Persistent may be the parameter: $P_{\text{O_UE_PUSCH}}^{(0)}$. In an example, its unit may be in dB. In an example, this field may be applicable for persistent scheduling. In an example, if choice setup is used and p0-Persistent is absent, the value of p0-UE-PUSCH for p0-UE-PUSCH-Persistent may be applied. In an example, if uplink power control subframe sets are configured by tpc-SubframeSet, this field may apply for uplink power control subframe set 1.

In an example, p0-UE-PUSCH-PersistentSubframeSet2 may be the Parameter: $P_{\text{O_UE_PUSCH}}^{(0)}$. In an example, its unit may be in dB. In an example, this field may be applicable for persistent scheduling. In an example, if p0-PersistentSubframeSet2-r12 is not configured, the value of p0-UE-PUSCH-SubframeSet2 for p0-UE-PUSCH-PersistentSubframeSet2 may be applied. In an example, E-UTRAN may configure this field only if uplink power control subframe sets are configured by tpc-SubframeSet, in which case this field may apply for uplink power control subframe set 2.

In an example, semiPersistSchedC-RNTI may be the Semi-persistent Scheduling C-RNTI.

In an example, semiPersistSchedIntervalDL may be the Semi-persistent scheduling interval in downlink. In an example, its value may be in number of sub-frames. In an example, a value sf10 may correspond to 10 sub-frames, sf20 may correspond to 20 sub-frames and so on. For TDD, the UE may round this parameter down to the nearest integer (of 10 sub-frames), e.g. sf10 may correspond to 10 sub-frames, sf32 may correspond to 30 sub-frames, sf128 may correspond to 120 sub-frames.

In an example, semiPersistSchedIntervalUL may be the Semi-persistent scheduling interval in uplink. In an example, its value may be in number of sub-frames. The value sf10 may correspond to 10 sub-frames, sf20 may correspond to 20 sub-frames and so on. For TDD, when the configured Semi-persistent scheduling interval is greater than or equal to 10 sub-frames, the UE may round this parameter down to the nearest integer (of 10 sub-frames), e.g. sf10 may correspond to 10 sub-frames, sf32 may correspond to 30 sub-frames, sf128 corresponds to 120 sub-frames.

In an example, *twoIntervalsConfig* may be a trigger of two-intervals-Semi-Persistent Scheduling in uplink. In an example, if this field is present and the configured Semi-persistent scheduling interval greater than or equal to 10 sub-frames, two-intervals-SPS may be enabled for uplink. Otherwise, two-intervals-SPS may be disabled.

In an example, in order to transmit on the UL-SCH the MAC entity must have a valid uplink grant (except for non-adaptive HARQ retransmissions) which it may receive dynamically on the PDCCH or in a Random Access Response or which may be configured semi-persistently. In an example, to perform requested transmissions, the MAC layer may receive HARQ information from lower layers. When the physical layer is configured for uplink spatial multiplexing, the MAC layer may receive up to two grants (e.g., one per HARQ process) for the same TTI from lower layers.

In an example, if the MAC entity has a C-RNTI, a Semi-Persistent Scheduling C-RNTI, or a Temporary C-RNTI, the MAC entity may for each TTI and for each Serving Cell belonging to a TAG that has a running *timeAlignmentTimer* and for each grant received for this TTI:

- if an uplink grant for this TTI and this Serving Cell has been received on the PDCCH for the MAC entity's C-RNTI or Temporary C-RNTI; or
- if an uplink grant for this TTI has been received in a Random Access Response:
 - if the uplink grant is for MAC entity's C-RNTI and if the previous uplink grant delivered to the HARQ entity for the same HARQ process was either an uplink grant received for the MAC entity's Semi-Persistent Scheduling C-RNTI or a configured uplink grant:
 - consider the NDI to have been toggled for the corresponding HARQ process regardless of the value of the NDI.
 - deliver the uplink grant and the associated HARQ information to the HARQ entity for this TTI.
- else, if this Serving Cell is the SpCell and if an uplink grant for this TTI has been received for the SpCell on the PDCCH of the SpCell for the MAC entity's Semi-Persistent Scheduling C-RNTI:
 - if the NDI in the received HARQ information is 1:
 - consider the NDI for the corresponding HARQ process not to have been toggled;
 - deliver the uplink grant and the associated HARQ information to the HARQ entity for this TTI.
 - else if the NDI in the received HARQ information is 0:
 - if PDCCH contents indicate SPS release:
 - if the MAC entity is configured with *skipUplinkTxSPS*:
 - trigger an SPS confirmation;
 - if an uplink grant for this TTI has been configured:
 - consider the NDI bit for the corresponding HARQ process to have been toggled;
 - deliver the configured uplink grant and the associated HARQ information to the HARQ entity for this TTI;
 - else:
 - clear the configured uplink grant (if any).
 - else:
 - if the MAC entity is configured with *skipUplinkTxSPS*:

- trigger an SPS confirmation;
 - store the uplink grant and the associated HARQ information as configured uplink grant;
 - initialise (if not active) or re-initialise (if already active) the configured uplink grant to start in this TTI and to recur according to SPS rules;
 - if UL HARQ operation is asynchronous, set the HARQ Process ID to the HARQ Process ID associated with this TTI;
 - consider the NDI bit for the corresponding HARQ process to have been toggled;
 - deliver the configured uplink grant and the associated HARQ information to the HARQ entity for this TTI.
- else, if this Serving Cell is the SpCell and an uplink grant for this TTI has been configured for the SpCell:
- if UL HARQ operation is asynchronous, set the HARQ Process ID to the HARQ Process ID associated with this TTI;
 - consider the NDI bit for the corresponding HARQ process to have been toggled;
 - deliver the configured uplink grant, and the associated HARQ information to the HARQ entity for this TTI.

In an example, the period of configured uplink grants is expressed in TTIs.

In an example, if the MAC entity receives both a grant in a Random Access Response and a grant for its C-RNTI or Semi persistent scheduling C-RNTI requiring transmissions on the SpCell in the same UL subframe, the MAC entity may choose to continue with either the grant for its RA-RNTI or the grant for its C-RNTI or Semi persistent scheduling C-RNTI.

In an example, when a configured uplink grant is indicated during a measurement gap and indicates an UL-SCH transmission during a measurement gap, the MAC entity may process the grant but may not transmit on UL-SCH. In an example, when a configured uplink grant is indicated during a Sidelink Discovery gap for reception and indicates an UL-SCH transmission during a Sidelink Discovery gap for transmission with a SL-DCH transmission, the MAC entity may process the grant but may not transmit on UL-SCH.

In an example, for configured uplink grants, the HARQ Process ID associated with this TTI may be derived from the following equation for asynchronous UL HARQ operation:

HARQ Process ID = $\lfloor \text{CURRENT_TTI} / \text{semiPersistSchedIntervalUL} \rfloor \text{ modulo } \text{numberOfConfULSPS-Processes}$,

where $\text{CURRENT_TTI} = (\text{SFN} * 10) + \text{subframe number}$ and it may refer to the subframe where the first transmission of a bundle takes place.

In an example, a HARQ process may be associated with a HARQ buffer.

In an example, for synchronous HARQ, a HARQ process may maintain a state variable CURRENT_TX_NB , which may indicate the number of transmissions that have taken place for the MAC PDU currently in the buffer, and a state variable HARQ_FEEDBACK , which may indicate the HARQ feedback for the MAC PDU currently in the buffer. When the HARQ process is established, CURRENT_TX_NB may be initialized to 0.

In an example, the sequence of redundancy versions may be 0, 2, 3, 1. The variable CURRENT_IRV may be an index into the sequence of redundancy versions. This variable may be up-dated modulo 4. For BL UEs or UEs in enhanced coverage, the sequence of redundancy versions and redundancy version determination may be determined. For NB-IoT UEs the sequence of redundancy versions and redundancy version determination may be determined.

In an example, for NB-IoT UEs, BL UEs or UEs in enhanced coverage for UL_REPETITION_NUMBER for Mode B operation, the same redundancy version may be used multiple times before cycling to the next redundancy version.

In an example, new transmissions may be performed on the resource and with the MCS indicated on PDCCH or Random Access Response. Adaptive retransmissions may be performed on the resource and, if provided, with the MCS indicated on PDCCH. Non-adaptive retransmission may be performed on the same resource and with the same MCS as was used for the last made transmission attempt.

In an example, for synchronous HARQ, the MAC entity may be configured with a maximum number of HARQ transmissions and a maximum number of Msg3 HARQ transmissions by RRC: *maxHARQ-Tx* and *maxHARQ-Msg3Tx* respectively. For transmissions on HARQ processes and logical channels except for transmission of a MAC PDU stored in the Msg3 buffer, the maximum number of transmissions may be set to *maxHARQ-Tx*. For transmission of a MAC PDU stored in the Msg3 buffer, the maximum number of transmissions may be set to *maxHARQ-Msg3Tx*.

In an example, when the HARQ feedback is received for this TB, the HARQ process may set HARQ_FEEDBACK to the received value.

In an example, if the HARQ entity requests a new transmission and if UL HARQ operation is synchronous, the HARQ process may set CURRENT_TX_NB to 0; set HARQ_FEEDBACK to NACK; and set CURRENT_IRV to 0. If the HARQ entity requests a new transmission and if UL HARQ operation is not synchronous, the HARQ process may set CURRENT_IRV to the index corresponding to the redundancy version value provided in the HARQ information, except for BL UEs and for UEs in enhanced coverage and for NB-IoT UEs.

In an example, if the HARQ entity requests a new transmission, the HARQ process may store the MAC PDU in the associated HARQ buffer; store the uplink grant received from the HARQ entity; and generate a transmission as described below.

In an example, if the HARQ entity requests a retransmission and if UL HARQ operation is synchronous, the HARQ process may increment CURRENT_TX_NB by 1;

In an example, if the HARQ entity requests a retransmission and if the HARQ entity requests an adaptive retransmission, the HARQ process may store the uplink grant received from the HARQ entity; the HARQ process may set CURRENT_IRV to the index corresponding to the redundancy version value provided in the HARQ information; if UL HARQ operation is synchronous the HARQ process may set HARQ_FEEDBACK to NACK; the HARQ process may generate a transmission as described below.

In an example, if the HARQ entity requests a retransmission and if and if the HARQ entity requests a non-adaptive retransmission and if UL HARQ operation is asynchronous or HARQ_FEEDBACK = NACK, the HARQ process may generate a transmission as described below.

