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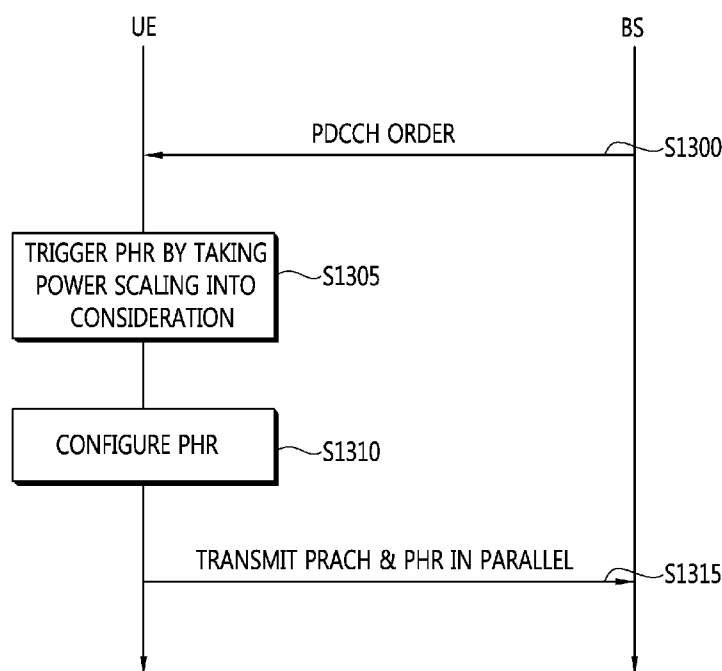
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(54) **Title:** APPARATUS AND METHOD FOR REPORTING POWER HEADROOM IN MULTIPLE COMPONENT CARRIER SYSTEM



(57) **Abstract:** According to the present invention, apparatus and method for reporting power headroom are described. In the present invention, a method of user equipment (UE) transmitting a power headroom report (PHR) in a wireless communication system may include receiving a physical downlink control channel (PDCCH) order, ordering random access, from a base station (BS) through a PDCCH, triggering a PHR based on a PHR triggering condition, transmitting a physical random access channel (PRACH), including a random access (RA) preamble that is a response to the PDCCH order, and a physical uplink shared channel (PUSCH), including the PHR, to the BS in parallel. The PHR triggering condition may include a condition that the PUSCH is not attenuated and scaled when the PUSCH including the PHR and the PRACH are to be transmitted in parallel in an identical subframe.

Description

Title of Invention: APPARATUS AND METHOD FOR REPORTING POWER HEADROOM IN MULTIPLE COMPONENT CARRIER SYSTEM

Technical Field

- [1] The present invention relates to wireless communication, and more particularly, to a method and apparatus for performing a power headroom report in a multiple component carrier system.

Background Art

- [2] In a common wireless communication system, although an uplink bandwidth and a downlink bandwidth are differently set, only one carrier is chiefly taken into consideration. In 3rd generation partnership project (3GPP) long term evolution (LTE), the number of carriers forming uplink and downlink is one and an uplink bandwidth is commonly symmetrical to a downlink bandwidth based on a single carrier. In this single carrier system, random access is performed using one carrier. As multiple component carrier systems are recently introduced, random access has been able to be implemented through several component carriers.
- [3] A multiple carrier system (or also called a multiple component carrier system) means a wireless communication system capable of supporting a carrier aggregation. The carrier aggregation is technology in which small fragmented bands are efficiently used, and the carrier aggregation creates an effect that uses a logically wide band by aggregating a plurality of physically non-continuous bands in a frequency domain.
- [4] A terminal experiences a random access (RA) process in order to access a network. An object of a terminal to perform a random access procedure on a network can include initial access, a handover, a scheduling request, and uplink timing alignment.
- [5] One of methods in which a base station efficiently utilizes the resources of a terminal is to use power headroom information from the terminal. Power control technology (or also called power coordination technology) is essential technology for minimizing interference factors in order to efficiently distribute resources in wireless communication and reducing the consumption of the battery of a terminal. When a terminal provides power headroom information to a base station, the base station can estimate maximum UL transmission power that can be processed by the terminal. Accordingly, the base station can provide the terminal with uplink scheduling, such as transmit power control (TPC), a modulation and coding scheme (MCS), and a bandwidth, within a range of the estimated maximum UL transmission power.
- [6] If a terminal performs parallel transmission in a process of performing a power

headroom report, distortion is generated in a process of calculating power headroom. Accordingly, a problem in that a base station is unable to properly perform uplink scheduling can occur.

Disclosure of Invention

Technical Problem

- [7] The present invention provides a method and apparatus for performing a power headroom report in a multiple component carrier system.
- [8] The present invention also provides an apparatus and method for efficiently performing a power headroom report simultaneously with a random access procedure.
- [9] The present invention also provides an apparatus and method for transmitting a power headroom value not distorted by power scaling.

Solution to Problem

- [10] In an aspect, a method of user equipment (UE) transmitting a power headroom report (PHR) in a wireless communication system comprises receiving a physical downlink control channel (PDCCH) order, ordering random access, through a PDCCH from a base station (BS), triggering a PHR based on a PHR triggering condition, transmitting a physical random access channel (PRACH), comprising a random access (RA) preamble that is a response to the PDCCH order, and a physical uplink shared channel (PUSCH), comprising the PHR, to the BS in parallel. The PHR triggering condition may comprise a condition that the PUSCH is not attenuated and scaled when the PUSCH comprising the PHR and the PRACH are to be transmitted in parallel in an identical subframe.
- [11] In another aspect, a method of user equipment (UE) performing a power headroom report (PHR) in a wireless communication system comprises receiving a physical downlink control channel (PDCCH) order, ordering random access, from a base station (BS) through a PDCCH, triggering a PHR based on a PHR triggering condition, prohibiting a transmission of the PHR if a physical uplink shared channel (PUSCH) comprising the PHR is not substantially transmitted or a transmission power of the PUSCH through which the PHR is transmitted is attenuated and scaled due to a parallel transmission of a PRACH, comprising a random access (RA) preamble that is a response to the PDCCH order, and the PUSCH within an identical subframe and transmitting the PUSCH comprising the PHR and the PRACH to the BS if the transmission of the PHR is not prohibited.
- [12] In yet another aspect, a User equipment (UE) performing a power headroom report (PHR) in a wireless communication system comprises a reception unit configured to receive a physical downlink control channel (PDCCH) order, ordering random access, from a base station (BS) through a PDCCH, a PHR triggering unit configured to

trigger a PHR based on a PHR triggering condition, a transmission unit configured to transmit a physical random access channel (PRACH), comprising a random access (RA) preamble that is a response to the PDCCH order, and a physical uplink shared channel (PUSCH), comprising the PHR, to the BS in parallel. The PHR triggering unit may trigger the PHR under a condition that the PUSCH is not attenuated and scaled when the PUSCH comprising the PHR and the PRACH are to be transmitted in parallel in an identical subframe.

- [13] In yet another aspect, a User equipment (UE) performing a power headroom report (PHR) in a wireless communication system comprises a reception unit configured to receive a physical downlink control channel (PDCCH) order, ordering random access, from a base station (BS) through a PDCCH, a PHR triggering unit configured to trigger a PHR based on a PHR triggering condition, a PHR prohibition unit configured to prohibit a transmission of the PHR if a physical uplink shared channel (PUSCH) comprising the PHR is not substantially transmitted or a transmission power of the PUSCH through which the PHR is transmitted is attenuated and scaled due to a parallel transmission of a PRACH, comprising a random access (RA) preamble that is a response to the PDCCH order, and the PUSCH within an identical subframe and a transmission unit configured to transmit the PUSCH comprising the PHR and the PRACH to the BS if the transmission of the PHR is not prohibited.

Advantageous Effects of Invention

- [14] In accordance with the present invention, a terminal that performs parallel transmission can selectively provide a base station with information about power headroom that can be distorted due to a transmission power configuration related to a physical random access channel and can properly perform the scheduling and power control of a base station.

Brief Description of Drawings

- [15] FIG. 1 shows a wireless communication system to which the present invention is applied.
- [16] FIG. 2 shows an example of a protocol structure for supporting multiple carriers.
- [17] FIG. 3 shows an example of a frame structure for a multiple carrier operation to which the present invention is applied.
- [18] FIG. 4 shows linkage between downlink CCs and uplink CCs in a multiple carrier system to which the present invention is applied.
- [19] FIG. 5 is a flowchart illustrating a procedure for obtaining multiple TA values which is applied to the present invention.
- [20] FIG. 6 is a diagram showing timing when an actual TA value including propagation delay is applied according to the present invention.

- [21] FIG. 7 is a flowchart illustrating a random access procedure to which the present invention is applied.
- [22] FIG. 8 shows an example of an extended PHR MAC CE to which the present invention is applied.
- [23] FIG. 9 is a block diagram showing the structure of a random access response message (RAR) in accordance with an embodiment of the present invention.
- [24] FIG. 10 shows an example of the sub-headers of an MAC PDU to which the present invention is applied.
- [25] FIG. 11 shows an example of an error in calculating an MPR value which is applied to the present invention.
- [26] FIG. 12 shows an example of an error in power scaling which is applied to the present invention.
- [27] FIG. 13 is a flowchart illustrating a PHR between UE and a BS in accordance with the present invention.
- [28] FIG. 14 is a block diagram showing the structure of a random access response (RAR) message in accordance with another embodiment of the present invention.
- [29] FIG. 15 shows an example of an MAC sub-header applied to the present invention.
- [30] FIG. 16 shows an example of an MAC CE to which the present invention is applied.
- [31] FIG. 17 is a flowchart illustrating another example of a PHR between UE and a BS in accordance with the present invention.
- [32] FIG. 18 is a flowchart illustrating an example of the operation of UE which transmits a PHR by taking power scaling into consideration in accordance with the present invention.
- [33] FIG. 19 is a flowchart illustrating another example of the operation of UE which transmits a PHR by taking power scaling into consideration in accordance with the present invention.
- [34] FIG. 20 is a flowchart illustrating the operation of a BS in accordance with the present invention.
- [35] FIG. 21 is a block diagram showing UE 2100 and a BS 2150 in accordance with an embodiment of the present invention.

Mode for the Invention

- [36] Hereinafter, some exemplary embodiments of the present invention are described in detail with reference to the accompanying drawings. It is to be noted that in assigning reference numerals to elements in the drawings, the same reference numerals denote the same elements throughout the drawings although the elements are shown in different drawings. Furthermore, in describing the embodiments of the present invention, a detailed description of the known functions and constitutions will be

omitted if it is deemed to make the gist of the present invention unnecessarily vague.

[37] FIG. 1 shows a wireless communication system to which the present invention is applied.

[38] Referring to FIG. 1, a plurality of wireless communication systems 10 is widely deployed in order to provide various types of communication service, such as voice and packet data. The wireless communication system 10 includes one or more Base Stations (BS) 11. The BSs 11 provide communication service to specific cells 15a, 15b, and 15c. Each of the cells can be classified into a plurality of areas (called sectors).

[39] User Equipment (UE) 12 can be fixed or mobile and can also be called another terminology, such as a Mobile Station (MS), a Mobile Terminal (MT), a User Terminal (UT), a Subscriber Station (SS), a wireless device, a Personal Digital Assistant (PDA), a wireless modem, or a handheld device. The BS 11 can also be called another terminology, such as an evolved-NodeB (eNB), a Base Transceiver System (BTS), an access point, a femto BS, a home NodeB, or a relay. The cell should be interpreted as a comprehensive meaning that indicates some area covered by the BS 11. The cell has a meaning that covers a variety of coverage areas, such as a mega cell, a macro cell, a micro cell, a pico cell, and a femto cell.

[40] Hereinafter, downlink refers to communication from the BS 11 to the UE 12, and uplink refers to communication from the UE 12 to the BS 11. In downlink, a transmitter can be part of the BS 11, and a receiver can be part of the UE 12. In uplink, a transmitter can be part of the UE 12, and a receiver can be part of the BS 11. Multiple access schemes applied to the wireless communication system are not limited. A variety of multiple access schemes, such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal frequency division multiple access (OFDMA), single carrier-frequency division multiple access (SC-FDMA), OFDM-FDMA, OFDM-TDMA, and OFDM-CDMA, can be used. Uplink transmission and DL transmission can be performed according to a time division duplex (TDD) scheme using different times or a frequency division duplex (FDD) scheme using different frequencies.

[41] A carrier aggregation (CA) supports a plurality of component carriers. The CA is also called a spectrum aggregation or a bandwidth aggregation. A unit carrier aggregated by a CA is called a component carrier (CC). Each CC is defined by a bandwidth and a center frequency. A CA is introduced in order to support an increased throughput, prevent an increase of expenses due to the introduction of wideband radio frequency (RF) devices, and guarantee compatibility with existing systems. For example, if 5 CCs are allocated as the granularity of a carrier unit having a 20 MHz bandwidth, a maximum of a 100 MHz bandwidth can be supported.

- [42] A CA can be divided into a contiguous CA performed between continuous CCs and a non-contiguous CA performed between discontinuous CCs in a frequency domain. The number of carriers aggregated in downlink can be set differently from the number of carriers aggregated in uplink. A case where the number of downlink CCs is equal to the number of uplink CCs is called a symmetric aggregation, and a case where the number of downlink CCs is different from the number of uplink CCs is called an asymmetric aggregation.
- [43] CCs can have different sizes (i.e., bandwidths). For example, assuming that 5 CCs are used to form a 70 MHz band, a resulting configuration can be, for example, 5 MHz CC (carrier #0) + 20 MHz CC (carrier #1) + 20 MHz CC (carrier #2) + 20 MHz CC (carrier #3) + 5 MHz CC (carrier #4).
- [44] Hereinafter, a multiple carrier system (or multiple component carrier system) refers to a system that supports a CA. In a multiple carrier system, a contiguous CA and/or a non-continuous CA can be used and a symmetric aggregation or an asymmetric aggregation can be used.
- [45] FIG. 2 shows an example of a protocol structure for supporting multiple carriers.
- [46] Referring to FIG. 2, a common medium access control (MAC) entity 210 manages a physical layer 220 using a plurality of carriers. An MAC management message that is transmitted through a specific carrier can be applied to other carriers. That is, the MAC management message is a message capable of controlling other carriers including the specific carrier. The physical layer 220 can operate according to a time division duplex (TDD) method and/or a frequency division duplex (FDD) method.
- [47] Several physical control channels are used in the physical layer 220. A physical downlink control channel (PDCCH) informs UE of the resource assignment of a paging channel (PCH) and a downlink shared channel (DL-SCH) and hybrid automatic repeat request (HARQ) information related to a DL-SCH. The PDCCH can carry an uplink grant that informs UE of resource assignment for UL transmission. The DL-SCH is mapped to a physical downlink shared channel (PDSCH). A physical control format indicator channel (PCFICH) informs UE of the number of OFDM symbols used in PDCCHs, and the PCFICH is transmitted in each subframe. A physical hybrid ARQ indicator channel (PHICH) is a DL channel, and it carries an HARQ ACK/NAK signal, that is, a response to UL transmission. A physical uplink control channel (PUCCH) carries an HARQ ACK/NAK signal for DL transmission, a scheduling request, and UL control information, such as a channel quality indicator (CQI). A physical uplink shared channel (PUSCH) carries an uplink shared channel (UL-SCH). A physical random access channel (PRACH) carries an RA preamble.
- [48] FIG. 3 shows an example of a frame structure for a multiple carrier operation to which the present invention is applied.

- [49] Referring to FIG. 3, a frame includes 10 subframes. The subframe includes a plurality of OFDM symbols. Each carrier can have its own control channel (e.g., a PDCCH). Multiple carriers may be contiguous to each other or may not be contiguous to each other. UE can support one or more carriers depending on its capability.
- [50] A CC can be divided into a primary component carrier (PCC) and a secondary component carrier (SCC). UE may use only one PCC or may use one or more SCCs together with a PCC. UE can receive a PCC and/or one or more SCCs allocated by a BS.
- [51] FIG. 4 shows linkage between downlink CCs and uplink CCs in a multiple carrier system to which the present invention is applied.
- [52] Referring to FIG. 4, in downlink, downlink CCs D1, D2, and D3 are aggregated and in uplink, uplink CCs U1, U2, and U3 are aggregated. Here, D_i is the index of the downlink CC, and U_i is the index of the uplink CC ($i=1, 2, 3$). At least one downlink CC is a PCC, and the remaining CCs are SCCs. Likewise, at least one uplink CC is a PCC, and the remaining CCs are SCCs. For example, D1 and U1 are PCCs, and D2, U2, D3, and U3 are SCCs.
- [53] In an FDD system, a DL CC and an UL CC can be linked to each other in a one-to-one manner. For example, D1 is linked to U1, D2 is linked to U2, and D3 is linked to U3. UE establishes linkage between DL CCs and UL CCs through system information transmitted through a logical channel BCCH or a UE-dedicated RRC message transmitted through a DCCH. Each linkage may be established in a cell-specific way or a UE-specific way.
- [54] FIG. 4 illustrates only 1:1 linkage between a DL CC and an UL CC, but 1:n or n:1 linkage may also be established. Furthermore, the index of a CC is not identical with order of the CC or the location of the CC in a frequency band.
- [55] A primary serving cell means one serving cell that provides security input and non-access stratum (NAS) mobility information in an RRC establishment (also called RRC configuration) or RRC re-establishment (also called RRC re-configuration) state. At least one cell can be configured to form a set of serving cells along with a primary serving cell depending on the capabilities of UE. The at least one cell is called a secondary serving cell.
- [56] Accordingly, a set of serving cells configured for a piece of UE may include only one primary serving cell or one primary serving cell and at least one secondary serving cell.
- [57] A DL CC corresponding to a primary serving cell is called a downlink primary component carrier (DL PCC), and an UL CC corresponding to a primary serving cell is called an uplink primary component carrier (UL PCC). Furthermore, in downlink, a CC corresponding to a secondary serving cell is called a downlink secondary

component carrier (DL SCC), and in uplink, a CC corresponding to a secondary serving cell is called an uplink secondary component carrier (UL SCC). Only one DL CC may correspond to one serving cell, and both a DL CC and an UL CC may correspond to one serving cell.