In an example, when receiving a HARQ ACK alone, the MAC entity may keep the data in the HARQ buffer.

In an example, when no UL-SCH transmission can be made due to the occurrence of a measurement gap or a Sidelink Discovery Gap for Transmission, no HARQ feedback may be received and a non-adaptive retransmission may follow.

In an example, for asynchronous HARQ operation, UL retransmissions may be triggered by adaptive retransmission grants, except for retransmissions within a bundle.

In an example, to generate a transmission, if the MAC PDU was obtained from the Msg3 buffer; or if Sidelink Discovery Gaps for Transmission are not configured by upper layers, and there is no measurement gap at the time of the transmission and, in case of retransmission, the retransmission does not collide with a transmission for a MAC PDU obtained from the Msg3 buffer in this TTI; or if Sidelink Discovery Gaps for Transmission are configured by upper layers, and there is no measurement gap at the time of the transmission and, in case of retransmission, the retransmission does not collide with a transmission for a MAC PDU obtained from the Msg3 buffer, and there is no Sidelink Discovery Gap for Transmission in this TTI; or if Sidelink Discovery Gaps for Transmission are configured

by upper layers, and there is no measurement gap at the time of the transmission and, in case of retransmission, the retransmission does not collide with a transmission for a MAC PDU obtained from the Msg3 buffer, and there is a Sidelink Discovery Gap for Transmission, and there is no configured grant for transmission on SL-DCH in this TTI, the HARQ process may instruct the physical layer to generate a transmission according to the stored uplink grant with the redundancy version corresponding to the CURRENT_IRV value; increment CURRENT_IRV by 1; and if UL HARQ operation is synchronous and there is a measurement gap or Sidelink Discovery Gap for Reception at the time of the HARQ feedback reception for this transmission and if the MAC PDU was not obtained from the Msg3 buffer, the HARQ process may set HARQ_FEEDBACK to ACK at the time of the HARQ feedback reception for this transmission.

In an example, after performing above actions, if UL HARQ operation is synchronous and if CURRENT_TX_NB = maximum number of transmissions – 1, the HARQ process then may flush the HARQ buffer.

In an example, when Semi-Persistent Scheduling is enabled by RRC, the following example information may be provided:

- Semi-Persistent Scheduling C-RNTI;
- Uplink Semi-Persistent Scheduling interval *semiPersistSchedIntervalUL* and number of empty transmissions before implicit release *implicitReleaseAfter*, if Semi-Persistent Scheduling is enabled for the uplink;
- Whether *twoIntervalsConfig* is enabled or disabled for uplink, only for TDD;
- Downlink Semi-Persistent Scheduling interval *semiPersistSchedIntervalDL* and number of configured HARQ processes for Semi-Persistent Scheduling *numberOfConfSPS-Processes*, if Semi-Persistent Scheduling is enabled for the downlink;

In an example, when Semi-Persistent Scheduling for uplink or downlink is disabled by RRC, the corresponding configured grant or configured assignment may be discarded.

In an example, Semi-Persistent Scheduling is supported on the SpCell.

In an example, Semi-Persistent Scheduling may not be supported for RN communication with the E-UTRAN in combination with an RN subframe configuration.

In an example, when eIMTA is configured for the SpCell, if a configured uplink grant or a configured downlink assignment occurs on a subframe that can be reconfigured through eIMTA L1 signalling, then the UE behaviour may be left unspecified.

In an example, after a Semi-Persistent downlink assignment is configured, the MAC entity may consider sequentially that the Nth assignment occurs in the subframe for which:

- $(10 * SFN + \text{subframe}) = [(10 * SFN_{\text{start time}} + \text{subframe}_{\text{start time}}) + N * \text{semiPersistSchedIntervalDL}] \text{ modulo } 10240.$

Where $SFN_{\text{start time}}$ and $\text{subframe}_{\text{start time}}$ are the SFN and subframe, respectively, at the time the configured downlink assignment were (re-)initialised.

In an example, for BL UEs or UEs in enhanced coverage $SFN_{\text{start time}}$ and $\text{subframe}_{\text{start time}}$ may refer to SFN and subframe of the first transmission of PDSCH where configured downlink assignment was (re-)initialized.

In an example, after a Semi-Persistent Scheduling uplink grant is configured, the MAC entity may:

- if *twoIntervalsConfig* is enabled by upper layer:
 - set the Subframe_Offset according to the rules
- else:
 - set Subframe_Offset to 0.

- consider sequentially that the N^{th} grant occurs in the subframe for which:
 - $(10 * \text{SFN} + \text{subframe}) = [(10 * \text{SFN}_{\text{start time}} + \text{subframe}_{\text{start time}}) + N * \text{semiPersistSchedIntervalUL} + \text{Subframe_Offset} * (N \text{ modulo } 2)] \text{ modulo } 10240$.

Where $\text{SFN}_{\text{start time}}$ and $\text{subframe}_{\text{start time}}$ are the SFN and subframe, respectively, at the time the configured uplink grant were (re-)initialised.

In an example, for TDD, the MAC entity may be configured with *semiPersistSchedIntervalUL* shorter than 10 subframes, the N^{th} grant may be ignored if it occurs in a downlink subframe or a special subframe.

In an example, if the MAC entity is not configured with *skipUplinkTxSPS*, the MAC entity may clear the configured uplink grant immediately after *implicitReleaseAfter* number of consecutive new MAC PDUs each containing zero MAC SDUs have been provided by the Multiplexing and Assembly entity, on the Semi-Persistent Scheduling resource.

In an example, if SPS confirmation has been triggered and not cancelled:

- if the MAC entity has UL resources allocated for new transmission for this TTI:
 - instruct the Multiplexing and Assembly procedure to generate an SPS confirmation MAC Control Element;
 - cancel the triggered SPS confirmation.

In an example, the MAC entity may clear the configured uplink grant immediately after first transmission of SPS confirmation MAC Control Element triggered by the SPS release.

In an example, retransmissions for Semi-Persistent Scheduling may continue after clearing the configured uplink grant.

In an example, for BL UEs or UEs in enhanced coverage $\text{SFN}_{\text{start time}}$ and $\text{subframe}_{\text{start time}}$ may refer to SFN and subframe of the first transmission of PUSCH where configured uplink grant was (re-)initialized.

In an example, Subframe_Offset values may be as in Table below.

Example Subframe_Offset values

TDD UL/DL configuration	Position of initial Semi-Persistent grant	Subframe_Offset value (ms)
0	N/A	0
1	Subframes 2 and 7	1
	Subframes 3 and 8	-1
2	Subframe 2	5
	Subframe 7	-5
3	Subframes 2 and 3	1
	Subframe 4	-2
4	Subframe 2	1
	Subframe 3	-1
5	N/A	0
6	N/A	0

In an example, the Logical Channel Prioritization procedure may be applied when a new transmission is performed.

In an example, RRC may control the scheduling of uplink data by signalling for each logical channel: *priority* where an increasing *priority* value may indicate a lower priority level, *prioritisedBitRate* which may set the Prioritized Bit Rate (PBR), *bucketSizeDuration* which may set the Bucket Size Duration (BSD). In an example, for NB-IoT, *prioritisedBitRate*, *bucketSizeDuration* and the corresponding steps of the Logical Channel Prioritisation procedure (e.g., Step 1 and Step 2 below) may not be applicable.

In an example, the MAC entity may maintain a variable B_j for each logical channel j . B_j may be initialized to zero when the related logical channel is established, and incremented by the product $PBR \times TTI$ duration for each TTI, where PBR is Prioritized Bit Rate of logical channel j . In an example, the value of B_j may not exceed the bucket size and if the value of B_j is larger than the bucket size of logical channel j , it may be set to the bucket size. The bucket size of a logical channel may be equal to $PBR \times BSD$, where PBR and BSD may be configured by upper layers.

In an example, the MAC entity may perform the following Logical Channel Prioritization procedure when a new transmission is performed:

- The MAC entity may allocate resources to the logical channels in the following steps:
 - Step 1: The logical channels with $B_j > 0$ may be allocated resources in a decreasing priority order. If the PBR of a logical channel is set to “infinity”, the MAC entity may allocate resources for all the data that is available for transmission on the logical channel before meeting the PBR of the lower priority logical channel(s);
 - Step 2: the MAC entity may decrement B_j by the total size of MAC SDUs served to logical channel j in Step 1;

In an example, the value of B_j can be negative.

- Step 3: if any resources remain, the logical channels are served in a strict decreasing priority order (regardless of the value of B_j) until either the data for that logical channel or the UL grant is exhausted, whichever comes first. Logical channels configured with equal priority may be served equally.
- The UE may also follow the rules below during the scheduling procedures above:
 - the UE may not segment an RLC SDU (or partially transmitted SDU or retransmitted RLC PDU) if the whole SDU (or partially transmitted SDU or retransmitted RLC PDU) fits into the remaining resources of the associated MAC entity;
 - if the UE segments an RLC SDU from the logical channel, it may maximize the size of the segment to fill the grant of the associated MAC entity as much as possible;
 - the UE may maximise the transmission of data.
 - if the MAC entity is given an UL grant size that is equal to or larger than 4 bytes while having data available for transmission, the MAC entity may not transmit only padding BSR and/or padding (unless the UL grant size is less than 7 bytes and an AMD PDU segment needs to be transmitted);
 - for transmissions on serving cells operating according to Frame Structure Type 3, the MAC entity may only consider logical channels for which *laa-Allowed* has been configured.

In an example, the MAC entity may not transmit data for a logical channel corresponding to a radio bearer that is suspended.

In an example, if the MAC PDU includes only the MAC CE for padding BSR or periodic BSR with zero MAC SDUs and there is no aperiodic CSI requested for this TTI, the MAC entity may not generate a MAC PDU for the HARQ entity in the following cases:

- in case the MAC entity is configured with *skipUplinkTxDynamic* and the grant indicated to the HARQ entity was addressed to a C-RNTI; or
- in case the MAC entity is configured with *skipUplinkTxSPS* and the grant indicated to the HARQ entity is a configured uplink grant;

In an example, for the Logical Channel Prioritization procedure, the MAC entity may take into account the following relative priority in decreasing order:

- MAC control element for C-RNTI or data from UL-CCCH;

- MAC control element for SPS confirmation;
- MAC control element for BSR, with exception of BSR included for padding;
- MAC control element for PHR, Extended PHR, or Dual Connectivity PHR;
- MAC control element for Sidelink BSR, with exception of Sidelink BSR included for padding;
- data from any Logical Channel, except data from UL-CCCH;
- MAC control element for BSR included for padding;
- MAC control element for Sidelink BSR included for padding.