- [58] Accordingly, in a carrier system, communication performed through a DL CC or an UL CC between UE and a BS has the same concept as communication performed through a serving cell between UE and a BS. For example, in a method of performing random access in accordance with the present invention, what UE transmits a preamble using an UL CC can be considered as the same concept as what the UE transmits a preamble using a primary serving cell or a secondary serving cell. Furthermore, what UE receives downlink information using a DL CC can be considered as the same concept as what the UE receives downlink information using a primary serving cell or a secondary serving cell.
- [59] Meanwhile, a primary serving cell and a secondary serving cell have the following characteristics.
- [60] First, a primary serving cell is used to transmit a PUCCH. In contrast, a secondary serving cell is unable to transmit a PUCCH, but is able to transmit some control information of pieces of information within the PUCCH through a PUSCH.
- [61] Second, a primary serving cell is always activated, whereas a secondary serving cell is activated/deactivated according to specific conditions. The specific conditions may include that the activation/deactivation indicator is received from a BS and that a deactivation timer within UE expires. Activation means that the transmission or reception of traffic data is being performed or the transmission or reception of traffic data is in a ready state. Deactivation means that the transmission or reception of traffic data is impossible and that measurement or the transmission or reception of minimum information is possible.
- [62] Third, when a primary serving cell experiences a radio link failure (RLF), RRC re-establishment is triggered. However, when a secondary serving cell experiences an RLF, RRC re-establishment is not triggered. An RLF is generated when downlink performance is maintained to a threshold or lower for a specific time or when a random access (RA) fails by a threshold or higher.
- [63] Fourth, a primary serving cell can be changed by a change of a security key or by a handover procedure accompanied by an RACH procedure. In the case of a contention resolution (CR) message, however, only a PDCCH indicative of the contention resolution message must be transmitted through a primary serving cell, and the contention resolution message can be transmitted through a primary serving cell or a secondary serving cell.
- [64] Fifth, NAS information is received through a primary serving cell.

- [65] Sixth, in a primary serving cell, a DL PCC and an UL PCC always form a pair.
- [66] Seventh, a different CC can be configured as a primary serving cell in each UE.
- [67] Eighth, procedures, such as the reconfiguration, adding, and removal of a secondary serving cell, can be performed by a radio resource control (RRC) layer. In adding a new secondary serving cell, RRC signaling can be used to transmit system information about a dedicated secondary serving cell.
- [68] Ninth, a primary serving cell can provide both a PDCCH assigned to a UE-specific search space configured to transmit control information (e.g., DL allocation information or uplink grant information) to only specific UE within a region in which the control information is transmitted and a PDCCH assigned to a common search space configured to transmit control information (e.g., system information, a random access response, or transmit power control (TPC)) to all MSs within a cell or a plurality of MSs complying with a specific condition. In contrast, only a UE-specific search space can be configured in a secondary serving cell. That is, since UE does not know a common search space through a secondary serving cell, the UE is unable to receive pieces of control information transmitted through a common search space and data indicated by the pieces of control information.
- [69] A secondary serving cell in which a common search space can be configured, from among secondary serving cells, can be defined. This secondary serving cell is called a special secondary serving cell. The special secondary serving cell is always configured as a scheduling cell when cross-carrier scheduling is performed. Furthermore, a PUCCH configured in a primary serving cell can be defined for the special secondary serving cell.
- [70] The PUCCH for the special secondary serving cell may be fixedly configured when configuring the special secondary serving cell or may be assigned (configured) or released by RRC signaling (or an RRC reconfiguration message) when a BS reconfigures the special secondary serving cell.
- [71] The PUCCH for the special secondary serving cell includes ACK/NACK information or channel quality information (CQI) for secondary serving cells within a corresponding secondary timing alignment group (sTAG). As described above, a BS can configure the PUCCH for the special secondary serving cell through RRC signaling.
- [72] Furthermore, a BS may configure one of a plurality of secondary serving cells within a sTAG as a special secondary serving cell or may not configure a special secondary serving cell. The reason why the BS does not configure the special secondary serving cell is that it is determined that a common search space and a PUCCH do not need to be configured. For example, if it is determined that a contention-based random access procedure does not need to be performed in any secondary serving cell or it is determined that the capacity of the PUCCH of a current primary serving cell is sufficient

and a PUCCH for an additional secondary serving cell does not need to be configured, a common search space and a PUCCH are not configured.

- [73] The technical spirit of the present invention related to the characteristics of a primary serving cell and a secondary serving cell are not limited to the above description. The above description is only an example, and the characteristics of a primary serving cell and a secondary serving cell may include more examples.
- [74] In a wireless communication environment, electric waves transmitted by a transmitter may experience propagation delay while being transferred to a receiver. Accordingly, although both the transmitter and the receiver precisely know the time when the electric waves are propagated by the transmitter, the time when the signal reaches the receiver is influenced by the distance between the transmitter and the receiver and surrounding propagation environments. If the receiver moves, the time when the signal reaches the receiver is changed over time. If the receiver does not precisely know the time when the signal transmitted by the transmitter is received, the reception of the signal fails or a distorted signal is received although the signal is received, resulting in impossible communication.
- [75] Accordingly, in a wireless communication system, synchronization between a BS and UE must be predetermined both in downlink and uplink in order to receive an information signal. The type of synchronization may include frame synchronization, information symbol synchronization, and sample period synchronization. Here, the sample period synchronization is synchronization that must be obtained most basically in order to distinguish physical signals from each other.
- [76] UE obtains downlink synchronization based on a signal from a BS. A BS transmits an agreed and specific signal to UE so that the UE can easily obtain downlink synchronization. The UE must be able to precisely distinguish the time when the BS transmitted the specific signal. In the case of downlink, MSs can obtain synchronization independently because one BS transmits the same synchronization signal to a plurality of MSs at the same time.
- [77] In the case of uplink, a BS receives signals from a plurality of MSs. If the distance between each UE and a BS is different, signals received by the BS have different transmission delay time. If uplink information is transmitted based on downlink synchronization obtained by each UE, a corresponding BS receives uplink information from each UE at a different time. In this case, the BS is unable to obtain synchronization on the basis of any piece of UE. Accordingly, in order to obtain uplink synchronization, a different procedure from that of downlink is necessary.
- [78] Timing alignment (TA) or timing advance (TA) and multiple alignment (TA) or multiple advance (TA) for obtaining uplink synchronization by UE are described below.

- [79] In order for UE to obtain uplink synchronization, a random access process is performed. During the random access process, the UE obtains uplink synchronization based on a TA value (also called a TA value) received from a BS. From a viewpoint that an uplink time is advanced, a TA value may also be called a timing advanced value.
- [80] When UE obtains uplink synchronization, the UE starts a timing alignment timer (TAT). During the time when a TAT operates, mutual uplink synchronization has been established between the UE and a BS. If the TAT expires or does not operate, the UE and the BS determines that mutual synchronization has not be established, and thus the UE does not perform UL transmission other than the transmission of an RA preamble.
- [81] Meanwhile, in a multiple carrier system, a piece of UE performs communication with a BS through a plurality of CCs or a plurality of serving cells. If all the signals of a plurality of serving cells configured in UE have the same timing delay, the UE can obtain uplink synchronization for all the serving cells using only one TA value. In contrast, if the signals of a plurality of serving cells have different timing delays, a different TA value is necessary for each serving cell. That is, multiple TA values are necessary. If UE performs random access to each of serving cells in order to obtain multiple TA values, overhead is generated in limited uplink resources and the complexity of the random access can be increased. In order to reduce this overhead and complexity, a timing alignment group (TAG) is defined.
- [82] A TAG is a group that includes a serving cell(s) using the same TA value and the same timing reference, from among serving cells in which an UL CC has been configured. Each TAG includes only a serving cell in which an UL CC has been configured and includes at least one serving cell in which the UL CC has been configured. Information about a serving cell mapped to each TAG is called TAG configuration information.
- [83] For example, if a first serving cell and a second serving cell belong to the same TAG, the same TA value TA1 is applied to the first serving cell and the second serving cell. In contrast, if a first serving cell and a second serving cell belong to different TAGs, different TA values TA1 and TA2 are applied to the first serving cell and the second serving cell.
- [84] A TAG can include a primary serving cell, may include at least one secondary serving cell, and may include a primary serving cell and at least one secondary serving cell.
- [85] In a TAG, the first group configuration and group reorganization are determined by a serving BS that has configured a corresponding serving cell. TAG configuration information is transmitted to UE through RRC signaling.
- [86] A primary serving cell does not change a TAG.

- [87] UE supports two or more TAGs if multiple TA values are necessary. For example, UE supports TAGs, including a primary TAG (pTAG) including a primary serving cell and a secondary TAG (sTAG) not including a primary serving cell. Here, only one pTAG is present, whereas one or more sTAGs may be present if multiple TA values are necessary. Here, the number of TAGs may be set to 2 or a maximum of 4. Furthermore, a pTAG may always be configured to have a TAG ID = 0.
- [88] A serving BS and UE can perform some of or all the following operations in order to obtain and maintain a TA value for each TAG.
- [89] 1. The acquisition and maintenance of a TA value for a pTAG are always performed through a primary serving cell. Furthermore, timing reference, that is, a criterion for downlink synchronization for calculating a TA value for a pTAG, is always a DL CC within a primary serving cell.
- [90] 2. In order for UE to obtain an initial uplink TA value for a sTAG, a random access procedure that is essentially flushed by a BS is used.
- [91] 3. One of activated secondary serving cells can be used as timing reference for a sTAG. Here, it is assumed that there is no unnecessary change of the timing reference.
- [92] 4. Each TAG has one timing reference and one TAT. Each TAT can have a different timer expiration value, and the TATs can operate independently. A TAT is started or restarted right after a TA value is obtained from a serving BS in order to determine whether or not the TA value obtained and applied by each TAG is valid.
- [93] 5. If the TAT of a pTAG is not in progress, TATs for all sTAG are not in progress. That is, if the TATs of all TAGs including a pTAG have expired and the TAT for the pTAG is not in progress, TATs for all sTAG are not started. If the TAT of a pTAG expires, UE flushes the HARQ buffers of all serving cells. Furthermore, the UE clears all resource assignment configurations for downlink and the uplink. For example, if periodic resource assignment is configured without control information transmitted to assign downlink or uplink resources, such as a PDCCH, as in a semi-persistent scheduling (SPS) method, an SPS configuration is flushed. Furthermore, the configurations of the PUCCHs and type0 SRS (periodic sounding reference signal (SRS)) of all serving cells are released.
- [94] 6. If only the TAT of an sTAG expires, UE stops SRS transmission through the UL CCs of secondary serving cells within the sTAG, UE releases a type0 SRS (periodic SRS) configuration, UE maintains a type1 SRS (aperiodic SRS) configuration, UE maintains configuration information about a CSI report, and UE flushes HARQ buffers for the uplink of secondary serving cells within the sTAG.
- [95] 7. If a TAT for a sTAG is in progress, even when all secondary serving cells within the sTAG have been deactivated, UE performs the TAT of the sTAG without stopping the TAT. This means that a situation in which all the secondary serving cells within the

sTAG have been deactivated and thus the transmission of any SRS and UL transmission for tracking uplink synchronization has not been performed can guarantee the validity of the TA value of the sTAG through the TAT even the TAT is maintained for a specific time.

- [96] 8. If the last secondary serving cell within a sTAG has been removed, that is, if any secondary serving cell has not been configured in the sTAG, a TAT within the sTAG is stopped.
- [97] 9. A random access procedure for a secondary serving cell can be performed when a BS transmits only a PDCCH order for an activated secondary serving cell. That is, the random access procedure for a secondary serving cell is performed through only a non-contention-based random access procedure. Information about an RA preamble included in the PDCCH order is indicated by information other than '000000'.
- [98] 10. A PDCCH for a random access response transmission can be transmitted through another serving cell other than a secondary serving cell through which an RA preamble has been transmitted.
- [99] 11. A procedure when a maximum retransmission number of RA preambles through a secondary serving cell reaches a maximum permitted retransmission number is as follows. A) A MAC layer stops a random access procedure. B) The MAC layer informs an RRC layer that random access has failed and thus does not generate the triggering of an RLF. C) UE does not inform a BS that the random access to the secondary serving cell has failed.
- [100] 12. The pathloss (or path attenuation) reference of a pTAG can be a primary serving cell or a secondary serving cell within the pTAG. The pathloss (or path attenuation) reference can be differently set in each serving cell within the pTAG through the RRC signaling of a BS.
- [101] 13. The pathloss reference of the UL CCs of serving cells within a sTAG is a DL CC linked to each system information block 2.
- [102] FIG. 5 is a flowchart illustrating a procedure for obtaining multiple TA values which is applied to the present invention.
- [103] Referring to FIG. 5, UE performs an RRC connection establishment procedure with a BS through a selected cell at step S500. The selected cell is a primary serving cell.
- [104] The BS performs an RRC connection configuration procedure or an RRC connection reconfiguration procedure for adding one or more secondary serving cells to the UE at step S505. For example, if more radio resources need to be assigned to the UE at the request of the UE, at the request of a network, or based on the determination of the BS, one or more secondary serving cells may be added to the UE.
- [105] The BS configures (or defines) a TAG for the one or more serving cells added to the UE at step S510. In a carrier aggregation situation, a TAG configuration between

serving cells can be performed in a cell-specific way. For example, if a serving cell having a specific frequency band is always served through a frequency selective repeater (FSR) or a remote radio head (RRH), a serving cell having a specific frequency band and a serving cell directly served by a BS are configured to belong to different TAGs although they can be configured to belong to the same TA value in relation to all MSs within the service coverage of the BS.

- [106] If the BS determines that the same TA value as that of a primary serving cell can be applied to the added secondary serving cell, the BS configures the added secondary serving cell so that it belongs to the same TAG as the primary serving cell. In this case, the BS may not transmit TAG configuration information, such as that at step S515 below. If the UE receives an activation indicator for the added secondary serving cell and uplink scheduling information without receiving TAG configuration information, the UE may determine that the added secondary serving cell has been configured to belong to the same TAG as that of the primary serving cell.
- [107] If the BS determines that the same TA value as that of the primary serving cell cannot be applied to the added secondary serving cell, the BS configures a sTAG including the added secondary serving cell. A TAG ID for identifying a TAG is assigned to each TAG. Here, the BS may selectively assign a TAG ID for the sTAG.
- [108] For example, if the BS checks that a sTAG including the added secondary serving cell is different from previously configured TAGs, the BS may assign a TAG ID for the sTAG before obtaining uplink synchronization through a random access procedure.
- [109] For another example, if the BS determines that the added secondary serving cell may be included in a previously configured TAG or cannot check that the added secondary serving cell is included in any TAG, the BS may not assign a TAG ID for the sTAG before obtaining uplink synchronization through a random access procedure. In this case, the BS can transmit TAG configuration information to the UE, if necessary, after the UE obtains uplink synchronization, and the UE can obtain the TAG ID for the sTAG.
- [110] After the step S510, the BS transmits TAG configuration information to the UE at step S515.
- [111] For example, the TAG configuration information may have a format that includes TAG ID information about each secondary serving cell. More particularly, uplink configuration information about each secondary serving cell may include TAG ID information.
- [112] For another example, the TAG configuration information may have a format that maps a serving cell index *ServCellIndex* assigned to each serving cell or a secondary serving cell index *ScellIndex* assigned to only secondary serving cells. For example, the TAG configuration information may be configured like a format, such as $pTAG =$

{ServCellIndex = 1, 2}, sTAG1 = {ServCellIndex = 3, 4}.