In an example, when the MAC entity is requested to transmit multiple MAC PDUs in one TTI, steps 1 to 3 and the associated rules may be applied either to each grant independently or to the sum of the capacities of the grants. In an example, the order in which the grants are processed is left up to UE implementation. In an example, it is up to the UE implementation to decide in which MAC PDU a MAC control element is included when MAC entity is requested to transmit multiple MAC PDUs in one TTI. In an example, when the UE is requested to generate MAC PDU(s) in two MAC entities in one TTI, it is up to UE implementation in which order the grants are processed.

In an example, the MAC entity may multiplex MAC control elements and MAC SDUs in a MAC PDU.

In an example, the SPS confirmation MAC control element may be identified by a MAC PDU subheader with LCID as specified below.

Example Values of LCID for UL-SCH

Index	LCID values
00000	CCCH
00001-01010	Identity of the logical channel
01011	CCCH
01100-10100	Reserved
10101	SPS confirmation
10110	Truncated Sidelink BSR
10111	Sidelink BSR
11000	Dual Connectivity Power Headroom Report
11001	Extended Power Headroom Report
11010	Power Headroom Report
11011	C-RNTI
11100	Truncated BSR
11101	Short BSR
11110	Long BSR
11111	Padding

In an example, the SPS confirmation MAC control element may have a fixed size of zero bits.

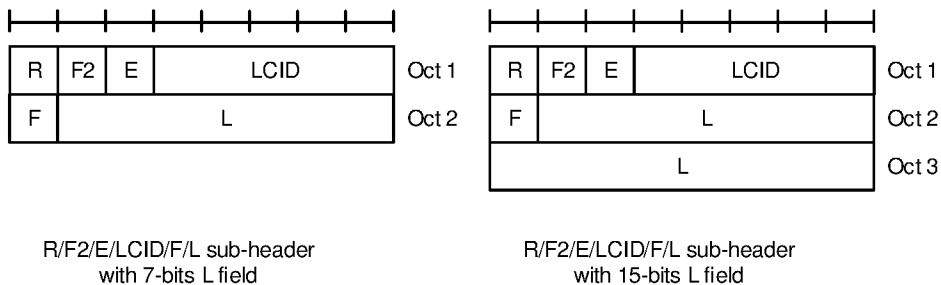
In an example, a MAC PDU may consist of a MAC header, zero or more MAC Service Data Units (MAC SDU), zero, or more MAC control elements, and optionally padding.

In an example, the MAC header and the MAC SDUs may be of variable sizes.

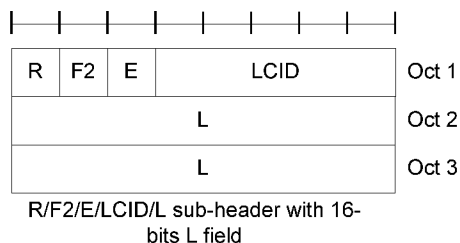
In an example, a MAC PDU header may consist of one or more MAC PDU subheaders; a subheader may correspond to either a MAC SDU, a MAC control element or padding.

In an example, a MAC PDU subheader may consist of the five or six header fields R/F2/E/LCID/(F)/L but for the last subheader in the MAC PDU and for fixed sized MAC control elements. In an example, the last subheader in the MAC PDU and subheaders for fixed sized MAC control elements may consist solely of the four header fields

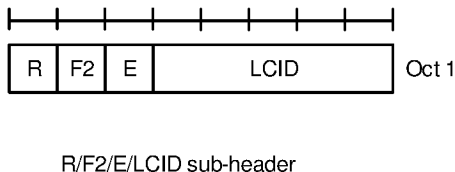
R/F2/E/LCID. In an example, a MAC PDU subheader corresponding to padding may consist of the four header fields R/F2/E/LCID.



Example R/F2/E/LCID/F/L MAC subheader



Example R/F2/E/LCID/L MAC subheader



Example R/F2/E/LCID MAC subheader

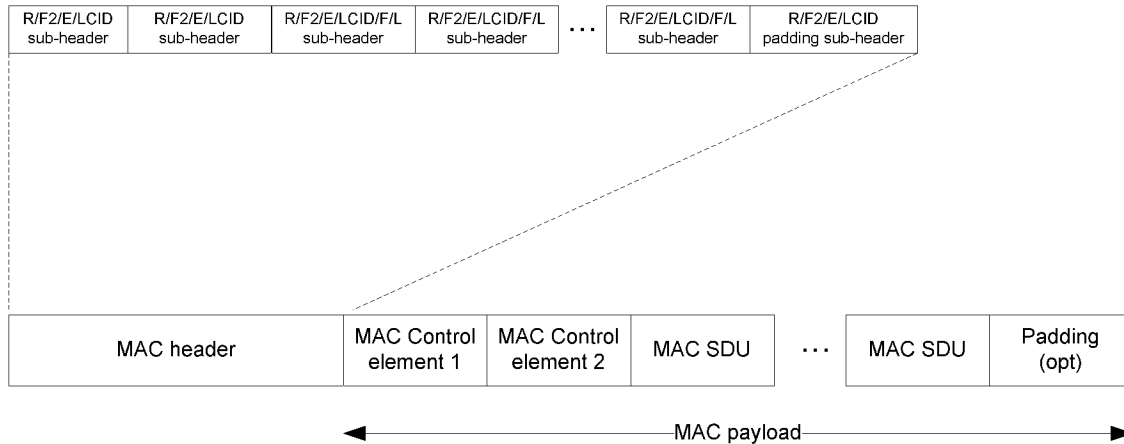
In an example, MAC PDU subheaders may have the same order as the corresponding MAC SDUs, MAC control elements and padding.

In an example, MAC control elements may always be placed before any MAC SDU.

In an example, Padding may occur at the end of the MAC PDU, except when single-byte or two-byte padding is required. In an example, padding may have any value and the MAC entity may ignore it. In an example, when padding is performed at the end of the MAC PDU, zero or more padding bytes are allowed.

In an example, when single-byte or two-byte padding is required, one or two MAC PDU subheaders corresponding to padding are placed at the beginning of the MAC PDU before any other MAC PDU subheader.

In an example, a maximum of one MAC PDU can be transmitted per TB per MAC entity. In an example, a maximum of one MCH MAC PDU may be transmitted per TTI.



Example of MAC PDU consisting of MAC header, MAC control elements, MAC SDUs and padding

In an example, the MAC header may be of variable size and may consist of the following fields:

LCID: The Logical Channel ID field may identify the logical channel instance of the corresponding MAC SDU or the type of the corresponding MAC control element or padding as described in tables below for the DL-SCH, UL-SCH and MCH respectively. There may be one LCID field for each MAC SDU, MAC control element or padding included in the MAC PDU. In addition to that, one or two additional LCID fields may be included in the MAC PDU, when single-byte or two-byte padding is required but cannot be achieved by padding at the end of the MAC PDU. A UE of Category 0 may indicate CCCH using LCID "01011", otherwise the UE may indicate CCCH using LCID "00000". The LCID field size is 5 bits;

L: The Length field may indicate the length of the corresponding MAC SDU or variable-sized MAC control element in bytes. There may be one L field per MAC PDU subheader except for the last subheader and subheaders corresponding to fixed-sized MAC control elements. The size of the L field may be indicated by the F field and F2 field;

F: The Format field may indicate the size of the Length field as indicated in table below. There may be one F field per MAC PDU subheader except for the last subheader and subheaders corresponding to fixed-sized MAC control elements and except for when F2 is set to 1. The size of the F field may be 1 bit. If the F field is included; if the size of the MAC SDU or variable-sized MAC control element is less than 128 bytes, the value of the F field may be set to 0, otherwise it may be set to 1;

F2: The Format2 field may indicate the size of the Length field as indicated in table below. There may be one F2 field per MAC PDU subheader. The size of the F2 field may be 1 bit. If the size of the MAC SDU or variable-sized MAC control element is larger than 32767 bytes, and if the corresponding subheader is not the last subheader, the value of the F2 field may be set to 1, otherwise it may be set to 0.

Example Values of F and F2 fields:

Index of F2	Index of F	Size of Length field (in bits)
0	0	7
	1	15
1	-	16

E: The Extension field may be a flag indicating if more fields are present in the MAC header or not. The E field may be set to "1" to indicate another set of at least R/F2/E/LCID fields. The E field may be set to "0" to indicate that either a MAC SDU, a MAC control element or padding starts at the next byte;

R: Reserved bit, may be set to "0".

In an example, the MAC header and subheaders may be octet aligned.

Example Values of LCID for DL-SCH

Index	LCID values
00000	CCCH
00001-01010	Identity of the logical channel
01011-10111	Reserved
11000	Activation/Deactivation (4 octets)
11001	SC-MCCH, SC-MTCH (see note)
11010	Long DRX Command
11011	Activation/Deactivation (1 octet)
11100	UE Contention Resolution Identity
11101	Timing Advance Command
11110	DRX Command
11111	Padding
NOTE: Both SC-MCCH and SC-MTCH cannot be multiplexed with other logical channels in the same MAC PDU except for Padding	

For NB-IoT the following LCID values for DL-SCH may be applicable: CCCH, Identity of the logical channel, UE Contention Resolution Identity, Timing Advance Command, DRX Command and Padding.

Example Values of LCID for UL-SCH

Index	LCID values
00000	CCCH
00001-01010	Identity of the logical channel
01011	CCCH
01100-10100	Reserved
10101	SPS confirmation
10110	Truncated Sidelink BSR
10111	Sidelink BSR
11000	Dual Connectivity Power Headroom Report
11001	Extended Power Headroom Report
11010	Power Headroom Report
11011	C-RNTI
11100	Truncated BSR
11101	Short BSR
11110	Long BSR
11111	Padding

For NB-IoT only the following LCID values for UL-SCH may be applicable: CCCH (LCID "00000"), Identity of the logical channel, C-RNTI, Short BSR and Padding.

Example Values of LCID for MCH

Index	LCID values
00000	MCCH (see note)
00001-11100	MTCH
11101	Reserved
11110	MCH Scheduling Information or Extended MCH Scheduling Information
11111	Padding
NOTE: If there is no MCCH on MCH, an MTCH could use this value.	

In an example, various DCI formats may be used for SPS scheduling. For example, the DCI format 0 may be used for uplink SPS. In an example, the fields for DCI format 0 may comprise one or more of the following fields:

Carrier indicator – 0 or 3 bits.

Flag for format0/format1A differentiation – 1 bit, where value 0 may indicate format 0 and value 1 may indicate format 1A

Frequency hopping flag – 1 bit. This field may be used as the MSB of the corresponding resource allocation field for resource allocation type 1.

Resource block assignment and hopping resource allocation – $\left\lceil \log_2 (N_{RB}^{UL} (N_{RB}^{UL} + 1) / 2) \right\rceil$ bits where N_{RB}^{UL} may be the uplink bandwidth configuration in number of resource blocks.

Modulation and coding scheme and redundancy version – 5 bits

New data indicator – 1 bit

TPC command for scheduled PUSCH – 2 bits

Cyclic shift for DM RS and OCC index – 3 bits

UL index – 2 bits (this field may be present only for TDD operation with uplink-downlink configuration 0)

Downlink Assignment Index (DAI) – 2 bits (this field may be present only for cases with TDD primary cell and either TDD operation with uplink-downlink configurations 1-6 or FDD operation)

CSI request – 1, 2 or 3 bits. The 2-bit field may apply to UEs configured with no more than five DL cells and to UEs that are configured with more than one DL cell and when the corresponding DCI format is mapped onto the UE specific search space given by the C-RNTI, UEs that are configured by higher layers with more than one CSI process and when the corresponding DCI format is mapped onto the UE specific search space given by the C-RNTI, UEs that are configured with two CSI measurement sets by higher layers with the parameter csi-MeasSubframeSet, and when the corresponding DCI format is mapped onto the UE specific search space given by the C-RNTI; the 3-bit field may apply to the UEs that are configured with more than five DL cells and when the corresponding DCI format is mapped onto the UE specific search space given by the C-RNTI; otherwise the 1-bit field applies

SRS request – 0 or 1 bit. This field may only be present in DCI formats scheduling PUSCH which are mapped onto the UE specific search space given by the C-RNTI.

Resource allocation type – 1 bit. This field may only be present if $N_{RB}^{UL} \leq N_{RB}^{DL}$ where N_{RB}^{UL} may be the uplink bandwidth configuration in number of resource blocks and N_{RB}^{DL} may be the downlink bandwidth configuration in number of resource blocks.

If the number of information bits in format 0 mapped onto a given search space is less than the payload size of format 1A for scheduling the same serving cell and mapped onto the same search space (including any padding bits appended to format 1A), zeros may be appended to format 0 until the payload size equals that of format 1A.

In an example, a UE may validate a Semi-Persistent Scheduling assignment PDCCH 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, 2C and 2D, the new data indicator field may refer to the one for the enabled transport block.

A UE may validate a Semi-Persistent Scheduling assignment EPDCCH if all the following conditions are met:

the CRC parity bits obtained for the EPDCCH 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, 2C and 2D, the new data indicator field may refer to the one for the enabled transport block.

In an example, validation may be achieved if all the fields for the respective used DCI format are set according to Tables below.

If validation is achieved, the UE may consider the received DCI information accordingly as a valid semi-persistent activation or release.

If validation is not achieved, the received DCI format may be considered by the UE as having been received with a non-matching CRC.

Example Special fields for Semi-Persistent Scheduling Activation PDCCH/EPDCCH Validation

	DCI format 0	DCI format 1/1A	DCI format 2/2A/2B/2C/2D
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'

Example Special fields for Semi-Persistent Scheduling Release PDCCH/EPDCCH Validation

	DCI format 0	DCI format 1A
TPC command for scheduled PUSCH	set to '00'	N/A
Cyclic shift DM RS	set to	N/A
Modulation and coding scheme and redundancy version	set to '11111'	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 '11111'
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 may be used as an index to one of the four PUCCH resource values configured by higher layers, with the mapping defined in Table below

Example 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

In the current LTE standard, a maximum of one downlink SPS and/or one uplink SPS may be configured for the PCell. Configuration of multiple SPSs are not supported for the PCell or any other cell. An SPS C-RNTI is configured for the UE to support one DL SPS configuration and/or one UL SPS configuration.

```
SPS-Config ::= SEQUENCE {
    semiPersistSchedC-RNTI      C-RNTI                OPTIONAL,      -- Need OR
    sps-ConfigDL                SPS-ConfigDL            OPTIONAL,      -- Need ON
    sps-ConfigUL                SPS-ConfigUL            OPTIONAL,      -- Need ON
}
```

In an example, SPS configurations may be used for transmission of various V2X traffic and/or voice traffic by a UE. In an example, a UE supporting V2X may need to support multiple uplink SPS configurations for transmitting various periodic (or semi-periodic) traffic and/or voice traffic in the uplink. Other examples may be provided. For example, CAM messages in V2X may be semi-periodic. In some scenarios, CAM message generation may be dynamic in terms of size, periodicity and timing. Such changes may result in misalignment between SPS timing and CAM timing. There may be some regularity in size and periodicity between different triggers. Enhanced SPS mechanisms may be beneficial to transmit V2X traffic, voice traffic, and/or the like. In an example, various SPS periodicity, for example 100 ms and 1s may be configured.

In an example, multiple SPS configurations may be configured for UU and/or PC5 interface. An eNB may configure multiple SPS configurations for a given UE. In an example, SPS configuration specific MCS (e.g. MCS as a part of the RRC SPS-configuration) and/or SPS-configuration-specific periodicity may be configured. Some of the SPS configuration parameters may be the same across multiple SPS and some other SPS configuration parameters may be different across SPS configurations. The eNB may dynamically trigger/release the different SPS-configurations

employing (E)PDCCH DCIs. In an example, the multiple SPS configurations may be indicated by eNB RRC signaling. The dynamical triggering and releasing may be performed by eNB transmitting (E)PDCCH DCI to the UE employing SPS C-RNTI.

In an example embodiment, a UE may indicate to an eNB that the UE does not intend and/or intend to transmit data before a transmission associated to an SPS configuration. The eNB may acknowledge the UE indication.

In an example, an eNB may provide one or more SPS configurations for the UE via RRC signaling. When the UE to start transmitting a type of message employing SPS, the UE may report information about the message to the eNB, e.g. message type, logical channel, traffic size, SPS index, and/or traffic type, etc. The eNB may transmit an SPS transmission grant based on the report and provide an SPS grant for a configuration and radio resources. After receiving the grant, the UE may initialize the corresponding SPS configuration and may transmit the data via the radio resources allocated to the UE.

In an example, multiple SPSs may be active in parallel. For example, a new service may be triggered while the previous service is on-going. In an example, the UE may indicate the new messages to the serving eNB. The eNB may provide another transmission grant for the new service/message(s). The UE may choose another SPS configuration and select the resources. In an example, the previous SPS grant and the new SPS grant may continue in parallel.

Some example V2X messages are shown in the Table below.

Example V2X message characteristics

	CAM	DENM	BSM
Area/Country	EU	EU	US
Content	status (time, position, motion state, activated system, etc) attribute (data about dimension, vehicle type and role in the road traffic)	Contain information related to a variety of events	Part I contains some of the basic vehicle state information such as the message ID, vehicle ID, vehicle latitude/longitude, speed and acceleration status. Part II contains two option data frames: VehicleSafetyExtension and VehicleStatus.
Periodicity	typical time difference between consecutive packets generation is bounded to the [0.1, 1] sec range	Event triggers the DENM update. In between two consequent DENM updates, it is repeated with a pre-defined transmission interval.	Periodic, the periodicity may be different considering whether BSM part II is included or not and the different application type
Length	Variable	Fixed until DENM update	Fixed, with different message size considering whether part II exists or not

In an example, SPS may be employed for the transmission of BSM, DENMs and CAMs. For example, the UE's speed/position/direction changes within a range. BSM may be periodic traffic with a period of 100ms. The message size of BSM may be in the range of 132 ~ 300 Bytes without certificate and 241~409 Bytes with certificate. DENMs, once triggered, may be transmitted periodically with a given message period which may remain unchanged. The message size of the DENM may be 200 ~ 1200 Bytes. If the UE's speed/position/direction does not change or only changes within a small range, the CAM generation periodicity may be fixed.

The SPS may be supported for the UL and DL VoIP transmission. In the current SPS specification, the eNodeB may configure SPS periodicity via dedicated RRC signaling. The periodicity of VoIP packet is generally fixed.

The UE may transmit multiple V2X services, which may require different periodicity and packet sizes. The SPS TB size and period may be adapted to different V2X services. Multiple parallel SPS processes may be activated at the UE. The SPS processes may differ in the amount of resource blocks (RBs) allocated and/or SPS period and may correspond to different types of V2X packets. Once the AS layer of UE receives the V2X packets from upper layer, the UE may trigger V2X packet transmissions on the corresponding SPS grant. Multiple UL SPS configurations may be configured for the UE.

The eNB may configure different SPS C-RNTIs for different SPS processes of the UE. The legacy SPS activation and release mechanism may be reused. Based on the different SPS C-RNTIs, the eNB may trigger which SPS process is activated or released. In an example implementation, in order to support multiple SPS configurations a different SPS C-RNTI may be configured for different SPS traffic. For example, a first SPS C-RNTI may be configured for SPS configuration to transmit voice traffic, a second SPS C-RNTI may be configured for SPS configuration to transmit a V2X traffic. An eNB may transmit one or more RRC messages comprising multiple SPS configuration parameters. The multiple SPS configuration parameters may comprise multiple SPS-RNTI parameters for multiple SPS configurations (e.g. multiple UL SPS configurations).

A UE configured with multiple SPS C-RNTIs may need to monitor search space of PDCCH for multiple SPS C-RNTIs, this mechanism may increase UE processing requirements and/or power consumption. There is a need to improve eNB and UE implementation and enhance network performance when multiple SPSs are configured for a given UE. Some of the example embodiments may implement multiple SPS C-RNTI, and some may implement a single SPS C-RNTI.