- [113] For yet another example, a primary serving cell always has TAG ID = 0 and does not include configuration information. Furthermore, if TAG ID information is not included in any of secondary serving cells, it may mean that the secondary serving cells are serving cells within a pTAG.
- [114] The TAG configuration information may further include information about a timing reference cell within each TAG. If the TAG configuration information does not include information about a timing reference cell, UE itself can recognize a timing reference cell within each TAG. For example, UE may recognize a timing reference cell through the above-described timing reference cell configuration method. Or, when a BS configures a secondary serving cell, the BS may select a serving cell in which parameters for a random access procedure have been configured as a timing reference cell. If the number of serving cells that comply with conditions on which the serving cells can become a timing reference cell is plural or if a timing reference cell has been deactivated, a BS may select a secondary serving cell having the smallest secondary serving cell index as a timing reference cell.
- [115] After the step S515, if it is necessary to perform scheduling on a specific secondary serving cell, the BS transmits an activation indicator for activating the specific secondary serving cell to the UE at step S520.
- [116] A random access procedure ordered by the BS is performed at step S525. If the UE has not obtained uplink synchronization from a specific sTAG, the UE can obtain a TA value that must be adjusted for the specific sTAG.
- [117] Here, a random access procedure for an activated secondary serving cell within the sTAG can be started by a PDCCH order transmitted by the BS. A secondary serving cell capable of receiving a PDCCH order may be only a secondary serving cell including a timing reference designated within the sTAG or may be all secondary serving cells in which RACHs have been configured.
- [118] Furthermore, a BS performs control so that UE does not perform two or more random access procedures at the same time. The simultaneous execution of the random access procedures includes a case where two or more random access procedures are synchronized with each other and performed at the same time and a case where a random access procedure is performed in some of the time during which another random access procedure is performed. For example, when UE performs a random access procedure through a primary serving cell, another random access procedure may be started (e.g., a PDCCH order is received) through a secondary serving cell during the time while the UE waits for a random access response (RAR) message.
- [119] Furthermore, if a BS has not secured information enough to map a specific secondary serving cell to a specific TAG through existing information within a network or

assistant information (e.g. location information, RSRP, and RSRQ) received from UE, the BS configures a secondary serving cell necessary for timing alignment grouping as another sTAG and obtains an uplink TA value through a random access procedure.

[120] FIG. 6 is a diagram showing timing when an actual TA value including propagation delay is applied according to the present invention.

[121] Referring to FIG. 6, a TAC (TAC) for uplink synchronization between UE and a BS relates to all TA values transmitted through a random access response or a TAC MAC Control Element (CE).

[122] After a TAC is transmitted in the DL reception of the UE, the TAC is applied in the UL transmission of the UE after '5 ms - round trip time (RTT) (e.g., minimum 4.33 ms)'.

[123] The UE may start or restart the TAT from a subframe in which a random access response has been received or may start or restart the TAT from an uplink subframe to which a TA value has been applied.

[124] Meanwhile, the random access procedure at step S525 can be performed as in the following procedure of FIG. 7.

[125] FIG. 7 is a flowchart illustrating a random access procedure to which the present invention is applied. FIG. 7 shows an example of a non-contention-based random access procedure.

[126] Referring to FIG. 7, a BS transmits a PDCCH order, ordering the start of a random access procedure regarding a secondary serving cell configured in UE, to the UE at step S700. An RA preamble assignment can be performed. In the case of a non-contention-based random access procedure, the BS selects one of previously agreed dedicated RA preambles, from among all available RA preambles, and transmits RA preamble assignment information, including the index of the selected RA preamble and information about available time/frequency resources, to the UE through the PDCCH order. This is because the BS has to assign a dedicated RA preamble without a possible collision to the UE for the non-contention-based random access procedure.

[127] For example, if a random access procedure is performed during a handover process, UE can obtain a dedicated RA preamble, generated by a target BS, from a handover command message through a source BS. For another example, if a random access procedure is performed in response to the PDCCH order of a BS, UE can obtain a dedicated RA preamble through a PDCCH, that is, physical layer signaling. In this case, the physical layer signaling may have a downlink control information (DCI) format 1A and may include the following fields shown in Table 1.

[128] Table 1

[Table 1]

A carrier indicator field (CIF) - 0 or 3 bits.
- A flag for identifying format 0/1A - 1 bit (indicates format 0 in the case of 0 and format 1A in the case of 1)
If format 1A CRC is scrambled into a C-RNTI and the remaining fields are set as follows, format 1A is used for a random access procedure started by a PDCCH order.
- Below-
- A localized/distributed VRB assignment flag - 1 bit. Set to 0.
- Resource block assignment - $\lceil \log_2(N_{RB}^{DL}(N_{RB}^{DL}+1)/2) \rceil$ bits. All bits are set to 1
- A preamble index - 6 bits
- A PRACH mask index - 4 bits
- All the remaining bits of format 1A for the temporary scheduling assignment of one PDSCH codeword are set to 0.

[129] Referring to Table 1, the preamble index is an index indicating one preamble selected from previously agreed dedicated RA preambles for a non-contention-based random access procedure, and the PRACH mask index is information about available time/frequency resources. The information about available time/frequency resources is different depending on a frequency division duplex (FDD) system and a time division duplex (TDD) system as in Table 2.

[130] Table 2 below shows the PRACH mask index.

[131] Table 2

[Table 2]

PRACH Mask Index	Allowed PRACH (FDD)	Allowed PRACH (TDD)
0	All	All
1	PRACH Resource Index 0	PRACH Resource Index 0
2	PRACH Resource Index 1	PRACH Resource Index 1
3	PRACH Resource Index 2	PRACH Resource Index 2
4	PRACH Resource Index 3	PRACH Resource Index 3
5	PRACH Resource Index 4	PRACH Resource Index 4
6	PRACH Resource Index 5	PRACH Resource Index 5
7	PRACH Resource Index 6	Reserved
8	PRACH Resource Index 7	Reserved
9	PRACH Resource Index 8	Reserved
10	PRACH Resource Index 9	Reserved
11	Every, in the time domain, even PRACH opportunity 1st PRACH Resource Index in subframe	Every, in the time domain, even PRACH opportunity 1st PRACH Resource Index in subframe
12	Every, in the time domain, odd PRACH opportunity 1st PRACH Resource Index in subframe	Every, in the time domain, odd PRACH opportunity 1st PRACH Resource Index in subframe
13	Reserved	1st PRACH Resource Index in subframe
14	Reserved	2nd PRACH Resource Index in subframe
15	Reserved	3rd PRACH Resource Index in subframe

[132] The UE transmits an RA preamble to the BS at step S705. The transmission of the RA preamble through a secondary serving cell can be performed only when it is indicated by the BS.

[133] When the BS successfully receives the RA preamble, the BS can check that what UE has transmitted the RA preamble through what serving cell based on the received RA preamble and time/frequency resources.

[134] Meanwhile, in configuring preamble transmission power in a random access procedure, the preamble transmission power is configured based on reception power

that is expected when a BS receives the preamble. More particularly, the preamble transmission power can be configured as in Equation below.

[135] [Equation 1]

[136]
$$\begin{aligned} & \text{PREAMBLE_RECEIVED_TARGET_POWER} \\ & = \text{preambleInitialReceivedTargetPower} + \text{DELTA_PREAMBLE} \\ & + (\text{PREAMBLE_TRANSMISSION_COUNTER} - 1) \times \text{powerRampingStep} \end{aligned}$$

[137] In Equation 1, preambleInitialReceivedTargetPower is a value that a BS sets MSs within the BS in common and is a reference value for transmission power that is set when a preamble is first transmitted. Furthermore, DELTA_PREAMBLE can be previously set to 0 or a specific offset value depending on a preamble format. Furthermore, a value 'powerRampingStep' is a transmission power value that is additionally increased when a preamble is retransmitted. Furthermore, a BS instructs UE to transmit a preamble using a PRACH selected in a physical layer, a corresponding random access-radio network temporary identifier (RA-RNTI), a preamble index, and a value 'PREAMBLE_RECEIVED_TARGET_POWER'.

[138] Table 3 below shows the format of an RA preamble.

[139] Table 3

[Table 3]

Preamble Format	T_{CP}	T_{SEQ}
0	$3168 * T_s$	$24576 * T_s$
1	$21024 * T_s$	$24576 * T_s$
2	$6240 * T_s$	$2 * 24576 * T_s$
3	$21024 * T_s$	$2 * 24576 * T_s$
4	$448 * T_s$	$4096 * T_s$

[140] Referring to Table 3, T_{CP} is a parameter indicative of the cyclic prefix (CP) section of a PRACH symbol, T_{SEQ} is a parameter indicative of a sequence section, and T_s indicates a sampling time. The number of subframes occupied by a PRACH can be variably defined depending on each format. For example, regarding the preamble format 0, the sum of a CP and a sequence is smaller than a subframe, and a maximum cell size (two times the radius) into which propagation delay may be taken into consideration is the smallest. In contrast, regarding the preamble formats 1, 2, and 3, the sum of a CP and a sequence is one subframe or more. In the preamble format 1 or format 2, the number of subframes occupied by a PRACH is 2, and in the preamble format 3, the number of subframes occupied by a PRACH is 3.

[141] The transmission of an RA preamble triggered by a MAC layer is restricted to specific time/frequency resources. The time/frequency resources are listed in ascending powers of a subframe number within a radio frame and a physical resource block in a

frequency domain, and an index 0 corresponds to a physical resource block having the smallest number and the subframe of a radio frame. PRACH resources within a radio frame are indicated by PRACH resources indices and are as follows.

[142] Table 4

[Table 4]

PRACH Configuration Index	Preamble Format	System frame number	Subframe number	PRACH Configuration Index	Preamble Format	System frame number	Subframe number
0	0	Even	1	32	2	Even	1
1	0	Even	4	33	2	Even	4
2	0	Even	7	34	2	Even	7
3	0	Any	1	35	2	Any	1
4	0	Any	4	36	2	Any	4
5	0	Any	7	37	2	Any	7
6	0	Any	1, 6	38	2	Any	1, 6
7	0	Any	2, 7	39	2	Any	2, 7
8	0	Any	3, 8	40	2	Any	3, 8
9	0	Any	1, 4, 7	41	2	Any	1, 4, 7
10	0	Any	2, 5, 8	42	2	Any	2, 5, 8
11	0	Any	3, 6, 9	43	2	Any	3, 6, 9
12	0	Any	0, 2, 4, 6, 8	44	2	Any	0, 2, 4, 6, 8
13	0	Any	1, 3, 5, 7, 9	45	2	Any	1, 3, 5, 7, 9
14	0	Any	0, 1, 2, 3, 4, 5, 6, 7, 8, 9	46	N/A	N/A	N/A
15	0	Even	9	47	2	Even	9

[143]

16	1	Even	1	48	3	Even	1
17	1	Even	4	49	3	Even	4
18	1	Even	7	50	3	Even	7
19	1	Any	1	51	3	Any	1
20	1	Any	4	52	3	Any	4
21	1	Any	7	53	3	Any	7
22	1	Any	1, 6	54	3	Any	1, 6
23	1	Any	2, 7	55	3	Any	2, 7
24	1	Any	3, 8	56	3	Any	3, 8
25	1	Any	1, 4, 7	57	3	Any	1, 4, 7
26	1	Any	2, 5, 8	58	3	Any	2, 5, 8
27	1	Any	3, 6, 9	59	3	Any	3, 6, 9
28	1	Any	0, 2, 4, 6, 8	60	N/A	N/A	N/A
29	1	Any	1, 3, 5, 7, 9	61	N/A	N/A	N/A
30	N/A	N/A	N/A	62	N/A	N/A	N/A
31	1	Even	9	63	3	Even	9

[144] Table 4 shows the random access configuration of a frame structure type 1 for the preamble formats 0 to 3.

[145] In relation to the frame structure type 1 of the preamble formats 0 to 3, a maximum of one random access resource is present per subframe. Table 4 shows subframes in which an RA preamble can be transmitted in the preamble formats according to Table 3 and the configuration given in the frame structure type 1. A parameter 'prach-ConfigurationIndex' is given by a higher layer. The start of an RA preamble is aligned with the start of the uplink subframe of UE, that is, $N_{TA}=0$. In relation to PRACH configuration indices 0, 1, 2, 15, 16, 17, 18, 31, 32, 33, 34, 47, 48, 49, 50, and 63, UE assumes that the absolute difference of relative time differences between the radio frame i of a current cell and a target cell is $153600 \cdot T_s$, for a handover purpose. The first physical resource block n^{RA}_{PRB} assigned to a PRACH opportunity that is taken into consideration in the preamble formats 0, 1, 2, and 3 is defined by $n^{RA}_{PRBoffset}$. Here, a parameter 'prach-FrequencyOffset ($n^{RA}_{PRBoffset}$)' is represented by a physical resource block number set by a higher layer. $n^{RA}_{PRBoffset}$ is set to be greater than 0 or to be equal to or smaller than $N^{UL}_{RB}-6$.

[146] After the step S705, the BS transmits the PDCCH of the UE and a PDSCH to which

the RAR message has been mapped to the UE at step S710. The PDCCH and the PDSCH can be semi-synchronized with the transmission of the RA preamble at step S705 and transmitted within a flexible window having a 2 or higher transmission time interval (TTI) size.

- [147] Here, a hybrid automatic repeat request (HARQ) is not transmitted.
- [148] Furthermore, the PDCCH may be scrambled into an RA-RNTI and transmitted, for example.
- [149] In the above example, a PDCCH for the random access response of a primary serving cell and a secondary serving cell can be scrambled into an RA-RNTI and transmitted. A random access response to a serving cell on which corresponding UE has transmitted an RA preamble can be included within a PDSCH indicated by the PDCCH and transmitted.
- [150] Furthermore, TA information and an initial uplink grant for handover can be transmitted. Or, TA information for downlink data arrival can be transmitted. Or, an RA preamble identifier for identifying one or more UE can be transmitted.
- [151] The RAR message of an MAC layer may be solely mapped to a PDSCH or may be multiplexed with the random access responses of other MSs within a single RAR MAC PDU and then mapped to a PDSCH.
- [152] The PDSCH to which the RAR message has been mapped is indicated by a PDCCH. The PDCCH scrambled by an RA-RNTI is assigned to a common search space. However, since a common search space is not defined, but only a UE-specific search space is defined in a secondary serving cell, UE is unable to receive the PDCCH scrambled by the RA-RNTI and the RAR message indicated by the PDCCH on a secondary serving cell. Accordingly, the PDCCH and the PDSCH including the RAR message can be always transmitted on a primary serving cell. Resources used to transmit the PDSCH to which the RAR message has been mapped are indicated by a resource block allocation field within a DCI.
- [153] UE knows information about an RA preamble, allocated by a BS and transmitted by the UE, and a serving cell in which the RA preamble was transmitted. Furthermore, the UE is unable to perform two or more random access procedures at the same time. Accordingly, if the information about the RA preamble is checked within the RAR message of an MAC layer, the UE can know whether or not the information about the random access response is for the UE and whether the information is about what serving cell. In order to guarantee this UE operation, a network including a BS must assign a preamble to each of the serving cells of each UE so that the preamble is not redundantly assigned to the UE and the serving cell.
- [154] Power headroom (PH) is described below.
- [155] Power headroom means excess power that can be additionally used by UE in

addition to power used for UL transmission. For example, it is assumed that maximum transmission power, that is, UL transmission power that is an allowed range of UE, is 10 W and the UE is now using power of 9 W in a frequency band of 10 MHz. Here, power headroom is 1 W because the UE can use 1 W additionally.

- [156] Here, if a BS assigns a frequency band of 20 MHz to the UE, power of 18 W (=9W*2) is necessary. Since the maximum power of the UE is 10 W, however, if the frequency band of 20 MHz is assigned to the UE, the UE may not use the entire frequency band or the BS may not properly receive a signal from the UE because of insufficient power. In order to solve this problem, the UE reports to the BS that its power headroom is 1 W so that the BS can schedule a frequency band within the power headroom range. This report is called a power headroom report (PHR).
- [157] Through a PHR procedure, 1) information about a difference between the maximum transmission power of UE that has been nominated in each activated serving cell and estimated UL-SCH (PUSCH) transmission power, 2) information about a difference between the maximum transmission power of UE nominated in a primary serving cell and estimated PUCCH transmission power, or 3) information about a difference between maximum transmission power reserved in a primary serving cell and estimated UL-SCH and PUCCH transmission power can be transmitted to a serving BS.
- [158] The PHR of UE can be defined by two types Type 1 and Type 2. Power headroom of specific UE can be defined in relation to a subframe i for a serving cell c .
- [159] 1. PHR Type 1 (Type 1 PH)
- [160] Type 1 power headroom includes 1) a case where UE transmits only a PUSCH without a PUCCH, 2) a case where UE transmits a PUCCH and PUSCH at the same time, and 3) a case where a PUSCH is not transmitted.
- [161] First, if UE transmits a PUSCH without a PUCCH in relation to a subframe i for a serving cell c , power headroom for a Type 1 report is expressed as in Equation below.
- [162] [Equation 2]
- [163]
$$PH_{type1,c}(i) = P_{CMAX,c}(i) - \{10\log_{10}(M_{PUSCH,c}(i)) + P_{O_PUSCH,c}(j) + \alpha_c(j) \cdot PL_c + \Delta_{TF,c}(i) + f_c(i)\} [dB]$$
- [164] In Equation 2, $P_{CMAX,c}(i)$ is a value obtained by converting maximum UE transmission power $\hat{P}_{CMAX,c}(i)$, configured for the serving cell c , into a decibel value [dB].
- [165] Furthermore, $P_{CMAX}(i)$ is a maximum UE transmission power value calculated using offset values that is set in a network on the basis of a maximum transmission power value set based on a smaller value, from among a P_{EMAX} value set based on P-max, that is, a value transmitted from a BS to UE through RRC signaling, and a $P_{PowerClass}$ value determined based on a transmission power class determined by the level of the hardware of each UE. Here, the offset values can include a maximum power reduction

(MPR) value, an additional maximum power reduction (A-MPR) value, and a power management maximum power reduction (P-MPR) value. In addition, an offset value ΔT_c applied depending on whether or not a band greatly subject to filter characteristics within the transmission unit of UE is present may be applied.

- [166] The $P_{\text{CMAX},c}(i)$, unlike $P_{\text{CMAX}}(i)$, is a value configured to only the serving cell c . Accordingly, the P-max value is a value $P_{\text{EMAX},c}$ configured to the serving cell c , and the offset values are also calculated for each serving cell c . That is, the offset values include MPR_c , A-MPR_c , P-MPR_c , and $\Delta T_{c,c}$. However, the value $P_{\text{PowerClass}}$ is calculated using the same value that has been used for each UE.
- [167] Furthermore, $M_{\text{PUSCH},c}(i)$ is a value obtained when the bandwidth of resources to which a PUSCH has been assigned is represented by the number of RBs in the subframe i for the serving cell c .
- [168] Furthermore, $P_{\text{O_PUSCH},c}(j)$ is the sum of $P_{\text{O_NOMINAL_PUSCH},c}(j)$ and $P_{\text{O_UE_PUSCH},c}(j)$ for the serving cell c . j is 0 or 1 from a higher layer. In the case of semi-persistent grant PUSCH transmission (or retransmission), j is 0. In contrast, in the case of dynamically scheduled grant PUSCH transmission (or retransmission), j is 1. In the case of random access response grant PUSCH transmission (or retransmission), j is 2. Furthermore, in the case of random access response grant PUSCH transmission (or retransmission), $P_{\text{O_UE_PUSCH},c}(2)=0$, and $P_{\text{O_NOMINAL_PUSCH},c}(2)$ is the sum of $P_{\text{O_PRE}}$ and $\Delta_{\text{PREAMBLE_Msg3}}$. Here, parameters $P_{\text{O_PRE}}$ (preambleInitialReceivedTargetPower) and $\Delta_{\text{PREAMBLE_Msg3}}$ are signaled by a higher layer.
- [169] If j is 0 or 1, one of values $\alpha_c \in \{0, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1\}$ can be selected by a 3-bit parameter provided by a higher layer. If j is 2, $\alpha_c(j)=1$ always.
- [170] PL_c is the dB value of a downlink pathloss (PL) (or path attenuation) estimation value for the serving cell c that has been calculated in the UE and can be calculated from 'referenceSignalPower - higher layer filtered RSRP'. Here, 'referenceSignalPower' is a value provided by a higher layer and is the dBm unit of the energy per resource element (EPRE) value of a downlink reference signal. Reference signal received power (RSRP) is the reception power value of a reference signal for a reference serving cell. The determination of a serving cell selected as a reference serving cell and of 'referenceSignalPower' and higher layer filtered RSRP used to calculate the PL_c is configured by 'pathlossReferenceLinking' that is a higher layer parameter. Here, the reference serving cell configured by the higher layer parameter 'pathlossReferenceLinking' may become a primary serving cell or the DL SCC of a secondary serving cell subject to SIB2 linkage with an UL CC.
- [171] Furthermore, $\Delta_{\text{TF},c}(i)$ is a parameter into which an influence due to a modulation coding scheme (MCS) is incorporated, and a value thereof is $10 \log_{10}((2^{\frac{B_{\text{PRE}} \cdot K_s}{2}} - 1) \cdot \beta_{\text{offset}}^{\text{PUSCH}})$.

Here, K_s is a parameter provided by a higher layer as deltaMCS-Enabled in relation to each serving cell c and is 1.25 or 0. In particular, in the case of transmission mode 2 that is a mode for transmit diversity, K_s is always 0. Furthermore, when only control information is transmitted through a PUSCH without UL-SCH data, $BPRE = O_{CQI}/N_{RE}$, and in other cases, $BPRE = \sum_{r=0}^{C-1} K_r / N_{RE}$. Here, C is the number of code blocks, K_r is the size of each code block, O_{CQI} is the number of CQI/PMI bits including the number of CRC bits, and N_{RE} is the number of determined resource elements (i.e.,

$N_{RE} = M_{sc}^{PUSCH-initial} \cdot N_{symb}^{PUSCH-initial}$). Furthermore, if only control information is transmitted

through a PUSCH without UL-SCH data, $\beta_{offset}^{PUSCH} = \beta_{offset}^{CQI}$. In other cases, β_{offset}^{PUSCH} is always set to 1.

- [172] Furthermore, $\delta_{PUSCH,c}$ is a correction value and is determined with reference to a TPC command present within DCI format 0 or DCI format 4 for a serving cell c or a TPC command within DCI format 3/3A that is encoded in common with other MSs and transmitted. DCI format 3/3A can be checked by only UE to which an RNTI value obtained by scrambling CRC parity bits into a TPC-PUSCH-RNTI has been assigned. Here, if specific UE includes a plurality of serving cells, a different RNTI value can be assigned to each serving cell in order to distinguish the serving cells from one another. Here, a PUSCH power control coordination state for a current serving cell c is $f_c(i)$. If accumulation for the serving cell c has been activated by a higher layer or if DCI format 0 into which a TPC command $\delta_{PUSCH,c}$ has been scrambled by a temporary-C-RNTI is included in a PDCCH, ' $f_c(i) = f_c(i-1) + \delta_{PUSCH,c}(i - K_{PUSCH})$ '. Here, $\delta_{PUSCH,c}(i - K_{PUSCH})$ is a TPC command within DCI format 0/4 or 3/3A within a PDCCH that has been transmitted in an $(i - K_{PUSCH})^{th}$ subframe, and $f_c(0)$ is the first value after the accumulation is reset. Furthermore, the value K_{PUSCH} is 4 in the case of FDD. If a TDD UL/DL configuration is 0, there is a PDCCH that schedules PUSCH transmission in a subframe 2 or 7, and the least significant bit (LSB) value of an UL index in DCI format 0/4 within the PDCCH is set to 1, K_{PUSCH} is 7.

- [173] Second, if UE transmits a PUCCH and a PUSCH at the same time in relation to a subframe i for a serving cell c , a Type 1 power headroom value is given as in Equation below.

- [174] [Equation 3]

- [175] $PH_{type1,c}(i) = \tilde{P}_{MAX,c}(i) - \{10 \log_{10}(M_{PUSCH,c}(i)) + P_{O_PUSCH,c}(j) + \alpha_c(j) \cdot PL_{C+\Delta_{TF,c}}(i) + f_c(i)\} [dB]$

- [176] In Equation 3, $\tilde{P}_{MAX,c}(i)$ is calculated assuming that only the PUSCH is transmitted in the subframe i . In this case, a physical layer transfers $\tilde{P}_{MAX,c}(i)$ to a higher layer instead of $P_{MAX,c}(i)$.

- [177] Third, if the UE does not transmit the PUSCH in relation to the subframe i for the

serving cell c, a Type 1 power headroom value is calculated as in Equation below.

[178] [Equation 4]

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

[180] In Equation 4, $\tilde{P}_{CMAX,c}(i)$ is calculated assuming that an MPR is 0 dB, an A-MPR is 0 dB, a P-MPR is 0 dB, and ΔT_C is 0 dB.

[181] 2. PHR Type 2 (Type 2 PH)

[182] Type 2 power headroom includes a case where UE transmits a PUCCH and a PUSCH at the same time, a case where UE transmits a PUSCH without a PUCCH, a case where UE transmits a PUCCH without a PUSCH, and a case where UE does not transmit a PUCCH or PUSCH, in relation to a subframe i for a primary serving cell.

[183] First, if UE transmits a PUCCH and a PUSCH at the same time in relation to a subframe i for a primary serving cell, a Type 2 power headroom value is calculated as in Equation below.

[184] [Equation 5]

[185]
$$PH_{type2}(i) = P_{CMAX,c}(i) - 10 \log_{10} \left(10^{\frac{(10 \log_{10}(M_{PUSCH,c}(i)) + P_{O_PUSCH,c}(j) + \alpha_c(j) \cdot PL_c + \Delta_{TF,c}(i) + f_c(i))}{10}} + 10^{\frac{(P_{0_PUCCH} + PL_c + h(n_{CQI}, n_{HARQ}, n_{SR})) + \Delta_{F_PUCCH}(F) + \Delta_{TXD}(F') + g(i))}{10}} \right) [dB]$$

[186] In Equation 5, $\Delta_{F_PUCCH}(F)$ is defined by a higher layer (RRC), and a value of each $\Delta_{F_PUCCH}(F)$ is identical with that of a PUCCH format F related to a PUCCH format 1a. Here, each PUCCH format F is given as in the following table.

[187] Table 5

[Table 5]

PUCCH format	Modulation scheme	Number of bits per subframe, M_{bit}
1	N/A	N/A
1a	BPSK	1
1b	QPSK	2
2	QPSK	20
2a	QPSK+BPSK	21
2b	QPSK+QPSK	22
3	QPSK	48

[188] If UE has configured PUCCH transmission for two antenna ports by way of a higher layer, a $\Delta_{TXD}(F')$ value for each PUCCH format F' is provided by a higher layer. If not,

$$\Delta_{\text{TXD}}(F')=0.$$

[189] Furthermore, $h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}})$ has a different value in each PUCCH format. Here, n_{CQI} indicates the number of bits of channel quality information (CQI). Furthermore, if a scheduling request (SR) has been configured in the subframe i and an SR configuration is not present in any transport block related to the UL-SCH of the UE, $n_{\text{SR}}=1$ and in other cases, $n_{\text{SR}}=0$. If the UE has been configured in one serving cell, n_{HARQ} is the number of HARQ-ACK bits transmitted in the subframe i . In relation to PUCCH format 1/1a/1b, $h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}})=0$. In relation to PUCCH format 1b for channel selection, if the UE has been configured in one or more serving cells, $h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}})=(n_{\text{HARQ}}-1)/2$, and in other cases, $h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}})=0$. In relation to PUCCH format 2/2a/2b and a normal cyclic prefix (CP), if n_{CQI} is greater than or equal to 4, $h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}})=10\log_{10}(n_{\text{CQI}}/4)$ and in other cases, $h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}})=0$. In relation to PUCCH format 2 and an extended CP, if ' $n_{\text{CQI}}+n_{\text{HARQ}}$ ' is greater than or equal to 4, $h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}})=10\log_{10}((n_{\text{CQI}}+n_{\text{HARQ}})/4)$ and in other cases, $h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}})=0$. In relation to PUCCH format 3, if the UE has been configured by a higher layer in such a way to transmit the PUCCH through 2 antenna ports or the UE has been configured by a higher layer in such a way to transmit an HARQ-ACK/SR having 11 bits, $h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}})=(n_{\text{HARQ}}+n_{\text{SR}}-1)/3$ and in other cases, $h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}})=(n_{\text{HARQ}}+n_{\text{SR}}-1)/2$. $P_{\text{O_PUCCH}}$ is a parameter having the sum of a parameter $P_{\text{O_NOMINAL_PUCCH}}$ and a parameter $P_{\text{O_UE_PUCCH}}$ provided by a higher layer.

[190] Second, if UE transmits only a PUSCH without a PUCCH in relation to a subframe i for a primary serving cell, a Type 2 power headroom value is calculated as in Equation below.

[191] [Equation 6]

$$[192] \quad PH_{\text{type2}}(i) = P_{\text{CMAX},c}(i) - 10\log_{10} \left(\frac{10^{(10\log_{10}(M_{\text{PUSCH},c}(i)) + P_{\text{O_PUSCH},c}(j) + \alpha_c(j) \cdot PL_c + \Delta_{\text{TF},c}(i) + f_c(i))/10}}{10^{(P_{\text{O_PUCCH}} + PL_c + g(i))/10}} \right) \quad [\text{dB}]$$

[193] Third, if UE transmits a PUCCH without a PUSCH in relation to a subframe i for a primary serving cell, a Type 2 power headroom value is calculated as in Equation below.

[194] [Equation 7]

$$[195] \quad PH_{\text{type2}}(i) = P_{\text{CMAX},c}(i) - 10\log_{10} \left(\frac{10^{(P_{\text{O_PUSCH},c}(1) + \alpha_c(1) \cdot PL_c + f_c(i))/10}}{10^{(P_{\text{O_PUCCH}} + PL_c + h(n_{\text{CQI}}, n_{\text{HARQ}}, n_{\text{SR}}) + \Delta_{\text{F_PUCCH}}(F) + \Delta_{\text{TXD}}(F') + g(i))/10}} \right) \quad [\text{dB}]$$

[196] Fourth, if UE does not transmit a PUCCH or a PUSCH in relation to a subframe i for a primary serving cell, a Type 2 power headroom value is calculated as in Equation below.

[197] [Equation 8]

[198]

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

[199]

In Equation 8, $\tilde{P}_{\text{CMAX},c}(i)$ is calculated assuming that an MPR 0 dB, an A-MPR is 0 dB, a P-MPR is 0 dB, and ΔT_C is 0 dB.

[200]

A power headroom value is determined per 1 dB and must be determined as the closest value, from among values within a range of 40 dB to -23 dB, through rounding-off. The determined power headroom value is transferred from a physical layer to a higher layer.

[201]

Meanwhile, the reported power headroom is a value estimated in one subframe.

[202]

If an extended PHR has not been configured, only a Type 1 power headroom value for the primary serving cell is reported. In contrast, if an extended PHR has been configured, a Type 1 power headroom value and a Type 2 power headroom value for each of serving cells in which uplink has been configured and which have been activated are reported. An extended PHR is described in detail later.

[203]

PHR delay refers to a difference the time when a power headroom reference section is started and the time when a power headroom value starts being transmitted to UE through a radio interface. PHR delay must be 0 ms, and PHR delay can be applied to all configured triggering schemes for a PHR.

[204]

The mapping of the reported power headroom can be given as in the following table.

[205]

Table 6

[Table 6]

Reported value	Measured quantity value (dB)
POWER_HEADROOM_0	$-23 \leq PH < -22$
POWER_HEADROOM_1	$-22 \leq PH < -21$
POWER_HEADROOM_2	$-21 \leq PH < -20$
POWER_HEADROOM_3	$-20 \leq PH < -19$
POWER_HEADROOM_4	$-19 \leq PH < -18$
POWER_HEADROOM_5	$-18 \leq PH < -17$
...	...
POWER_HEADROOM_57	$34 \leq PH < 35$
POWER_HEADROOM_58	$35 \leq PH < 36$
POWER_HEADROOM_59	$36 \leq PH < 37$
POWER_HEADROOM_60	$37 \leq PH < 38$
POWER_HEADROOM_61	$38 \leq PH < 39$
POWER_HEADROOM_62	$39 \leq PH < 40$
POWER_HEADROOM_63	$PH \geq 40$

[206] Referring to Table 6, power headroom falls within a range of -23 dB to +40 dB. If 6 bits are used to represent power headroom, $64 (=2^6)$ types of indices can be represented. Power headroom is classified into a total of 64 levels. For example, if bits used to represent power headroom are '0' ('000000' in 6 bits), it indicates that the level of power headroom is ' $-23 \leq P_{PH} < -22$ dB'.

[207] Meanwhile, a PHR can be performed through a periodic PHR timer (periodicPHR-Timer) (hereinafter referred to as a 'periodic timer') and a prohibition timer (prohibitPHR-Timer). When a 'dl-PathlossChange' value is transmitted through an RRC message, the UE controls the triggering of a PHR due to a change of a pathloss value measured in downlink and a change of a power backoff requirement value P-MPR according to power management.

[208] A PHR can be triggered when any of the following events is generated.