In an example embodiment, when multiple SPS grant types are configured for a UE, for example, when multiple SPS-ConfigUL are configured on a cell or when multiple SPS grant types are configured within an SPS-ConfigUL, RRC configuration parameters may comprise an index (may be called SPS index, SPS identifier, SPS parameter, or any other name). Multiple uplink SPSs parameters may be assigned to (associated with) the same SPS C-RNTI. A different SPS configuration (e.g. having different periods) may be assigned to the same SPS C-RNTI, and may be identified by different SPS indexes. The example mechanism may also be applied to DL and/or Sidelink SPS configurations. In example embodiment, multiple SPS configurations (e.g. multiple periodicity, MCS, and/or other parameters) may be triggered employing the same SPS C-RNTI.

In an example, SPS-ConfigUL1 may be assigned SPS C-RNTI and SPS-index1, and SPS-ConfigUL2 may be assigned SPS C-RNTI and SPS-Index2. An eNB may transmit one or more RRC messages comprising configuration parameters of one or more cells (e.g. PCell and/or SCell(s)). The configuration parameters may include configuration parameters for a plurality of SPSs. The configuration parameters may comprise the SPS C-RNTI, SPS-index1 and SPS-index2.

In an example, SPS-ConfigUL may be assigned SPS C-RNTI and may comprise SPS-index1 and SPS-Index2. One or more first SPS configuration parameters may be associated with SPS-index1 and one or more second SPS configuration parameters may be associated with SPS-Index2. Example of SPS configuration parameters maybe periodicity, MCS, grant size, and/or any other SPS configuration parameter presented in RRC SPS configuration. An eNB may transmit one or more RRC messages comprising configuration parameters of one or more cells (e.g. PCell and/or SCell(s)). The configuration parameters may include configuration parameters for SPSs. The configuration parameters may comprise the SPS C-RNTI, SPS-index1 and SPS-index2.

The UE configured with SPS configurations may monitor PDCCH and search for a DCI associated with the SPS C-RNTI (e.g. scrambled with SPS-CRNTI). The eNB may transmit a DCI associated to SPS C-RNTI to the UE to activate or release a SPS grant. The UE may decode a DCI associated with the SPS C-RNTI. The DCI may comprise

one or more fields comprising information about the grant. The DCI may further comprise an SPS index. The SPS index may determine which one of the SPS configurations are activated or released.

Example fields in the DCI grants for an SPS in a legacy system is presented in the specifications. Many of fields are marked by N/A. In an example embodiment, one of the existing fields (e.g. one of the N/A fields), or a new field may be introduced in a DCI for configuration of the SPS index. A field in the DCI may identify which one of the SPS configurations is activated or released. The UE may transmit or receive data according to the grant and SPS configuration parameters.

In an example embodiment, a wireless device may receive at least one message comprising: a semi-persistent scheduling (SPS) cell radio network temporary identifier (C-RNTI); a first SPS configuration parameter(s); a second SPS configuration parameter(s); a first index value associated with the first SPS configuration parameters; and a second index value associated with the second SPS configuration parameters. The wireless device may receive a downlink control information (DCI) associated with the SPS C-RNTI. The DCI comprises one or more fields of an SPS grant and an index value. The wireless device may transmit/receive SPS traffic on radio resources identified in the SPS grant considering the SPS configuration parameters associated with the index value. The SPS configuration parameter associated with the index may include, for example, SPS periodicity, MCS, radio resource parameters, and/or other SPS parameters included in SPS configurations.

In an example, the index may be implicitly configured. SPS configurations may include a sequence of various options for a parameter. An index of a parameter may be the order of the parameter in the sequence. In an example embodiment, a wireless device may receive at least one message comprising: a semi-persistent scheduling (SPS) cell radio network temporary identifier (C-RNTI); SPS configuration parameters; a sequence of a plurality of SPS parameter, e.g. periodicities. An SPS periodicity value may be identified by a periodicity index. The wireless device may receive a downlink control information (DCI) associated with the SPS C-RNTI. The DCI may comprise one or more fields of an SPS grant and a first periodicity index value. The wireless device may transmit/receive SPS traffic on radio resources identified in the SPS grant considering the SPS configuration parameters, and a first periodicity associated with the first periodicity index value. This embodiment may be employed when one or more SPS C-RNTI is configured. A given SPS traffic (message type) may be transmitted with various periodicity depending on vehicle speed or other parameters. This mechanism enables updating SPS grant periodicity with the need for reconfiguring SPS grants. A set of one or more RRC configuration parameters may be applicable to different SPS periodicities. The example embodiment may be extended to other parameters such as RBs, MCS, and others.

In an example, the SPS DCI may include the SPS grant periodicity, instead of the index value for the periodicity. Since a large number of periodicities may be supported. This embodiment may increase the size of DCI, but may reduce the size of the SPS RRC configuration.

In an example embodiment, an SPS grant may be for a specific message type. In current mechanisms, a DCI grant does not comprise information on traffic types associated with the grant. In an example embodiment, a wireless device may receive at least one message comprising: a semi-persistent scheduling (SPS) cell radio network temporary identifier (C-RNTI); a first SPS configuration parameters; a second SPS configuration parameters; a traffic index value associated with the first SPS configuration parameters; and/or a traffic index value associated with the second SPS configuration parameters. The index for the traffic type may be a logical channel identifier, bearer identifier, V2X traffic type identifier, and/or the like. The identifier may also determine a relative priority of the traffic type compared with other traffics. The wireless device may receive a downlink control information (DCI) associated with the SPS C-RNTI. The DCI may comprise one or more fields of an SPS grant and a traffic index value (LCI, bearer identifier, V2X traffic type identifier, and/or the like). The wireless device may transmit SPS traffic on radio resources identified in the SPS grant considering the SPS traffic associated with the traffic index value. The DCI grant may include one or more parameters identifying the traffic associated with the grant. Example embodiment may be employed with one or more SPS C-RNTI are configured.

In an example, eNB may configure a V2X UL SPS RNTI for a UE. The V2X UL SPS RNTI may be different from the legacy SPS C-RNTI. In an example, a DCI format 0 scrambled with V2X UL SPS RNTI may be used to activate and/or update the V2X SPS for the UE.

In an example, multiple SPS configurations can be active at the same time. In an example, one or more indicators in the DCI activating the SPS (e.g., DCI format 0) may be used to differentiate SPS configurations. In an example, the one or more indicator may be SPS index and/or one or more indicator mapped to the SPS index.

In an example, a SPS configuration index may be signaled to the UE when the eNB activates and/or reactivates and/or updates the SPS for the UE. In an example, the eNB may use the Cyclic shift DM RS field (3bits) in DCI 0 to indicate to the UE the UL SPS configuration index. In an example, another field in DCI format 0 (e.g., the TPC command field (2 bits) or another field) in DCI 0 may be used to indicate UL SPS configuration index.

In an example, the eNB may activate a single SPS configuration with a DCI and the UL SPS DCI may contain a single SPS configuration index. In an example, the eNB may transmit multiple DCIs for activation of multiple SPS configurations. In an example, the eNB may transmit as many DCIs as the SPS configurations that the eNB activates for a UE.

In an example, activation of one SPS configuration may release the previous allocation for the same SPS configuration.

In an example, the eNB may explicitly release a SPS configuration for a UE. In an example, the eNB may explicitly release the SPS by sending a DCI (e.g., DCI 0) and the UE may validate the DCI as an indication for release by comparing one or more fields of the DCI with pre-configured values. In an example, the UE may release the SPS without explicit indication of the eNB. Both explicit release and implicit release mechanisms for SPS over Uu may be supported.

In an example, the UE may explicitly signal to the eNB (e.g., using MAC CE and/or with one or more RRC messages) to indicate to the eNB when the UE desires to activate and/or update and/or release a SPS configuration. In an example, when the UE indicates to the eNB that it desires to activate a SPS configuration, the UE may include a desirable time offset in its indication to the eNB. In an example, the desirable time offset may be relative to system frame number 0 (SFN0).

In an example, when the UE desires to change the period of a SPS configuration, the UE may signal this to the eNB. In an example, the signaling may be in form of MAC CE. In an example, the signaling may be in form of RRC signaling. In an example, the signalling may be in form of MAC CE and RRC.

In an example, in the event of a resource conflict between SPS configurations (e.g., two or more SPS grants from two or more SPS configurations in a subframe), only one transmission may occur. In an example, a mechanism and/or rule may be used for resolving resource conflicts between SPS configurations.

In an example, the eNB may configure an SL SPS RNTI different from SL dynamic scheduling RNTI for a UE. In an example, two fields may be included in the DCI scheduling the SL SPS. In an example, a SL SPS configuration index may be included in the DCI scheduling SL SPS. In an example, the SL SPS configuration index may be 3 bits. In an example an Activation/release indication may be included in the DCI scheduling the SL SPS. In an example, the Activation/release indication field may be 1 bit.

In an example, a SL SPS DCI may contain a single SPS configuration index.

In an example, if the number of information bits in SL SPS DCI format mapped onto a given search space is less than the payload size of DCI format 0 mapped onto the same search space, zeros may be appended to SL SPS DCI format until the payload size equals that of DCI format 0 including any padding bits appended to DCI format 0.

In an example, the size of SL SPS DCI format may be larger than the size of DCI format 0 on the same search space.

In an example, a UE may use an acknowledgement feedback mechanism after the reception of a DCI indicating SL SPS activation and/or release.

In an example, a counter may be used by the MAC and the SPS may be released if there is no MAC PDU for a configured number of consecutive SPS occasions without data.

In an example, when a SPS configuration is activated for an SPS process, previously configured SPS process may be released.

In an example, a UE may identify a SPS process associated to a DCI based on the contents of the DCI. In an example, there may be one-to-one mapping between SPS configuration index and SPS process. In an example, there may be semi-static (e.g., configured by higher layer) association between SPS configuration index and SPS process. In an example, multiple SPS configurations may be associated to a SPS process. In an example, there may be dynamic indication (e.g., explicitly and/or implicitly) of SPS process associated to a SPS DCI.

In an example, a UE configured with SPS may transmit assistance information to the eNB to activate and/or release and/or update a SPS configuration. In an example, the UE assistance may be signaled to the eNB with MAC CE and/or one or more RRC messages.

In an example, the UE assistance information reporting may be triggered based on UE implementation. In an example, some rules may be used to limit the amount of UE assistance reporting from UE. In an example, the UE assistance report may not be sent if the offset to the next SPS occasion is not greater than a threshold. In an example, the threshold may be configured. In an example, a prohibit timer may be used. In an example, the eNB may control the UE assistance reporting. In an example, the trigger to transmit the UE assistance may be cancelled based on some rule. In an example, the trigger to transmit the UE assistance may be cancelled if the eNB activates and/or reactivates a SPS configuration that matches the UE requirement (e.g., with a periodicity and timing offset that matches the UE data).