[209] 1. A PHR is triggered if a pathloss value (e.g., a pathloss estimation value measured by UE) is changed into a greater pathloss value and a prohibition timer expires in at least one activated serving cell used as a pathloss reference after the UE secures uplink

resources for new transmission and performs the last PHR transmission or a pathloss value is changed into a greater pathloss value and a prohibition timer expires in at least one activated serving cell used as a pathloss reference. The pathloss estimation value can be measured by the UE based on RSRP.

- [210] 2. A PHR is triggered when a periodic timer expires. Since power headroom is frequently changed, UE triggers a PHR when the periodic timer expires and drives the periodic timer again when power headroom is reported, depending on a periodic PHR method.
- [211] 3. A PHR is triggered if a configuration or reconfiguration related to a PHR operation other than use prohibition is formed by a higher layer through RRC or MAC.
- [212] 4. A PHR is triggered when a secondary serving cell in which uplink has been configured is activated.
- [213] 5. A PHR is triggered if resources for UL transmission have been assigned to any of activated serving cells in which uplink has been configured or PUCCH transmission is present in a corresponding cell after the last PHR transmission is performed when uplink data or a PUCCH is transmitted through the uplink resources in a corresponding TTI and if a change of a power backoff request value $P\text{-MPR}_c$ after the last PHR transmission is greater than a 'dl-PathlossChange'[dB] value in case where the UE has secured uplink resources for new transmission.
- [214] As an example of the triggering, the following three steps are performed if resources for new transmission have been assigned to UE.
- [215] (1) A periodic timer is started when the first uplink resources for new transmission are assigned after the last MAC is reset.
- [216] (2) In case where at least one PHR has been triggered after the last PHR is transmitted or a transmitted PHR has been triggered for the first time and where assigned uplink resources provide a space enough to transmit a power headroom report MAC control element (PHR MAC CE) (including an extended PHR), if an extended PHR has been configured and each uplink has been configured, a Type 1 power headroom value for an activated serving cell is secured. If uplink resources for UL transmission have been assigned to the UE through a corresponding serving cell in a corresponding TTI, the UE obtains a value corresponding to a $P_{\text{CMAX},c}$ field from a physical layer and generates and transmits an extended PHR MAC CE. 2) If an extended PHR and a simultaneous PUCCH-PUSCH have been configured, the UE obtains a Type 2 power headroom value for a primary serving cell. If the UE transmits a PUCCH in a corresponding TTI, the UE obtains a value corresponding to a $P_{\text{CMAX},c}$ field from a physical layer. Next, the UE generates and transmits an extended PHR MAC CE. 3) If an extended PHR has not been configured, the UE obtains a Type 1 power headroom value from a physical layer and generates and transmits a PHR MAC

CE.

- [217] (3) The UE starts or restarts a periodic timer, starts or restarts a prohibition timer, and cancels all the triggered PHRs.
- [218] Meanwhile, an extended PHR MAC CE is checked by an LCID within the sub-header of an MAC PDU. An extended PHR MAC CE may have various sizes.
- [219] FIG. 8 shows an example of an extended PHR MAC CE to which the present invention is applied.
- [220] Referring to FIG. 8, a C_i field means a secondary serving cell index (ScellIndex) i . When the secondary serving cell index is '1', it means that a PH value is reported in the corresponding secondary serving cell. When the secondary serving cell index is '0', it means that a PH value is not reported in the corresponding secondary serving cell. An R field is reserved bits and set to 0.
- [221] Furthermore, a V field is an indicator indicating whether or not it is a PH value based on actual transmission or whether or not it is a PH value for a reference format. In the case of a Type 1 PHR, when $V=0$, it indicates that actual PUSCH transmission is present. When $V=1$, it indicates that a PUSCH reference format is used. In the case of a Type 2 PHR, when $V=0$, it indicates that actual PUCCH transmission is present. When $V=1$, it indicates that a PUCCH reference format is used. If $V=0$ for both a Type 1 PHR and Type 2 PHR, it indicates that a related $P_{\text{CMAX},c}$ field is present. If $V=1$ for both a Type 1 PHR and Type 2 PHR, it indicates that a related $P_{\text{CMAX},c}$ field is omitted.
- [222] A power headroom (PH) field is for a power headroom value and may be 6 bits.
- [223] A P field indicates whether or not UE has applied a power backoff P-MRP according to power control. If a $P_{\text{CMAX},c}$ field has a different value due to a power backoff, $P=1$.
- [224] The $P_{\text{CMAX},c}$ field indicates $P_{\text{CMAX},c}$ or $\tilde{P}_{\text{CMAX},c}$ used to calculate a previous PH field, and this field value may be or may not be present.
- [225] Table 7 below shows a UE transmission power level nominated for an extended PHR.
- [226] Table 7

[Table 7]

$P_{\text{CMAX},c}$	Nominal UE transmit power level
0	P_{CMAX,c_00}
1	P_{CMAX,c_01}
2	P_{CMAX,c_02}
...	...
61	P_{CMAX,c_61}
62	P_{CMAX,c_62}
63	P_{CMAX,c_63}

[227] A physically non-synchronized random access procedure is described below.

[228] From a viewpoint of a higher layer, a level 1 (L1) random access procedure encompasses the transmission of an RA preamble and a random access response. The L1 random access procedure refers to a random access procedure performed in a physical layer. That is, the L1 random access procedure is a step in terms of a random access procedure including the new signalings of a physical layer that should be defined for random access. For example, the RA preamble is a signal that should be defined in the physical layer for only random access, and a PDCCH scrambled into an RA-RNTI is also a physical layer message format defined for only random access. The remaining messages are scheduled to be transmitted in a data channel shared by higher layers and are not considered as part of the L1 random access procedure. A random access channel occupies 6 resource blocks in one subframe or consecutive subframe sets that are reserved for the transmission of the RA preamble. A BS is not prohibited to schedule data, from among resource blocks reserved for the transmission of the RA preamble.

[229] The L1 random access procedure requires the following processes. 1) The L1 random access procedure is triggered at the request of preamble transmission from higher layers. 2) A preamble index, target preamble reception power $\text{PREAMBLE_RECEIVED_TARGET_POWER}$, a corresponding RA-RNTI (or C-RNTI), and PRACH resources as some of the request are indicated by a higher layer. 3) A preamble transmission power P_{PRACH} is determined by the following Equation.

[230] [Equation 9]

[231]
$$P_{\text{PRACH}} = \min \{ P_{\text{CMAX},c}(i), \text{PREAMBLE_RECEIVED_TARGET_POWER} + PL_c \} [\text{dBm}]$$

- [232] Equation 9, $P_{\text{CMAX},c}(i)$ is UE transmission power configured for the subframe i of a primary serving cell, and PL_c is a downlink pathloss estimation value for the primary serving cell calculated in the UE.
- [233] 4) A preamble sequence is selected from a preamble sequence set using a preamble index. 5) A single preamble is transmitted in indicated PRACH resources using a selected preamble sequence with transmission power P_{PRACH} . 6) To detect a PDCCH using an indicated RA-RNTI (or C-RNTI) is attempted during a window that is controlled by a higher layer. If the PDCCH is detected, a corresponding DL-SCH transport block is transferred to a higher layer. Higher layers parse the transport block and indicate a 20-bit uplink grant for a physical layer.
- [234] In accordance with an existing random access procedure, an extended PHR including PH and $P_{\text{CMAX},c}$ values is transmitted to all activated serving cells. Furthermore, it is efficient to check whether or not the uplink synchronization of a TAG including an activated serving cell has been obtained and to transmit a PHR, including PH and $P_{\text{CMAX},c}$ information, in relation to the activated serving cell within the TAG.
- [235] First, in an extended PHR, even if secondary serving cells within an sTAG that have not obtained valid TA values for uplink have been activated, the secondary serving cells are not included in a PHR subject when the PHR is triggered, and secondary serving cells within an sTAG that have not obtained valid TA values for uplink are not related to conditions regarding PHR triggering.
- [236] FIG. 9 is a block diagram showing the structure of a random access response message (RAR) in accordance with an embodiment of the present invention.
- [237] Referring to FIG. 9, the RAR message can have a format of an MAC PDU 900. The MAC PDU 900 includes an MAC header 910, one or more MAC control elements (CEs), 920-1, ..., 920-n, one or more MAC service data units (SDUs) 930-1, ..., 930-m and padding 940.
- [238] The MAC CEs 920-1, ..., 920-n are control message generated by an MAC layer.
- [239] The MAC header 910 includes one or more sub-headers 910-1, 910-2, 910-3, 910-4, ..., 910-k, and each of the sub-headers 910-1, 910-2, 910-3, 910-4, ..., 910-k corresponds to one MAC SDU, one MAC CE, or padding 940. Order of the sub-headers 910-1, 910-2, 910-3, 910-4, ..., 910-k is the same as that of the MAC SDUs 930-1, ..., 930-m, the MAC CEs 920-1, ..., 920-n, and padding 940 within the MAC PDU 900.
- [240] Each of the sub-headers 910-1, 910-2, 910-3, 910-4, ..., 910-k may include four fields; R, R, E, and LCID or six fields; R, R, E, LCID, F, and L. The sub-header including the four fields corresponds to the MAC CEs 920-1, ..., 920-n or padding 940, and the sub-header including the six fields corresponds to the MAC SDUs 930-1, ..., 930-m.
- [241] FIG. 10 shows an example of the sub-headers of an MAC PDU to which the present

invention is applied.

[242] Referring to FIG. 10, the sub-header of the MAC PDU includes a total of four fields; R, R, E, and LCID fields. Each of the R field and the E field is 1 bit, and the LCID field includes 5 bits.

[243] The logical channel ID (LCID) field is an ID field that identifies a logical channel corresponding to the MAC SDUs 930-1, ..., 930-m or identifies the type of the MAC CEs 920, ..., 920-n or padding. When each of the sub-headers 910-1, 910-2, 910-3, 910-4, ..., 910-k has an octet structure, the LCID field may have 5 bits.

[244] For example, as in the following table, the LCID field identifies whether the MAC CEs 820-1, ..., 820-n are MAC CEs for indicating the activation/deactivation of a serving cell, contention resolution identity MAC CEs for a contention resolution between MSs, or MAC CEs for a TAC. The MAC CE for the TAC is an MAC CE used to a TA in random access.

[245] Table 8

[Table 8]

Index	LCID values
00000	CCCH
00001-01010	Identity of the logical channel
01011-11010	Reserved
11001	Extended Power Headroom Report
11010	Power Headroom Report
11011	C-RNTI
11100	Truncated BSR
11101	Short BSR
11110	Long BSR
11111	Padding

[246] Referring to Table 8, when a value of the LCID field is 11001, a corresponding MAC CE is for an extended PHR. When a value of the LCID field is 11010, a corresponding MAC CE is for a PHR.

[247] The parallel transmission of UE is described below.

[248] The parallel transmission of UE means that the UE transmits a PUSCH, a PUCCH, or an SRS in a serving cell other than a primary serving cell or a secondary serving cell in which a PRACH is transmitted in some of or the entire section in which the PRACH is transmitted through the primary serving cell or the secondary serving cell.

- [249] A case where the parallel transmission of UE is generated in the same subframe is called a full overlapping case, and a case where the parallel transmission of UE is generated in different subframes but is partially overlapped due to different TA values is called a partial overlapping case.
- [250] A power-limited case and a non-power-limited case are described below.
- [251] The power-limited case refers to a state in which the required transmission power of UE indicated by a BS is limited because the required transmission power of the UE is higher than maximum transmission power that can be transmitted by the UE when the UE performs UL transmission. In performing a PHR, a power headroom value having a negative form is reported.
- [252] In contrast, the non-power-limited case refers to a state in which the required transmission power of UE indicated by a BS is not limited because the required transmission power of the UE is lower than maximum transmission power that can be transmitted by the UE when the UE performs UL transmission. In performing a PHR, a power headroom value having a positive form is reported.
- [253] Power scaling is described below. Power scaling means that transmission power to be assigned is attenuated in a specific ratio in such a way as not to exceed the total transmission power of UE. Power scaling can be represented in various ways, such as power control, power coordination, and power adjustment.
- [254] If the total transmission power of UE exceeds $\hat{P}_{CMAX}(i)$, the UE scales $\hat{P}_{PUSCH,c}(i)$ for the serving cell c of a subframe i as in the following equation.
- [255] [Equation 10]
- [256]
$$\sum_c w(i) \cdot \hat{P}_{PUSCH,c}(i) \leq (\hat{P}_{CMAX}(i) - \hat{P}_{PUCCH}(i))$$
- [257] Referring to Equation 10, $\hat{P}_{PUCCH}(i)$ is a linear value of $P_{PUCCH}(i)$, $\hat{P}_{PUSCH,c}(i)$ is a linear value of $P_{PUSCH,c}(i)$, $\hat{P}_{CMAX}(i)$ is total-configured maximum output power P_{CMAX} configured in UE in a subframe i, and w(i) is the scaling factor (it may also be called a scaling element) of $\hat{P}_{PUSCH,c}(i)$ for a serving cell c and has a value between 0 to 1. If PUCCH transmission is not present in the subframe i, $\hat{P}_{PUCCH}(i)=0$.
- [258] If UE has PUSCH transmission including uplink control Information (UCI) in a serving cell j and has PUSCH transmission without UCI in any of the remaining serving cells and the total transmission power of the UE exceeds $\hat{P}_{CMAX}(i)$, the UE scales $\hat{P}_{PUSCH,c}(i)$ in relation to serving cells without UCI in a subframe i as in the following equation.
- [259] [Equation 11]
- [260]
$$\sum_{c \neq j} w(i) \cdot \hat{P}_{PUSCH,c}(i) \leq (\hat{P}_{CMAX}(i) - \hat{P}_{PUSCH,j}(i))$$
- [261] In Equation 11, $\hat{P}_{PUSCH,j}(i)$ is PUSCH transmission power for a cell with UCI, and w(i) is the

scaling factor of $\hat{P}_{PUSCHj}(i)$ for a serving cell c without UCI. Unless it is

$\sum_{c \neq j} w(i) \cdot \hat{P}_{PUSCH,c}(i) = 0$, the scaling factor is not applied to $\hat{P}_{PUSCHj}(i)$ and the total transmission power of UE exceeds $\hat{P}_{CMAX}(i)$. Here, if $w(i)$ is greater than 0, $w(i)$ is identical for serving cells, and $w(i)$ is 0 for specific serving cells.

[262] If UE transmits a PUCCH and a PUSCH with UCI for a serving cell j at the same time and transmits a PUSCH without UCI in any of the remaining serving cells and the total transmission power of the UE exceeds $\hat{P}_{CMAX}(i)$, the UE obtains $\hat{P}_{PUSCH,c}(i)$ as in the following equation.

[263] [Equation 12]

$$\begin{aligned} \hat{P}_{PUSCHj}(i) &= \min(\hat{P}_{PUSCHj}(i), (\hat{P}_{CMAX}(i) - \hat{P}_{PUCCH}(i))) \\ \sum_{c \neq j} w(i) \cdot \hat{P}_{PUSCH,c}(i) &\leq (\hat{P}_{CMAX}(i) - \hat{P}_{PUCCH}(i) - \hat{P}_{PUSCHj}(i)) \end{aligned}$$

[265] Meanwhile, when the parallel transmission of UE is performed, the priority of power scaling in the power-limited case is given as in the following equation.

[266] [Equation 13]

[267] *PRACH > PUCCH > PUSCH with UCI > PUSCH without UCI*

[268] Referring to Equation 13, 1) PRACH power is assigned as a top priority, and PUCCH power and PUSCH power are then assigned. 2) In the case of the full overlapping case, power scaling is performed on the OFDM symbols of all subframes. 3) In the case of the partial overlapping case, power scaling is performed on only overlapped OFDM symbols in some or of the entire section. If a partial overlapping section is within one OFDM symbol section, a corresponding OFDM symbol is not transmitted.

[269] A power scaling method for parallel transmission applied to the present invention is described below.

[270] <(1) Parallel transmission of PRACH and PUSCH>

[271] If the total transmission power of UE exceeds $\hat{P}_{CMAX}(i)$ and PUCCH transmission is not present, the UE performs power scaling on $\hat{P}_{PUSCH,c}(i)$ for the serving cell c of a subframe i as in the following equation.

[272] [Equation 14]

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

[274] In Equation 14, $\hat{P}_{PRACH}(i)$ is a linear value of $P_{PRACH}(i)$, $\hat{P}_{PUSCH,c}(i)$ is a linear value of $P_{PUSCH,c}(i)$, $\hat{P}_{CMAX}(i)$ is a linear value of the maximum transmission power P_{CMAX} of UE, and $w(i)$ is a scaling factor value of $\hat{P}_{PUSCH,c}(i)$ for a serving cell c.

[275] Here, if there is a PUSCH with UCI, a linear value $\hat{P}_{PUSCH,c}(i)$ of the transmission power of the PUSCH with UCI is subject to power scaling in relation to the serving

cell j of a subframe i as in the following equation.