In an example, the UE assistance information may include the periodicity and/or timing offset. In an example, the UE may send the preferred SPS interval in the assistance information if the periodicity of packet generation changes. In an example, the preferred SPS interval in the UE assistance information may be expected packet periodicity. In an example, the preferred SPS interval in the UE assistance information may be the interval between the last two generated packets. In an example, the preferred SPS interval in the UE assistance information may be average inter-packet generation time for a last period of time. In an example, the last period of time may be configured for the UE. In an example, the last period of time may be RRC configured for the UE. In an example, the UE may estimate the periodicity and timing offset based on UE implementation.

In an example, the UE assistance triggers may be left to UE implementation. In an example, the network may configure the UE assistance information for the UE.

In an example, explicit SPS resource release by eNB may be based on UE's transmission or indications.

In an example, the UE assistance information may include a set of preferred expected SPS interval, timing offset with respect subframe0 of the SFN0. In an example, SPS periodicity values may be 50ms, 100ms, 200ms, 300ms, 400ms, 500ms, 600ms, 700ms, 800ms, 900ms and 1000ms UL and/or SPS.

In an example, the UE assistance information may be per logical channel. In an example, the UE assistance information may be reported if change is estimated in periodicity of packet arrival. In an example, the UE assistance information may be reported if change is estimated in offset of packet arrival. In an example, the UE assistance information may be configured by the eNB. In an example, the UE assistance information may be reported in case SPS configured for the UE and/or in case SPS is not configured for the UE. In an example, the UE assistance information may include the existing and/or a suggested SPS configuration. In an example, the UE assistance information may include the index of SPS configuration.

In an example, up to 8 SPS configurations may be configured per UE. In an example, 3 bits may be used in the scheduling DCI that may correspond to the 8 SPS configurations. In an example, the configured SPSs may be simultaneously active. In an example, there may be an association between a SPS configuration and logical channel ID (LCID) and/or ProSe Per-Packet Priority (PPPP). In an example, the association in UL SPS may be based on LCID. In an example, the association in SL SPS may be based on PPPP. In an example, one traffic type (e.g., one LCID and/or one PPPP may be associated to multiple SPS configurations.

In an example, the eNB may configure the UE with a sidelink SPS release mechanism. In an example, after a configurable number of consecutive sidelink SPS occasions are not used by the UE, the UE may notify the network and then considers the specific sidelink SPS released. In an example, the eNB may configure a valid duration for an SPS activated. In an example, the valid duration may be configured by RRC. In an example, when the time elapsed exceeds the valid duration since the activation for a specific SPS, the UE and eNB may implicitly release the SPS. In an example, if a sidelink SPS release mechanism is not configured by the eNB, it may be up to UE implementation to determine when a sidelink traffic is terminated and report this information to the eNB. In an example, the UE may

report the information using MAC CE. In an example, the UE may report this information using PUCCH and/or a UCI.

In an example, the SPS configurations may be provided by the eNB to UEs in RRC signaling. In an example, the SPS configuration may comprise Sidelink SPS scheduling interval (e.g., the specific SPS periodicity for the SPS configuration), the index of the SPS configuration (e.g., the index that may be used by PDCCH in DCI to (re)activate/release a configured SPS configuration. The SPS index may also be used in the UE assistance information), the LCID associated to the SPS configuration, the PPPP associated to the SPS configuration, the number of sidelink empty transmissions before release, the carrier in which this SPS configuration applies (e.g., in case of multi-carrier sidelink transmissions, it may indicate the carrier in which a specific SPS configuration applies), the destination L2 ID associated to the SPS configuration, the valid duration associated to the SPS configuration, etc.

In an example, the UE assistance information may be reported both in case SPS is configured or not.

In an example, the report of the UE assistance information may be configured by the eNB only for certain logical channels/PPPP. In an example, the UE may report the periodicity/offset changes of the traffics associated to those logical channels/PPPP configured by the eNB.

In an example, the UE assistance information, if configured, may be reported by the UE for any logical channel/PPPP.

In an example, the UE assistance information may be reported by the UE for any logical channel identified by a pair of LCID and Destination L2 ID.

In an example, the UE assistance information may be delivered in a MAC CE and/or in RRC. In an example, the UE assistance information may use the existing RRC message UEAssistanceInformation with some new fields introduced.

In an example, the estimated periodicity of packet arrivals, the estimated offset with respect to subframe0 of the SFN0, and the the SPS index of the SPS configuration (e.g., if SPS is configured by the eNB) may be included in the UE assistance information. In an example, the UE may indicate in the UE assistance message, the LCID to which the content of the UE Assistance Information is associated. In an example, the UE may indicate in the UE assistance message, the PPPP to which the content of the UE Assistance Information is associated. In an example, the UE may indicate, in the UE assistance message, the estimated packet size of next transmission. In an example, the UE may indicate, in the UE assistance message, the Destination L2 ID for the associated logical channel.

In an example, the UEAssistanceInformation message may be used for the indication of UE assistance information to the eNB. In an example, the signalling radio bearer may be SRB1. In an example, the RLC-SAP mode may be AM. In an example, the corresponding logical channel may be DCCH. In an example, direction of this message may be from UE to the E-UTRAN. Example UEAssistanceInformation message is shown. New fields may be added to provide assistance information for SPS traffic. In an example, one or more UE SPS assistance parameters may be transmitted employing MAC CE messages and/or one or more RRC messages.

```
-- ASN1START
UEAssistanceInformation-r11 ::= SEQUENCE {
    criticalExtensions          CHOICE {
        c1                     CHOICE {
            ueAssistanceInformation-r11 UEAssistanceInformation-r11-IEs,
            spare3 NULL, spare2 NULL, spare1 NULL
        },
        criticalExtensionsFuture SEQUENCE {}
    }
}

UEAssistanceInformation-r11-IEs ::= SEQUENCE {
    powerPrefIndication-r11 ENUMERATED {normal, lowPowerConsumption} OPTIONAL,
    lateNonCriticalExtension OCTET STRING OPTIONAL,
    nonCriticalExtension     SEQUENCE {} OPTIONAL
}
-- ASN1END
```

In an example, the value `lowPowerConsumption` of `powerPrefIndication` may indicate the UE prefers a configuration that is primarily optimised for power saving. In an example, the value of `powerPrefIndication` may be set to normal.

////////

In current SPS mechanism, a single SPS is configured for a UE on a cell. When the UE is configured with UL transmission skipping for SPS (e.g., with SkipUplinkTXSPS IE), the UE transmits a SPS confirmation MAC CE after receiving a DCI indicating activation/reactivation/release of the SPS. For a UE capable of V2X transmission, more than one SPS configurations with different configuration parameters (e.g., different periodicities, offset, etc.) may be simultaneously active. Current SPS mechanism needs to be enhanced to distinguish the SPS in the MAC CE transmitted by a UE after receiving an SPS activation/reactivation/release DCI when the UE is configured with ULTXSkipping SPS.

When ULTXSkipping is configured for a UE as true for a grant type, the UE may skip a dynamic grant and/or a configured uplink transmissions (for the corresponding grant type) if no data is available for transmission. The UE may transmit some allowed type of MAC CE when no data is available for a dynamic grant.

When ULTXSkipping is not configured for a UE for a grant type, the UE may transmit MAC CE and/or padding in a dynamic grant and/or a configured uplink transmissions (for the corresponding grant type) if no data is available for transmission.

In an example embodiment, an eNB may configure a UE with one or more SPS configurations. In an example, the SPS-Config RRC IE may include the configuration parameters (e.g., SPS interval, etc.) of the one or more SPS configurations. In an example, a SPS configuration may be associated with one or more indicators. In an example, the one or more indicator may be a SPS index and/or SPS-RNTI. In an example, the eNB may signal (employing a DCI associated with an SPS-RNTI) the one or more SPS indicator (e.g., the SPS index) corresponding to a SPS configuration in a DCI that activates (e.g., initiates) and/or reactivates and/or releases the SPS configuration. The SPS activating/reactivating DCI may configure, for the UE, grants at subframes depending on the period and/or other parameters associated with the SPS configuration corresponding to the SPS indicator signaled to the UE. The SPS release DCI may clear the configured grants corresponding to the SPS configuration that is indicated to the UE (e.g., with a SPS index) in the SPS release DCI. In an example, legacy SPS configuration may not employ an SPS index.

In an example, a UE may be configured with SkipUplinkTXSPS IE. In an example, a UE configured with SkipUplinkTXSPS may skip transmission on a configured grant for which the UE has no data in its buffer for that grant. In an example, a UE configured with SkipUplinkTXSPS may skip transmission on a configured grant for which the UE has no data in its buffer for the one or more LCIDs corresponding to the configured SPS grant (e.g., if the configured grant corresponding to the SPS configuration is associated with an LCID). In an example, a UE configured with SkipUplinkTXSPS, may trigger a SPS confirmation MAC CE after receiving a DCI indicating activation/reactivation or release of a SPS configuration (or a SPS configuration that is configured with SkipUplinkTXSPS).

Current LTE technology does not provide required flexibility in configuring SkipUplinkTXSPS for various configured grants and this may reduce uplink transmission efficiency when multiple SPSs with different requirements are configured. There is a need to enhance the current RRC configuration and MAC/RRC mechanisms to enable configuration of SkipUplinkTXSPS (set as true) for a subset (e.g., one or more) of the configured SPS configurations. Example embodiments increase uplink transmission efficiency and flexibility by enabling SkipUplinkTXSPS for some configured SPS grants, while not configuring SkipUplinkTXSPS for one or more configured SPS grants depending on the traffic and/or grant requirements.

In an example embodiment, the eNB may configure the uplink transmission skipping for the UE for one or more of one or more configured SPS configurations. In an example, the eNB may include a bitmap in an RRC IE (e.g. the SPS-Config IE, or MACmain-Config) that indicates for which of the one or more (e.g., eight) SPS configurations the transmission skipping is configured and for which one of the SPS configurations the transmission skipping is not configured. In an example, the leftmost bit in the bitmap may correspond to the SPS configuration with smallest SPS index, the next bit after the leftmost bit in the bitmap may correspond to the SPS configuration with second smallest SPS index and so on. In an example, when C SPS configurations are configured for the UE and C is less than eight (e.g., C=2, 4, etc.), the UE may consider the first C bits in the bitmap to determine whether uplink transmission skipping is configured for the corresponding SPS and ignore the other bits.

In an example, eNB may indicate whether UL transmission skipping applies for a SPS configuration using a field (e.g., one bit) for a SPS configuration in the SPS-Config RRC IE. When a plurality of SPS-configurations are configured, a SPS-configuration (or other parameters e.g. MACmain-config) may comprise a parameter indicating whether UL transmission skipping is configured for that SPS configuration or not.

In an example, the eNB may indicate whether uplink skipping may be applied for a SPS configuration in the DCI activating/reactivating/releasing the SPS configuration, e.g., using a bit in the DCI. The UE may consider the bit in the DCI to determine whether uplink skipping is configured for the activated SPS.

In an example, if an eNB configures the SkipUplinkTXSPS IE for a UE, the UL transmission skipping may be applied to a predefined one or more SPS configurations (e.g. non-V2X traffic (e.g., VoIP), V2X traffic, and/or the like). For example, SkipUplinkTXSPS IE may be applied to SPS configuration using a first RNTI (e.g. VOIP, or V2X), and may not be applied to another SPS configuration using a second RNTI (e.g. VOIP, or V2X). In an example, SkipUplinkTXSPS IE may not be configurable for certain SPSs (e.g. corresponding to certain RNTI), and may be configurable for some other SPSs. In an example SkipUplinkTXSPS IE may be applied to legacy SPS-configuration, and may not be applied to enhanced SPS configuration.

In an example, eNB may indicate to the UE if uplink transmission skipping is enabled for a traffic type and/or LCID and/or if uplink transmission skipping is not enabled for a traffic type and/or LCID. For example, eNB may configure an SkipUplinkTXSPS IE for a corresponding SPS index, and/or corresponding SPS RNTI. In an example, an IE may comprise a sequence of (SkipUplinkTXSPS IE, and SPS configuration parameter) to configure or not configure SkipUplinkTXSPS IE for a particular SPS. SPS configuration parameter for example may identify the SPS config, e.g. SPS index and/or RNTI. In an example, an IE may comprise a sequence (list) of SkipUplinkTXSPS parameters. A SkipUplinkTXSPS in the sequence may correspond to a specific SPS configuration parameter (e.g. ordered based on SPS index). In an example, the sequence size may be constant (e.g. 8) or may depend on the number of configured SPSs.

In an example, SkipUplinkTXSPS configuration may employ one or more of the above examples. For example, legacy SkipUplinkTXSPS IE in the MAC-mainconfig may be applicable to legacy SPS configuration IE in the RRC SPS-Config IE (e.g. for VOIP traffic). One or more new SkipUplinkTXSPS IEs may be defined for one or more enhanced SPS configurations (e.g. for the V2X traffic) based on an example embodiment (described in above paragraphs) when multiple SPSs are configured.

Example embodiments enhance SPS confirmation mechanism when one or more SPSs are configured.

In an example, for a given SPS configuration, if SPS confirmation has been triggered and not cancelled and if the MAC entity has UL resources allocated for new transmission in a TTI on or after the SPS confirmation trigger (e.g., the TTI that the DCI is received), the MAC entity may instruct the Multiplexing and Assembly procedure to generate an SPS confirmation MAC CE and cancel the triggered SPS confirmation after its transmission. In an example, if the SPS confirmation MAC CE is triggered by a SPS release DCI, the MAC entity may clear the configured uplink grant associated with the released SPS after (e.g. as early as possible) first transmission of the SPS confirmation MAC CE.

In an example, when a UE is configured with an SPS configuration (legacy SPS configuration), SPS confirmation MAC CE may be identified by an SPS confirmation LCID (e.g. 10101). In an example, the SPS confirmation MAC control element is identified by a MAC PDU sub-header with SPS confirmation LCID. The MAC CE may have a fixed size of zero bits.

In an example, a new LCID may be pre-defined for a UE to identify a MAC CE for SPS configuration supporting multiple SPS configuration. The new LCID may be employed when SPS confirmation is transmitted for a particular SPS configuration. For example, when an RRC message configures an enhanced SPS configuration (e.g. multiple SPS configurations) an enhanced SPS confirmation LCID may be used to identify an enhanced SPS confirmation MAC CE. When a UE is configured with a predefined SPS configuration, MAC CE may have a fixed size of zero bits that may be identified by a first LCID. The predefined configuration for example, may be configuration of one SPS configuration (e.g. legacy SPS), or one SPS-RNTI, or configuration of legacy SPS-config, and/or configuration of SPS for VOIP, and/or when SPS indexes are not configured. When the UE is configured with an enhanced RRC SPS configuration, the UE may transmit an enhanced MAC CE for an enhanced SPS confirmation that may be identified by a second LCID (different from the first LCID). In an example, the legacy SPS confirmation MAC CE

may be employed for confirming activation/release of the legacy SPS configuration (legacy SPS-config IE e.g. using a first RNTI). And the enhanced SPS confirmation MAC CE may be employed for confirming activation/release of the enhanced SPS configuration (enhanced SPS-config IE e.g. using a second RNTI). This mechanism may increase the number of LCIDs required for SPS confirmation.

An enhanced SPS confirmation MAC CE may be equally have other names, e.g., extended SPS confirmation, multiple SPS confirmation, long SPS confirmation, and/or the like.

In an example, the legacy SPS confirmation LCID may be employed along with the RRC configuration for SPS to determine whether a UE transmits the legacy MAC SPS confirmation or the enhanced MAC SPS confirmation. An example embodiment may reduce the number of required LCIDs for SPS confirmation (one LCID is used for identifying both legacy and enhanced SPS MAC CEs). When a UE is configured with a predefined SPS configuration, MAC CE may have a fixed size of zero bits. The predefined configuration for example, may be configuration of one SPS configuration (e.g. legacy SPS), or one SPS-RNTI, or configuration of legacy SPS-config, and/or configuration of SPS for VOIP, and/or when SPS indexes are not configured. When the UE is configured with an enhanced RRC SPS configuration, the UE may transmit an enhance MAC CE for an enhanced SPS confirmation. Both MAC CEs may be identified by the same LCID. In an example, the legacy SPS confirmation MAC CE may be employed for confirming activation/release of the legacy SPS configuration (legacy SPS-config IE e.g. using a first RNTI). And the enhanced MAC CE SPS confirmation may be employed for confirming activation/release of the enhanced SPS configuration (enhanced SPS-config IE e.g. using a second RNTI).

In an example, an enhanced SPS confirmation MAC CE may have a fixed size of one octet. In an example the L (e.g., L=3) leftmost bits in the SPS confirmation MAC CE may indicate the SPS index of the SPS configuration for which the SPS confirmation MAC CE corresponds to.

In an example, an enhanced SPS confirmation MAC CE may have a fixed size of one octet. In an example, the MAC CE may comprise a bitmap (e.g. of 8 bits). A bit in the bitmap may correspond to an SPS configuration. In an example, bit i (C_i) may correspond to an SPS identified by index i . The UE may transmit the MAC CE. SPS confirmation for an SPS activation/release may be indicated by a predefined value of C_i (e.g. $C_i=1$). In an example, the UE/eNB may set the C_i for one or more SPS that do not require SPS confirmation or are not configured as zero. In an example, the UE/eNB may ignore the value of the C_i for one or more SPS that do not require SPS confirmation or are not configured.

In an example, after a UE receives a SPS activation/reactivation/release DCI from the eNB, with the SPS configuration indicated in the DCI, if the UE is configured with SkipUplinkTXSPS (e.g., if SkipUplinkTXSPS is configured for the SPS index indicated in the DCI or if SkipUplinkTXSPS is configured for the configured SPS configurations), the UE may trigger the SPS confirmation. If the MAC entity has UL resources allocated for new transmission in a TTI on or after the SPS confirmation trigger (e.g., the TTI that the DCI is received), the MAC entity may instruct the Multiplexing and Assembly procedure to generate an SPS confirmation MAC CE and cancel the triggered SPS confirmation after its transmission. In an example, the MAC entity may clear the configured uplink grants associated with a SPS configuration after (e.g., as early as possible) first transmission of the SPS confirmation MAC CE triggered by the receiving a release DCI for the SPS configuration.

Example embodiments enhance SPS confirmation mechanism when one or more SPSs are configured.

In an example, for a given SPS configuration, if SPS confirmation has been triggered and not cancelled and if the MAC entity has UL resources allocated for new transmission in a TTI on or after the SPS confirmation trigger (e.g., the TTI that the DCI is received), the MAC entity may instruct the Multiplexing and Assembly procedure to generate an SPS confirmation MAC CE and cancel the triggered SPS confirmation after its transmission. In an example, if the SPS confirmation MAC CE is triggered by a SPS release DCI, the MAC entity may clear the configured uplink grant associated with the released SPS after (e.g. as early as possible) first transmission of the SPS confirmation MAC CE.

In an example embodiment, the SPS confirmation MAC CE may be identified by a MAC PDU subheader with a LCID that corresponds to the SPS configuration for which the SPS confirmation MAC CE corresponds to. In an

example, with eight different SPS configurations, the LCIDs 01110, 01111, 10000, 10001, 10010, 10011, 10100 and 10101 may be used to identify the SPS configurations. This solution may require many LCIDs.

In an example, when a UE is configured with an SPS configuration (legacy SPS configuration), SPS configuration MAC CE may be identified by an SPS confirmation LCID (e.g. 10101). In an example, the SPS confirmation MAC control element is identified by a MAC PDU subheader with SPS confirmation LCID. The MAC CE may have a fixed size of zero bits.

In an example, two LCIDs may be employed for SPS confirmation. A first LCID may be employed for legacy SPS configuration with a MAC CE of zero bits. A second LCID may be employed for SPS confirmation of enhanced SPS configuration with MAC CE of zero bits. In an example, the legacy SPS configuration may be for VOIP traffic, and the enhanced SPS configuration may be for V2X traffic. One or more example embodiments may be used for SPS confirmation of the enhanced SPS configuration when the second LCID is employed.