[276] [Equation 15]

$$\begin{aligned} [277] \quad \hat{P}_{PUSCHj}(i) &= \min(\hat{P}_{PUSCHj}(i), (\hat{P}_{CMAX}(i) - \hat{P}_{PRACH}(i))) \\ \sum_{c \neq j} w(i) \cdot \hat{P}_{PUSCH,c}(i) &\leq (\hat{P}_{CMAX}(i) - \hat{P}_{PRACH}(i) - \hat{P}_{PUSCHj}(i)) \end{aligned}$$

[278] <(2) Parallel transmission of PRACH, PUSCH, and PUCCH>

[279] If the total transmission power of UE exceeds $\hat{P}_{CMAX}(i)$ and the UE includes PUCCH transmission, the UE performs power scaling on the linear value $\hat{P}_{PUCCH}(i)$ of the PUCCH transmission power in relation to the primary serving cell of the subframe i as in the following equation.

[280] [Equation 16]

$$[281] \quad \hat{P}_{PUCCH}(i) = \min(\hat{P}_{PUCCH}(i), (\hat{P}_{CMAX}(i) - \hat{P}_{PRACH}(i)))$$

[282] In Equation 16, $\hat{P}_{PUCCH}(i)$ is a linear value of $P_{aPUCCH}(i)$.

[283] If power scaling for a PUCCH is generated, UE does not transmit a PUSCH. In contrast, if power scaling for a PUCCH is not generated, UE performs power scaling for the serving cells c and j as in the following equation.

[284] [Equation 17]

$$\begin{aligned} [285] \quad \hat{P}_{PUSCHj}(i) &= \min(\hat{P}_{PUSCHj}(i), (\hat{P}_{CMAX}(i) - \hat{P}_{PRACH}(i) - \hat{P}_{PUCCH}(i))) \\ \sum_{c \neq j} w(i) \cdot \hat{P}_{PUSCH,c}(i) &\leq (\hat{P}_{CMAX}(i) - \hat{P}_{PRACH}(i) - \hat{P}_{PUCCH}(i) - \hat{P}_{PUSCHj}(i)) \end{aligned}$$

[286] Meanwhile, in a system to which a carrier aggregation (CA) is applied as in FIGS. 2 to 4, when a random access procedure is performed in a secondary serving cell in order to apply an M-TA as in FIGS. 5 to 7, UE can transmit a PRACH to a BS and at the same time transmits a PUSCH (or a PUCCH), including a PHR, to the BS.

[287] If the transmission power of a PUSCH (or a PUCCH or a PUCCH and PUSCH) is scaled as in Equation 14 to Equation 17 due to this parallel transmission, (1) An error in MPR value calculation and (2) an error in BS scheduling and power scaling can occur.

[288] This is described in detail below.

[289] (1) An error in MPR value calculation is first described below.

[290] UE first sets a $P_{CMAX,c}$ value in order to calculate power headroom PH_c for a serving cell c. Here, a value that has the greatest influence on the $P_{CMAX,c}$ value is an MPR value.

[291] The MPR value can be changed depending on a serving cell in which actual transmission is performed after a carrier aggregation. If a PRACH is transmitted in a specific secondary serving cell, MPR values of serving cells in which a PUCCH or PUSCH is transmitted simultaneously with the PRACH that is actually transmitted can be changed.

[292] Furthermore, if power scaling is performed due to the PRACH transmission and a

PUCCH or PUSCH not actually transmitted is present, a combination of serving cells in which the PUCCH or PUSCH is actually transmitted is changed and thus MPR values can be changed. However, a PH value within a PHR reported to a BS is calculated without being based on the $P_{\text{CMAX},c}$ value changed due to the PRACH transmission. As a result, an error can occur when calculating an MPR value for the serving cell c .

[293] FIG. 11 shows an example of an error in calculating an MPR value which is applied to the present invention.

[294] Referring to FIG. 11, in a subframe in which a PRACH is not transmitted in parallel, a PUSCH 1115 with UCI is transmitted in an RF1 1100 through a frequency band f_2 , and a PUSCH 1155 without UCI is transmitted in an RF2 1150 through a frequency band f_3 . That is, each of the RF1 1100 and RF2 1150 transmits one channel.

[295] If UE transmits the PRACH 1110 having higher priority than the PUSCH 1155 without UCI, transmission is not present in the RF2 1150, and the PRACH 1110 is transmitted in the RF1 1100 through the frequency band f_1 and the PUSCH 1115 with UCI is transmitted through the frequency band f_2 at the same time.

[296] Here, since two channels are transmitted in one RF (i.e., RF1, 1100), an MPR value is increased and thus a $P_{\text{CMAX},c}$ value is changed. As a result, the power headroom value of the UE is also changed. However, an error can occur because a BS does not detect a change of the MPR value.

[297] If an MPR value is changed due to PRACH transmission when calculating a $P_{\text{CMAX},c}$ value as described above, UE that actually calculates a PH value (Type 1 or Type 2) should calculate a PH value by taking the changed MPR value into consideration in relation to a serving cell c .

[298] For example, if a BS receives a PHR in a subframe scheduled for serving cells 2 and 3, the BS can determine that there is no transmission power scaling and determine that the entire actual transmission has been performed when a PH value has a positive value. In contrast, in the actual transmission of UE, a PUSCH may not be transmitted in the serving cell 2 due to a PRACH transmitted in a serving cell 4. Here, a $P_{\text{CMAX},c}$ value for the serving cells 2 and 3 is set to a value that appears when the actual transmission is performed in the serving cells 3 and 4, and a PH value calculated based on the $P_{\text{CMAX},c}$ value is erroneously transmitted.

[299] (2) An error in BS scheduling and power scaling is described below.

[300] UE can be placed in the power-limited case if it transmits a PRACH. Here, the transmission power of a PUCCH or PUSCH that is actually transmitted can be reduced. When calculating a PH value, however, the reduced transmission power may not be incorporated into the PH value. That is, in reality, the PH value must be a negative PH value (dB, the negative PH value is hereinafter referred to as 'N[dB]'), but

the PH value is set to a positive PH value (dB, the positive PH value is hereinafter referred to as 'M[dB]') by transmission power necessary to transmit the PRACH because the influence of transmission power consumed when transmitting the PRACH is not incorporated into the PH value. The M[dB] value is distorted information. A PH value that should be actually provided to a BS is N[dB], but the M value is reported due to the transmission power reduced by a value scaled by the PRACH (hereinafter referred to as 'K[dB]'). Here, 'N + K = M'.

[301] Accordingly, the BS may have an error in its operation because PH information is distorted. For example, the BS may determine that the current transmission power of a PUCCH or PUSCH is low and thus raise the transmission power based on an M[dB] value because a high PH value has been reported. As a result, the transmission power of the PUCCH or PUSCH is sufficiently secured in a corresponding serving cell, but transmission power for the transmission of a PUSCH in another serving cell may not be secured.

[302] FIG. 12 shows an example of an error in power scaling which is applied to the present invention.

[303] Referring to FIG. 12, if transmission power has been assigned for a secondary serving cell1 SCell1 and a secondary serving cell2 SCell2 within the transmission capacity of UE, but transmission power for a PRACH having higher priority than a PUCCH or PUSCH must be assigned, the transmission power for the secondary serving cell2 SCell2 and the PRACH is sufficiently secured, but the transmission power for the secondary serving cell1 SCell1 may not be secured.

[304] Furthermore, since a BS does not know a K[dB] value, information triggered after a prohibition timer expires may be transmitted to the BS or an error operation on power scaling may continue to be performed until a periodic timer (periodicPHR-timer) expires. As a result, a problem may become further serious.

[305] Meanwhile, in a situation in which a BS and UE support parallel transmission, there is a good possibility that a problem may occur because UE located at the cell boundary requires greater transmission power necessary to transmit a PRACH under the influence of path attenuation (or pathloss). For example, a percentage of MSs corresponding to 0.7 or higher around a cell radius 1 may be about 50%.

[306]

[307] Here, a method of UE transmitting a PHR and a PRACH simultaneously without an error due to power scaling (e.g., an MPR error and an error in the power scaling of a BS) in accordance with the present invention is described below.

[308] In accordance with the present invention, when UE transmits a PRACH and a PUSCH (or a PUCCH or a PUCCH and a PUSCH) simultaneously in a specific subframe in response to an order from a BS, if this parallel transmission is determined

to be a power-limited case, that is, a state in which the required transmission power of the UE is limited (although the UE can transmit a PHR through the PUSCH because the PHR is triggered), the transmission of the PHR by the UE is limited.

[309] A method of limitedly making a PHR in the power-limited case as described above can be applied to a PHR triggering condition (embodiment 1) or the prohibition of the PHR (embodiment 2).

[310] <(Embodiment 1) Case where a PHR is limited according to the PHR triggering condition of UE in the power-limited case>

[311] First, 1) the UE does not perform PHR triggering if at least one of a plurality of PUSCHs is not substantially transmitted due to the transmission of a PRACH. Second, 2) the UE does not perform PHR triggering if the transmission power of a PUSCH has been scaled due to the transmission of a PRACH. The scaling of the transmission power means the attenuation of the transmission power.

[312] That is, if all the PUSCHs have been substantially transmitted and the transmission power of a PUSCH has not been scaled despite the transmission of the PRACH, the UE performs PHR triggering.

[313] A PHR triggering condition in accordance with an embodiment of the present invention is as follows. The PHR triggering condition corresponds to a case where resources for new transmission in a corresponding TTI have been assigned to UE.

[314] (1) If uplink resources for new transmission are assigned for the first time after the last MAC is reset, a periodic timer (i.e., a periodic PHR-Timer) is started.

[315] (2) If at least one PHR is triggered in a PHR procedure after a PHR is finally transmitted or the at least one PHR is triggered for the first time, if assigned uplink resources provide a space enough to transmit a PHR MAC CE (or an extended PHR MAC CE), and if an extended PHR has been configured and power scaling has not occurred despite the transmission of an RA preamble in a specific serving cell, 1) the UE obtains a Type 1 power headroom value for a serving cell in which each uplink has been configured and which has been activated and the UE obtains a value corresponding to a $P_{\text{CMAX},c}$ field from a physical layer if uplink resources for UL transmission have been assigned to the UE through a corresponding serving cell in a corresponding TTI, 2) the UE obtains a Type 2 power headroom value for a primary serving cell if a simultaneous PUCCH-PUSCH has been configured and the UE obtains a value corresponding to a $P_{\text{CMAX},c}$ field from a physical layer if the UE transmits a PUCCH in a corresponding TTI, and 3) the UE generates and transmits an extended PHR MAC CE.

[316] <(Embodiment 2) Case where a PHR is limited as UE selectively prohibits the transmission of an extended PHR in the power-limited case>

[317] First, 1) if at least one of a plurality of PUSCHs is not substantially transmitted due

to the transmission of a PRACH, the transmission of a PHR (or extended PHR) is prohibited. Second, 2) if the transmission power of a PUSCH is scaled due to the transmission of a PRACH, the transmission of a PHR (or extended PHR) is prohibited.

[318] FIG. 13 is a flowchart illustrating a PHR between UE and a BS in accordance with the present invention.

[319] Referring to FIG. 13, the BS transmits a PDCCH order to the UE at step S1300. An RA preamble is assigned. Here, the PDCCH order can be transmitted through a layer 1 (L1). In response to the PDCCH order, a random access procedure is performed. For example, the PDCCH order can be assigned to the control information region of a secondary serving cell in which the random access procedure will be performed and transmitted. For another example, the UE may receive a random access procedure indicator having a different type other than the PDCCH order from the BS. Here, a random access procedure can be performed based on the random access procedure indicator.

[320] After the step S1300, after checking whether or not a serving cell (i.e., a secondary serving cell) has been activated, the UE performs PHR triggering by taking power scaling into consideration at step S1305.

[321] When receiving a PDCCH order for a specific secondary serving cell, UE triggers a PHR if a PHR triggering condition is satisfied (or when an event, that is, the triggering condition, is generated). Here, the event, that is, the triggering condition, may include a change of pathloss, a change of a power backoff, and various timers. The change of pathloss, the change of a power backoff, and the various timers may form the PHR triggering condition in combination or may form the PHR triggering condition independently.

[322] In addition, PHR triggering in accordance with an embodiment of the present invention can be performed only when an error due to power scaling does not occur if parallel transmission is performed.

[323] First, the UE checks whether or not a PHR and a PRACH are transmitted simultaneously in a subframe in which the PHR is triggered. That is, the UE checks the timing location of the subframe in which the PHR is triggered and checks whether or not the PHR and the PRACH are transmitted simultaneously based on the checked timing location.

[324] If, as a result of the check, the PHR and the PRACH are simultaneously transmitted, the UE triggers the PHR only if all PUSCHs have been substantially transmitted and the transmission power of a PUSCH has not been scaled. That is, the UE triggers the PHR only when an error due to power scaling is not generated.

[325] A PHR triggering condition in accordance with another embodiment of the present invention is as follows. The PHR triggering condition corresponds to a case where

resources for new transmission in a corresponding TTI have been assigned to UE.

- [326] (1) If uplink resources for new transmission are assigned for the first time after the last MAC is reset, a periodic timer (i.e., a periodic PHR-Timer) is started.
- [327] (2) If at least one PHR is triggered in a PHR procedure after a PHR is finally transmitted or the at least one PHR is triggered for the first time, if assigned uplink resources provide a space enough to transmit a PHR MAC CE (or an extended PHR MAC CE), and if an extended PHR has been configured and power scaling has not occurred despite the transmission of an RA preamble in a specific serving cell,
- [328] 1) the UE obtains a Type 1 power headroom value for a serving cell in which each uplink has been configured and which has been activated and the UE obtains a value corresponding to a $P_{\text{CMAX},c}$ field from a physical layer if uplink resources for UL transmission have been assigned to the UE through a corresponding serving cell in a corresponding TTI,
- [329] 2) the UE obtains a Type 2 power headroom value for a primary serving cell if a simultaneous PUCCH-PUSCH has been configured and the UE obtains a value corresponding to a $P_{\text{CMAX},c}$ field from a physical layer if the UE transmits a PUCCH in a corresponding TTI, and
- [330] 3) the UE generates and transmits an extended PHR MAC CE.
- [331] After the step S1305, the UE configures a PHR to be transmitted to the BS at step S1310.
- [332] The UE configures the PHR so that it includes the PH value or $P_{\text{CMAX},c}$ value of activated serving cells. The PH value has a value not including an error due to power scaling through the step S1305.
- [333] Next, the UE transmits the PRACH and a PUSCH including the PHR to the BS through parallel transmission at step S1315. Here, the PRACH can be transmitted through a layer 1 (L1), and the PHR can be transmitted through the PUSCH in the form of an extended PHR MAC CE. That is, the PRACH and the PHR are transmitted through different messages simultaneously.
- [334] In particular, the UE can transmit an RA preamble to the BS through the PRACH. The UE transmits the RA preamble through the uplink of a serving cell in response to a PDCCH order received from the BS. That is, the UE transmits the RA preamble through the uplink of a corresponding secondary serving cell based on PDCCH order information received from the BS.
- [335] After the step S1310, a random access response to the RA preamble can be transmitted to the UE through the DL CC of a primary serving cell. That is, a PDCCH, that is, a random access response grant, is transmitted through the common search space of the primary serving cell. Here, an RA-RNTI value can be calculated in the UE and the BS according to Equation 18 below.

[336] [Equation 18]

[337] $RA-RNTI = 1 + 1 \times t_{id} + 10 \times f_{id}$

[338] In Equation 18, t_{id} indicates the location 0 ~ 9 of an uplink subframe in which the RA preamble has been transmitted, and f_{id} indicates the index 0 ~ 5 of a frequency band which the RA preamble has been transmitted.

[339] Since the random access response grant is transmitted to the primary serving cell, a PDSCH including information about the random access response MAC PDU is also transmitted to the primary serving cell.

[340] FIG. 14 is a block diagram showing the structure of a random access response (RAR) message in accordance with another embodiment of the present invention.

[341] Referring to FIG. 14, the RAR message may have a format of an RAR MAC PDU 1400. The RAR MAC PDU 1400 includes an MAC header 1410, one or more MAC RAR fields 1415-1, ..., 1415-n, and padding 1440.

[342] The MAC header 1410 includes one or more sub-headers 1405-1, 1405-2, ..., 1405-n, and the sub-headers 1405-1, 1405-2, ..., 1405-n correspond to respective MAC RAR fields 1415-1, ..., 1415-n. The sub-headers 1405-1, 1405-2, ..., 1405-n may have the same order as the respective MAC RAR field 1415-1, 1415-2, ..., 1415-n within the RAR MAC PDU 1400.

[343] Meanwhile, the MAC header 1410 may further include a backoff indicator BI sub-header 1401. The backoff indicator BI sub-header 1401 includes a backoff indicator. An MAC RAR field corresponding to the backoff indicator sub-header 1401 is not present within the RAR MAC PDU 1400. However, the backoff indicator sub-header 1401 is a parameter that is applied to all MSs which have received the corresponding RAR message in common. If UE has never received a backoff indicator, the backoff parameter has '0ms' as an initial value or a default value.

[344] The backoff indicator sub-header 1401 may be included in the RAR MAC PDU 1400 only when a backoff parameter for a corresponding serving cell has to be changed by a BS. For example, if the transmission of RA preambles through a serving cell exceeds a specific level or a BS continues to fail in receiving an RA preamble, the BS may include the backoff indicator sub-header 1401 for increasing a backoff parameter value in the RAR MAC PDU 1400 and transmit the RAR MAC PDU 1400.

[345] The backoff indicator sub-header 1401 may include 5 fields; E, T, R, R, and BI. Here, the E field indicates whether or not a sub-header is the last sub-header or not. The T field indicates whether a corresponding sub-header is a sub-header, including an RA preamble ID (RAPID), or a backoff indicator sub-header. Furthermore, the R field indicates reserved bits. The BI field is defined by 4 bits. A value of the BI field indicates one of 16 index values. The BI field can be applied if UE determines that a random access procedure is not successful.

- [346] The RAPID is information for checking whether or not an RA preamble transmitted by corresponding UE, from among RA preambles transmitted by a plurality of MSs through the same time/frequency resources, is for an RAR MAC PDU. The sub-headers 1405-1, 1405-2, ..., 1405-n including the RAPID may include 3 fields; E, T, and RAPID. Here, the E field indicates whether or not a corresponding sub-header is the last sub-header. The T field indicates whether a corresponding sub-header is a sub-header, including the RAPID, or a backoff indicator sub-header. The RAPID field is defined by 6 bits, and the RAPID field is information about an RA preamble assigned by a BS or an RA preamble selected by UE.
- [347] FIG. 15 shows an example of an MAC sub-header applied to the present invention.
- [348] Referring to FIG. 15, the MAC sub-header corresponds to the MAC sub-headers 1405-1, 1405-2, ..., 1405-n included in the RAR MAC PDU of FIG. 14.
- [349] FIG. 16 shows an example of an MAC CE to which the present invention is applied.
- [350] Referring to FIG. 16, the MAC CE has an octet structure (8 bits) and includes 6 octets.
- [351] The MAC CE includes an R field having 1 bit, a timing advance command field having 11 bits, and an uplink grant having 20 bits. The MAC CE further includes a temporary C-RNTI field having 16 bits. Information about the uplink grant is information about UL resources assigned to a serving cell that has transmitted a preamble corresponding to an RAPID value.
- [352] FIG. 17 is a flowchart illustrating another example of a PHR between UE and a BS in accordance with the present invention.
- [353] Referring to FIG. 17, the BS transmits a PDCCH order to the UE at step S1700. An RA preamble assignment is performed. Here, the PDCCH order can be transmitted through an L1. In response to the PDCCH order, a random access procedure is performed.
- [354] After the step S1700, after checking whether or not a serving cell (e.g., a secondary serving cell) has been activated, the UE performs PHR triggering at step S1705.
- [355] In response to the PDCCH order for a specific secondary serving cell, the UE triggers a PHR when a PHR triggering condition is satisfied (or when an event, that is, the PHR triggering condition, is generated). Here, the event, that is, the PHR triggering condition, may include a change of pathloss, a change of a power backoff, and various timers. The change of pathloss, the change of a power backoff, and the various timers may form the PHR triggering condition in combination or may form the PHR triggering condition independently.
- [356] After the step S1705, the UE determines whether or not the PHR has been transmitted by taking power scaling into consideration and configures a PHR at step S1710.

- [357] In order to prevent an error due to power scaling from occurring in the power-limited case even though the PHR has been triggered, the UE may determine whether or not an extended PHR has been transmitted and selectively prohibit the transmission of the extended PHR.
- [358] For example, the UE may prohibit the transmission of a PHR (or extended PHR) if at least one of a plurality of PUSCHs has not been substantially transmitted due to the transmission of a PRACH.
- [359] For another example, the UE may prohibit the transmission of a PHR (or extended PHR) if the transmission power of a PUSCH has been scaled due to the transmission of a PRACH.
- [360] If, as a result of the determination, the transmission of the PHR has not been prohibited, the UE configures a PHR so that the PHR includes the PH value or $P_{CMAX,c}$ value of activated serving cells. The PH value is a value not including an error due to power scaling.
- [361] After the step S1710, the UE transmits the PRACH and the configured PHR to the BS simultaneously at step S1715. Here, the PRACH is transmitted through an L1, and the PHR is transmitted through the PUSCH in the form of an extended PHR MAC CE.
- [362] The UE transmits an RA preamble to the BS through the PRACH. Here, the UE transmits the RA preamble through the uplink of a serving cell based on the PDCCH order received from the BS.
- [363] FIG. 18 is a flowchart illustrating an example of the operation of UE which transmits a PHR by taking power scaling into consideration in accordance with the present invention.
- [364] Referring to FIG. 18, if the UE operates in a carrier aggregation system at step S1800, a PRACH and a PUSCH or a PUCCH are transmitted in parallel at step S1805, and power scaling is not performed at step S1810, the UE transmits the PRACH and the PUSCH including a PHR in parallel at step S1815.
- [365] In contrast, if the UE operates in a carrier aggregation system at step S1800, a PRACH and a PUSCH or a PUCCH are transmitted in parallel at step S1805, but power scaling is performed at step S1810, the UE does not perform PHR triggering or prohibits PHR transmission although the PHR triggering is performed and transmits the PRACH and the PUSCH not including a PHR at step S1820.
- [366] FIG. 19 is a flowchart illustrating another example of the operation of UE which transmits a PHR by taking power scaling into consideration in accordance with the present invention.
- [367] Referring to FIG. 19, the UE receives a PDCCH order from a BS at step S1900. An RA preamble assignment is performed, and the PDCCH order can be transmitted through an L1. In response to the PDCCH order, a random access procedure is

performed.

- [368] For example, the PDCCH order may be assigned to the control information region of a secondary serving cell through which the random access procedure will be performed and then transmitted. Here, the random access procedure may be transmitted through the secondary serving cell.
- [369] When the random access procedure is performed through the secondary serving cell, the UE determines whether or not a subframe through which a PRACH is transmitted and a subframe in which a PHR has been triggered are transmitted in parallel because the timing location of the subframe through which the PRACH is transmitted is identical with the timing location of the subframe in which the PHR has been triggered entirely or partially at step S1905.
- [370] If, as a result of the determination at step S1910, parallel transmission is not performed, the UE performs an existing operation because an error due to power scaling is not generated.
- [371] After the step S1905, after checking whether or not the serving cell through which the random access procedure has been performed is an activated serving cell (or a secondary serving cell), the UE performs PHR triggering at step S1915.
- [372] For example, the UE may perform PHR triggering only when an error due to power scaling is not generated.
- [373] For another example, the UE may perform PHR triggering if all PUSCHs have been substantially transmitted and the transmission power of a PUSCH has not been scaled.
- [374] If the UE has not transmitted a PHR because the PHR has not been triggered or the UE determines not to transmit a PHR although the PHR has been triggered at step S1920, the UE transmits a PRACH and a PUSCH without a PHR to the BS at step S1935.
- [375] For example, in the power-limited case, the UE may selectively prohibit the transmission of a PHR (or extended PHR) and may not transmit a PHR according to the occurrence of an error due to power scaling.
- [376] For another example, the UE may prohibit the transmission of a PHR (or extended PHR) if at least one of a plurality of PUSCHs has not been substantially transmitted due to the transmission of a PRACH.
- [377] For yet another example, the UE may prohibit the transmission of a PHR (or extended PHR) if the transmission power of a PUSCH has been scaled due to the transmission of a PRACH.
- [378] If, as a result of the determination at step S1920, it is determined to transmit the PHR, the UE configures a PHR so that the PHR includes the Power Headroom (PH) value and $P_{\text{CMAX},c}$ information of activated serving cells at step S1925.
- [379] Next, the UE transmits the PRACH and the PUSCH including the PHR to the BS in

parallel at step S1930. Here, the PRACH can be transmitted through an L1, and the PHR can be transmitted in the form of an extended PHR MAC CE. That is, the PRACH and the PHR are transmitted through different messages at the same time. In particular, the UE may transmit an RA preamble to the BS through the PRACH. The UE transmits the RA preamble through the uplink of a serving cell based on the PDCCH order received from the BS.

[380] FIG. 20 is a flowchart illustrating the operation of a BS in accordance with the present invention.

[381] Referring to FIG. 20, the BS transmits a PDCCH order to UE for a random access procedure at step S2000. Accordingly, an RA preamble is assigned. Here, the PDCCH order can be transmitted through an L1. For example, the PDCCH order may be assigned to the control information region of a secondary serving cell through which the random access procedure will be performed and then transmitted.

[382] The BS receives a PHR from the UE at step S2005. Here, the PHR can be transmitted in the form of an extended PHR MAC CE. A PRACH can be transmitted simultaneously with the PHR.

[383] For example, the PHR may include the PH value or $P_{\text{CMAX},c}$ value of activated serving cells.

[384] For example, the RA preamble for the PDCCH order may be received through the PRACH.

[385] The BS applies PH to scheduling for the UE based on the received PHR at step S2010.

[386] For example, the BS may include information about the scheduling to which PH has been applied based on the PHR in a random access response for the RA preamble and transmit the information to the UE.

[387] FIG. 21 is a block diagram showing UE 2100 and a BS 2150 in accordance with an embodiment of the present invention.

[388] Referring to FIG. 21, the UE 2100 includes a reception unit 2105, a PHR triggering unit 2110, a PHR determination unit 2115, and a transmission unit 2120.

[389] The reception unit 2105 receives a PDCCH order from the BS 2150. Here, the PDCCH order can be received through an L1. For example, the PDCCH order may be assigned to the control information region of a secondary serving cell through which a random access procedure will be performed and then received.

[390] The UE 2100 performs a random access procedure based on the PDCCH order.

[391] After the UE 2100 checks whether or not a serving cell (or a secondary serving cell) has been activated, the PHR triggering unit 2110 performs PHR triggering by taking power scaling into consideration.

[392] The PHR triggering unit 2110 triggers a PHR if a PHR triggering condition is

satisfied (or when an event, that is, the triggering condition, is generated). Here, the event, that is, the PHR triggering condition, may include a change of pathloss, a change of a power backoff, and various timers. The change of pathloss, the change of a power backoff, and the various timers may form the PHR triggering condition in combination or may form the PHR triggering condition independently

- [393] For example, the PHR triggering unit 2110 may trigger the PHR only when an error due to power scaling is not generated if the PHR and a PRACH are transmitted in parallel. Here, the UE 2100 can check whether or not this parallel transmission is performed in a subframe in which the PHR is triggered based on the timing location of the subframe in which the PHR has been triggered.
- [394] If, as a result of the check, the parallel transmission is performed, the PHR triggering unit 2110 triggers the PHE if all PUSCHs have been substantially transmitted and the transmission power of a PUSCH has not been scaled.
- [395] The UE 2100 may further include a PHR configuration unit. The PHR configuration unit configures a PHR to be transmitted to the BS 2150. The PHR configuration unit configures a PHR so that the PHR includes the PH value or $P_{\text{CMAX},c}$ value of activated serving cells.
- [396] The transmission unit 2120 transmits a PRACH and a PHR to the BS 2150 in parallel. Or, the transmission unit 2120 may transmit only a PRACH to the BS 2150. Here, the PRACH can be transmitted through an L1, and the PHR can be transmitted in the form of an extended PHR MAC CE. That is, the PRACH and the PHR can be transmitted through different messages at the same time.
- [397] The transmission unit 2120 can transmit an RA preamble to the BS 2150 through the PRACH. The transmission unit 2120 transmits the RA preamble through the uplink of a serving cell based on the PDCCH order.
- [398] The reception unit 2105 may further receive a random access response to the RA preamble through the DL CC of a primary serving cell from the BS 2150. A PDCCH, that is, a random access response grant, can be transmitted through the common search space of the primary serving cell, and an RA-RNTI value can be calculated according to Equation 18.
- [399] Although a PHR has been triggered, the PHR determination unit 2115 may determine whether or not to prohibit the transmission of a PHR (or extended PHR) in order to prevent an error due to power scaling from occurring in the power-limited case. Accordingly, the PHR determination unit 2115 may also be called a PHR prohibition unit.
- [400] For example, the PHR determination unit 2115 may prohibit the transmission of a PHR if at least one of a plurality of PUSCHs has not been substantially transmitted due to the transmission of a PRACH.
- [401] For another example, the PHR determination unit 2115 may prohibit the transmission

of a PHR if the transmission power of a PUSCH has been scaled due to the transmission of a PRACH.

- [402] If the transmission of a PHR has not been prohibited (or if it is determined to transmit a PHR), the UE 2100 configures the PHR so that the PHR includes the PH value or $P_{\text{CMAX},c}$ value of activated serving cells.
- [403] As described above, if an operation of the UE 2100 corresponds to a carrier operation, to a case where it transmits a PRACH and a PUSCH or a PUCCH in parallel, and to a case where power scaling is not performed, the UE 2100 transmits a PRACH and a PHR in parallel.
- [404] The BS 2150 includes a reception unit 2155, a control unit 2160, and a transmission unit 2165.
- [405] The transmission unit 2165 transmits a PDCCH order to the UE 2100 for a random access procedure at step S2000. Accordingly, an RA preamble is assigned. The PDCCH order can be transmitted through an L1. For example, the PDCCH order may be assigned to the control information region of a secondary serving cell through which a random access procedure will be performed and then transmitted.
- [406] The reception unit 2155 receives a PHR from the UE 2100. Here, the PHR can be transmitted in the form of an extended PHR MAC CE. A PRACH can be transmitted along with the PHR in parallel.
- [407] For example, the PHR may include the PH value or $P_{\text{CMAX},c}$ value of activated serving cells.
- [408] For example, an RA preamble for the PDCCH order may be received through a PRACH.
- [409] The control unit 2160 can apply PH to scheduling for the UE 2100 based on the received PHR.
- [410] For example, the control unit 2160 can include information about the scheduling to which the PH has been applied based on the PHR in a random access response to the RA preamble.
- [411] While some exemplary embodiments of the present invention have been described with reference to the accompanying drawings, those skilled in the art may change and modify the present invention in various ways without departing from the essential characteristic of the present invention. Accordingly, the disclosed embodiments should not be construed as limiting the technical spirit of the present invention, but should be construed as illustrating the technical spirit of the present invention. The scope of the technical spirit of the present invention is not restricted by the embodiments, and the scope of the present invention should be interpreted based on the following appended claims. Accordingly, the present invention should be construed as covering all modifications or variations derived from the meaning and scope of the appended claims and

their equivalents.