In an example, after a UE receives a SPS activation/reactivation/release DCI from the eNB, with the SPS configuration indicated in the DCI, if the UE is configured with SkipUplinkTXSPS (e.g., if SkipUplinkTXSPS is configured for the SPS index indicated in the DCI or if SkipUplinkTXSPS is configured for the configured SPS configurations), the UE may trigger the SPS confirmation. If the MAC entity has UL resources allocated for new transmission in a TTI on or after the SPS confirmation trigger (e.g., the TTI that the DCI is received), the MAC entity may instruct the Multiplexing and Assembly procedure to generate an SPS confirmation MAC CE and cancel the triggered SPS confirmation after its transmission. In an example, the MAC entity may clear the configured uplink grants associated with a SPS configuration after (e.g., as early as possible) first transmission of the SPS confirmation MAC CE triggered by the receiving a release DCI for the SPS configuration.

Example embodiments enhance SPS confirmation mechanism when one or more SPSs are configured.

In an example, for a given SPS configuration, if SPS confirmation has been triggered and not cancelled and if the MAC entity has UL resources allocated for new transmission in a TTI on or after the SPS confirmation trigger (e.g., the TTI that the DCI is received), the MAC entity may instruct the Multiplexing and Assembly procedure to generate an SPS confirmation MAC CE and cancel the triggered SPS confirmation after its transmission. In an example, if the SPS confirmation MAC CE is triggered by a SPS release DCI, the MAC entity may clear the configured uplink grant associated with the released SPS after (e.g. as early as possible) first transmission of the SPS confirmation MAC CE.

In an example, when a UE is configured with an SPS configuration (legacy SPS configuration), SPS configuration MAC CE may be identified by an SPS confirmation LCID (e.g. 10101). In an example, the SPS confirmation MAC control element is identified by a MAC PDU subheader with SPS confirmation LCID. The MAC CE may have a fixed size of zero bits.

In an example, one or more bits in the SPS confirmation MAC CE subheader may be employed to indicate whether the SPS confirmation is for a legacy SPS configuration or an enhanced SPS configuration. For example, an R bit may be employed to indicate how the MAC CE is used. One or more example embodiments may be used for SPS confirmation of the enhanced SPS configuration when the one or more bits indicate that the MAC CE is applicable to an enhanced SPS configuration. In an example, the length field in the MAC CE subheader may indicate that the MAC CE is for the legacy SPS configuration or enhanced SPS configuration. For example, when the length field has a first value (e.g. zero), the SPS confirmation MAC CE may be for legacy SPS configuration, and if the length field has a second value (e.g. one), the MAC CE is applicable to enhanced SPS configuration. In an example, a bit in the MAC CE may determine whether the MAC CE is applicable to a legacy SPS configuration or enhanced SPS configuration. In an example, RNTI associated with the SPS configuration may be included in the SPS confirmation. In an example, SPS index may be included in SPS confirmation MAC CE. In an example, SPS RNTI and/or SPS index may be included in the MAC CE to indicate the confirmation of a corresponding SPS. In an example, a bitmap may be included in a MAC CE, wherein a bit corresponds to a corresponding SPS index/RNTI.

In an example, SPS confirmation MAC CE may include other SPS related parameters for an SPS configuration, e.g. SPS UE assistance information, etc.

In an example, after a UE receives a SPS activation/reactivation/release DCI from the eNB, with the SPS configuration indicated in the DCI, if the UE is configured with SkipUplinkTXSPS (e.g., if SkipUplinkTXSPS is

configured for the SPS index indicated in the DCI or if SkipUplinkTXSPS is configured for the configured SPS configurations), the UE may trigger the SPS confirmation. If the MAC entity has UL resources allocated for new transmission in a TTI on or after the SPS confirmation trigger (e.g., the TTI that the DCI is received), the MAC entity may instruct the Multiplexing and Assembly procedure to generate an SPS confirmation MAC CE and cancel the triggered SPS confirmation after its transmission. In an example, the MAC entity may clear the configured uplink grants associated with a SPS configuration after (e.g., as early as possible) first transmission of the SPS confirmation MAC CE triggered by the receiving a release DCI for the SPS configuration.

Example embodiments enhance SPS confirmation mechanism when one or more SPSs are configured.

In an example, for a given SPS configuration, if SPS confirmation has been triggered and not cancelled and if the MAC entity has UL resources allocated for new transmission in a TTI on or after the SPS confirmation trigger (e.g., the TTI that the DCI is received), the MAC entity may instruct the Multiplexing and Assembly procedure to generate an SPS confirmation MAC CE and cancel the triggered SPS confirmation after its transmission. In an example, if the SPS confirmation MAC CE is triggered by a SPS release DCI, the MAC entity may clear the configured uplink grant associated with the released SPS after (e.g. as early as possible) first transmission of the SPS confirmation MAC CE.

In an example, when a UE is configured with an SPS configuration (legacy SPS configuration), SPS confirmation MAC CE may be identified by an SPS confirmation LCID (e.g. 10101). In an example, the SPS confirmation MAC control element is identified by a MAC PDU sub-header with SPS confirmation LCID. The MAC CE may have a fixed size of zero bits.

In an example embodiment, the SPS confirmation MAC CE may be identified by a MAC PDU subheader with an LCID (e.g. LCID of 10101) and may have a fixed size of zero bits. In an example, after a UE receives a SPS activation/reactivation/release DCI from the eNB, with the SPS configuration indicated in the DCI, if the UE is configured with SkipUplinkTXSPS (e.g., if SkipUplinkTXSPS is configured for the SPS index indicated in the DCI or if SkipUplinkTXSPS is configured for the configured SPS configurations), the UE may trigger the SPS confirmation. The MAC entity may instruct the Multiplexing and Assembly procedure to generate an SPS confirmation MAC CE in a TTI for which the MAC entity has a configured grant corresponding to the SPS configuration indicated in the DCI (the TTI may be a TTI for the next SPS grant) and cancel the triggered SPS confirmation after its transmission. In an example, the MAC entity may clear the configured uplink grants associated with a SPS configuration after (e.g., as early as possible) first transmission of the SPS confirmation MAC CE triggered by receiving a release DCI for the SPS configuration.

In an example, for a given SPS configuration, if SPS confirmation has been triggered and not cancelled and if the MAC entity has UL resources allocated for new transmission in a TTI on or after the SPS confirmation trigger (e.g., the TTI that the DCI is received), the MAC entity may instruct the Multiplexing and Assembly procedure to generate an SPS confirmation MAC CE and cancel the triggered SPS confirmation after its transmission. In an example, if the SPS confirmation MAC CE is triggered by a SPS release DCI, the MAC entity may clear the configured uplink grant associated with the released SPS after (e.g. as early as possible) first transmission of the SPS confirmation MAC CE.

In an example, when a UE is configured with an SPS configuration (legacy SPS configuration), SPS confirmation MAC CE may be identified by an SPS confirmation LCID (e.g. 10101). In an example, the SPS confirmation MAC control element is identified by a MAC PDU sub-header with SPS confirmation LCID. The MAC CE may have a fixed size of zero bits.

In an example embodiment, the SPS confirmation MAC CE may be identified by a MAC PDU subheader with an LCID (e.g. LCID of 10101) and may have a fixed size of zero bits. In an example, after a UE receives a SPS activation/reactivation/release DCI from the eNB, with the SPS configuration indicated in the DCI, if the UE is configured with SkipUplinkTXSPS (e.g., if SkipUplinkTXSPS is configured for the SPS index indicated in the DCI or if SkipUplinkTXSPS is configured for the configured SPS configurations), the UE may trigger the SPS confirmation. If the MAC entity has UL resources allocated for new transmission in a TTI on or after the SPS confirmation trigger (e.g., the TTI that the DCI is received), the MAC entity may instruct the Multiplexing and Assembly procedure to generate an SPS confirmation MAC CE and cancel the triggered SPS confirmation after its transmission. In an example, the eNB may not send a new SPS activation/reactivation/release DCI until the eNB

receives the MAC CE of the last SPS Activation/Release from the UE. In an example, the MAC entity may clear the configured uplink grants associated with a SPS configuration after (e.g., as early as possible) first transmission of the SPS confirmation MAC CE triggered by the receiving a release DCI for the SPS configuration.

Electronic Patent Application Fee Transmittal

Application Number:

Filing Date:

Title of Invention:

MAC Configuration in a Wireless Network

First Named Inventor/Applicant Name:

Alireza Babaei

Filer:

Esmail Hejazi Dinan

Attorney Docket Number:

16-1098P

Filed as Small Entity

Filing Fees for Provisional

Description

Fee Code

Quantity

Amount

**Sub-Total in
USD(\$)**

Basic Filing:

PROVISIONAL APPLICATION FILING FEE

2005

1

130

130

Pages:

Claims:

Miscellaneous-Filing:

Petition:

Patent-Appeals-and-Interference:

Post-Allowance-and-Post-Issuance:

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				130

Electronic Acknowledgement Receipt

EFS ID:	27506691
Application Number:	62421821
International Application Number:	
Confirmation Number:	3407
Title of Invention:	MAC Configuration in a Wireless Network
First Named Inventor/Applicant Name:	Alireza Babaei
Customer Number:	92629
Filer:	Esmail Hejazi Dinan
Filer Authorized By:	
Attorney Docket Number:	16-1098P
Receipt Date:	14-NOV-2016
Filing Date:	
Time Stamp:	18:04:24
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	\$ 130
RAM confirmation Number	111516INTEFSW00006080505124
Deposit Account	505124
Authorized User	Esmael Dinan

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

37 CFR 1.16 (National application filing, search, and examination fees)

37 CFR 1.17 (Patent application and reexamination processing fees)

37 CFR 1.19 (Document supply fees)
37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Drawings-only black and white line drawings	16-1098P-Master-FIGS-1-10-v3.pdf	133833	no	12
			787c8787ea5e91ebe9185790496b621f5be9d0c8		
Warnings:					
Information:					
2	Specification	16-1098P-Parent-Spec-TAG-DC-PUCCH-v3.pdf	1074931	no	25
			7b151e453d477e47a248a8a53dd136d88ebdd196		
Warnings:					
Information:					
3	Provisional Cover Sheet (SB16)	16-1098P-ProvisionalSB.pdf	2071543	no	3
			2601430ce94d0d0d4c75b7ed6590230759fa0d3b		
Warnings:					
Information:					
4	Specification	16-1098P-SPS_Confirmation_MAC_CE_V2_X_v4_clean.pdf	259023	no	34
			2b44c075316e311522fcd3ab263d261586c6bcb7		
Warnings:					
Information:					
5	Fee Worksheet (SB06)	fee-info.pdf	30297	no	2
			406d2f9b634150fe3f2510f4c20953794a235350		
Warnings:					
Information:					
Total Files Size (in bytes):			3569627		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.