Claims

- [Claim 1] A method of user equipment (UE) transmitting a power headroom report (PHR) in a wireless communication system, the method comprising:
receiving a physical downlink control channel (PDCCH) order,
ordering random access, through a PDCCH from a base station (BS);
triggering a PHR based on a PHR triggering condition;
transmitting a physical random access channel (PRACH), comprising a random access (RA) preamble that is a response to the PDCCH order, and a physical uplink shared channel (PUSCH), comprising the PHR, to the BS in parallel,
wherein the PHR triggering condition comprises a condition that the PUSCH is not attenuated and scaled when the PUSCH comprising the PHR and the PRACH are to be transmitted in parallel in an identical subframe.
- [Claim 2] The method of claim 1, wherein when transmission power of the PUSCH through which the PHR is transmitted is attenuated and scaled, the PUSCH not includes the PHR.
- [Claim 3] The method of claim 1, further comprising checking a timing location of a subframe in which the PHR is triggered and checking whether or not the PHR and the PRACH are transmitted in parallel in the subframe in which the PHR is triggered based on a result of the check.
- [Claim 4] The method of claim 1, wherein the PHR is configured to comprise a power headroom value of activated serving cells or a maximum UE transmission power value configured for each of the serving cells.
- [Claim 5] A method of user equipment (UE) performing a power headroom report (PHR) in a wireless communication system, the method comprising:
receiving a physical downlink control channel (PDCCH) order,
ordering random access, from a base station (BS) through a PDCCH;
triggering a PHR based on a PHR triggering condition;
prohibiting a transmission of the PHR if a physical uplink shared channel (PUSCH) comprising the PHR is not substantially transmitted or a transmission power of the PUSCH through which the PHR is transmitted is attenuated and scaled due to a parallel transmission of a PRACH, comprising a random access (RA) preamble that is a response to the PDCCH order, and the PUSCH within an identical subframe; and
transmitting the PUSCH comprising the PHR and the PRACH to the

- BS if the transmission of the PHR is not prohibited.
- [Claim 6] The method of claim 5, wherein the PHR is configured to comprise a power headroom value of activated serving cells or a maximum UE transmission power value configured for each of the serving cells.
- [Claim 7] The method of claim 5, further comprising checking a timing location of a subframe in which the PHR is triggered and checking whether or not the PHR and the PRACH are transmitted in parallel in the subframe in which the PHR is triggered based on a result of the check.
- [Claim 8] The method of claim 5, wherein the PHR is configured to report power headroom for each of a plurality of serving cells in which uplink has been configured and which has been activated.
- [Claim 9] User equipment (UE) performing a power headroom report (PHR) in a wireless communication system, the UE comprising:
a reception unit configured to receive a physical downlink control channel (PDCCH) order, ordering random access, from a base station (BS) through a PDCCH;
a PHR triggering unit configured to trigger a PHR based on a PHR triggering condition;
a transmission unit configured to transmit a physical random access channel (PRACH), comprising a random access (RA) preamble that is a response to the PDCCH order, and a physical uplink shared channel (PUSCH), comprising the PHR, to the BS in parallel,
wherein the PHR triggering unit triggers the PHR under a condition that the PUSCH is not attenuated and scaled when the PUSCH comprising the PHR and the PRACH are to be transmitted in parallel in an identical subframe.
- [Claim 10] The UE of claim 9, wherein the transmission unit transmits a PUSCH not including the PHR when transmission power of the PUSCH through which the PHR is transmitted is attenuated and scaled.
- [Claim 11] The UE of claim 9, the UE further checks a timing location of a subframe in which the PHR is triggered and checks whether or not the PHR and the PRACH are transmitted in parallel in the subframe in which the PHR is triggered based on a result of the check.
- [Claim 12] The UE of claim 9, wherein the PHR is configured to comprise a power headroom value of activated serving cells or a maximum UE transmission power value configured for each of the serving cells.
- [Claim 13] User equipment (UE) performing a power headroom report (PHR) in a wireless communication system, the UE comprising:

a reception unit configured to receive a physical downlink control channel (PDCCH) order, ordering random access, from a base station (BS) through a PDCCH;

a PHR triggering unit configured to trigger a PHR based on a PHR triggering condition;

a PHR prohibition unit configured to prohibit a transmission of the PHR if a physical uplink shared channel (PUSCH) comprising the PHR is not substantially transmitted or a transmission power of the PUSCH through which the PHR is transmitted is attenuated and scaled due to a parallel transmission of a PRACH, comprising a random access (RA) preamble that is a response to the PDCCH order, and the PUSCH within an identical subframe; and

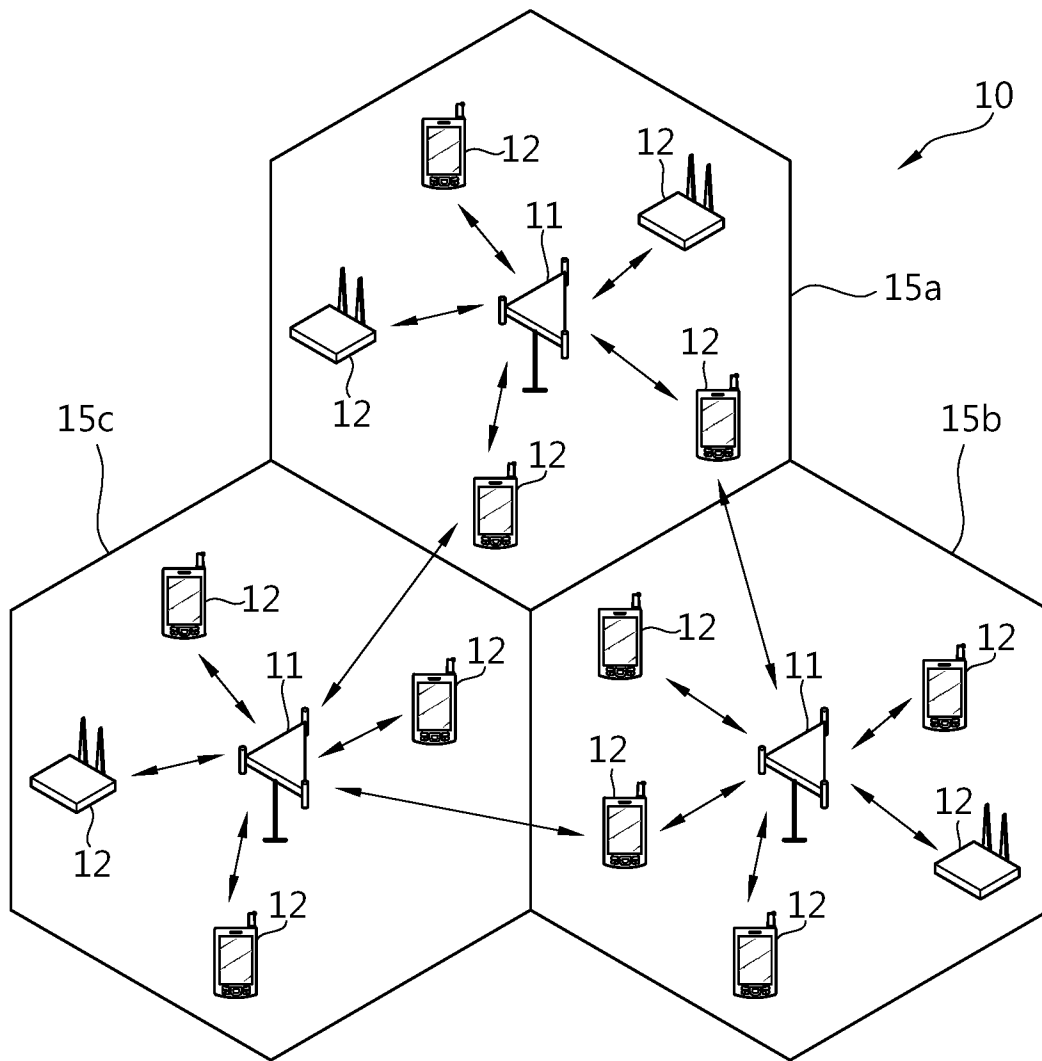
a transmission unit configured to transmit the PUSCH comprising the PHR and the PRACH to the BS if the transmission of the PHR is not prohibited.

[Claim 14] The UE of claim 13, wherein the PHR is configured to comprise a power headroom value of activated serving cells or a maximum UE transmission power value configured for each of the serving cells.

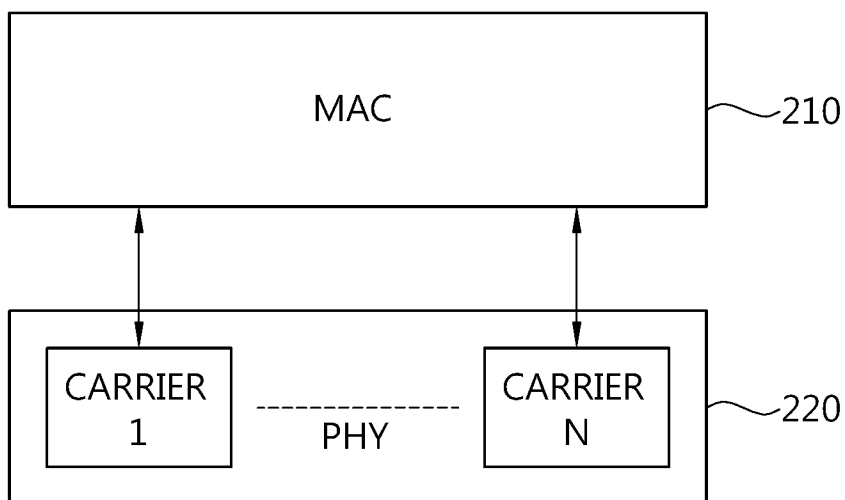
[Claim 15] The UE of claim 13, further comprising checking a timing location of a subframe in which the PHR is triggered and checking whether or not the PHR and the PRACH are transmitted in parallel in the subframe in which the PHR is triggered based on a result of the check.

[Claim 16] The UE of claim 13, wherein the PHR is configured to report power headroom for each of a plurality of serving cells in which uplink has been configured and which has been activated.

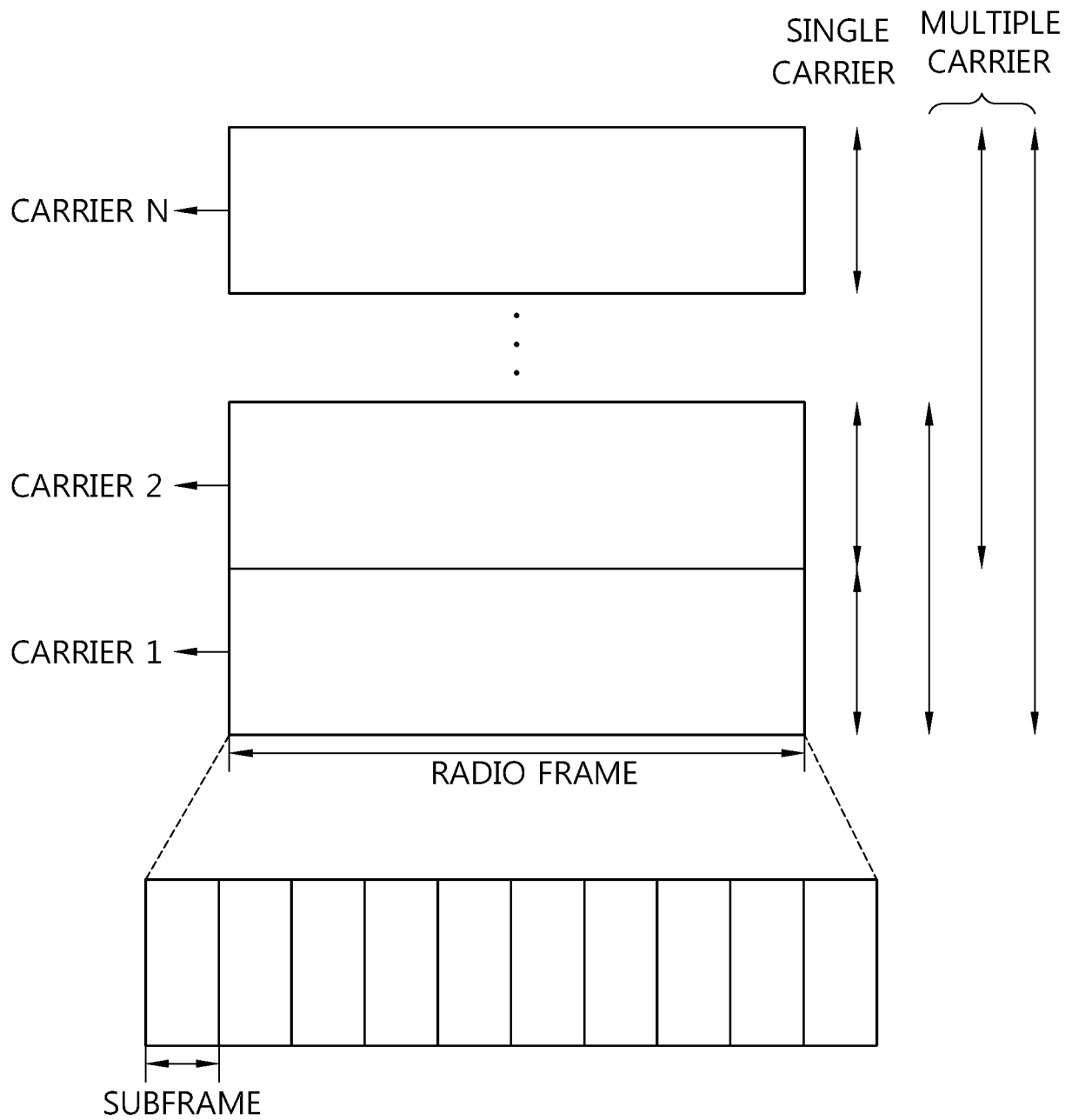
[Fig. 1]



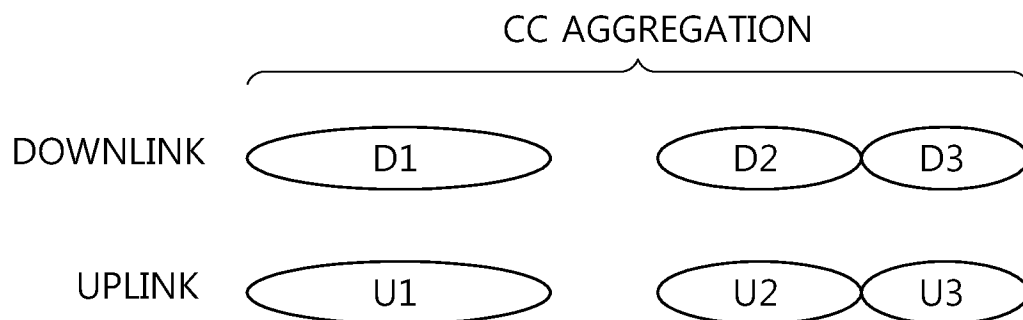
[Fig. 2]



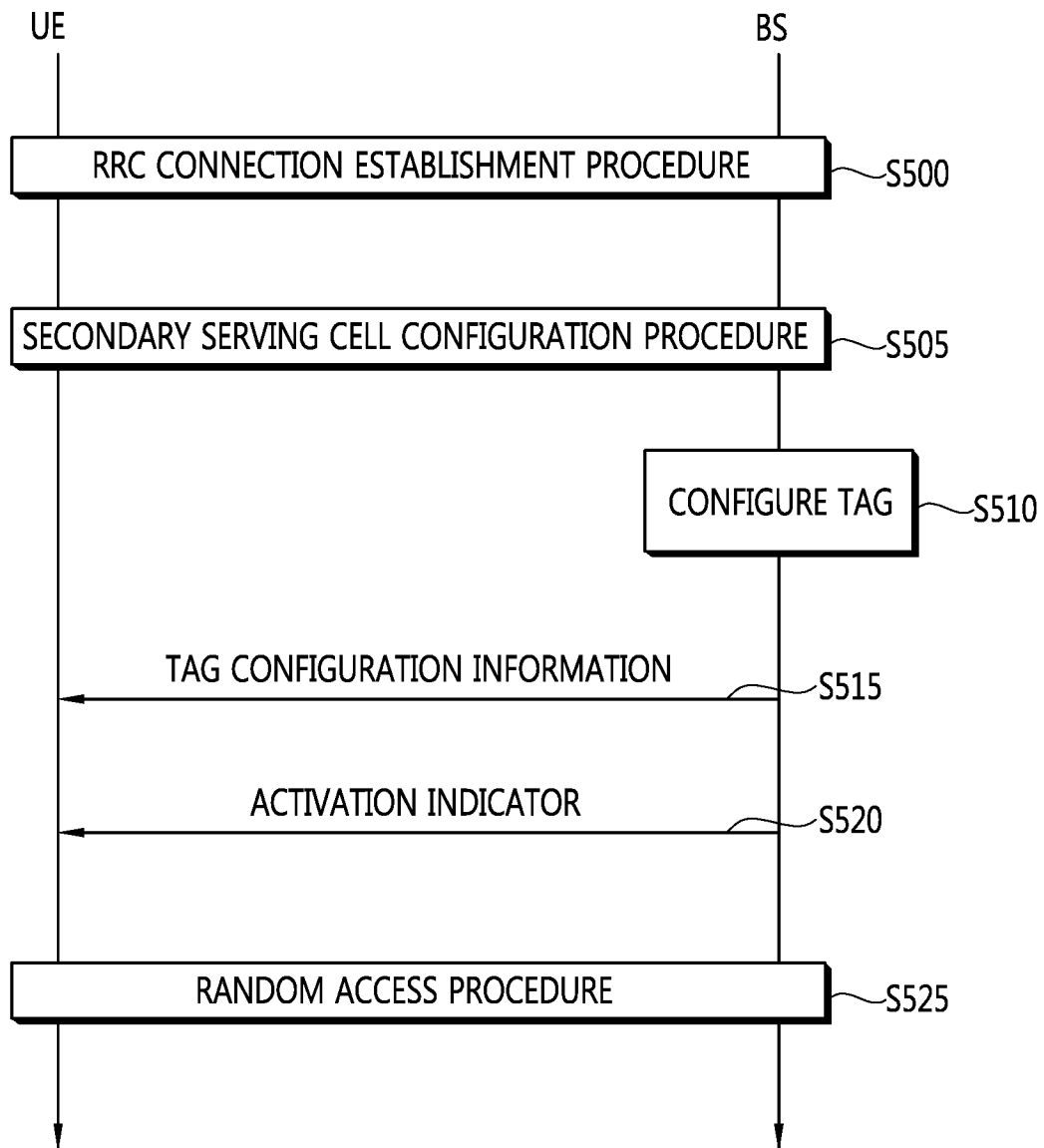
[Fig. 3]



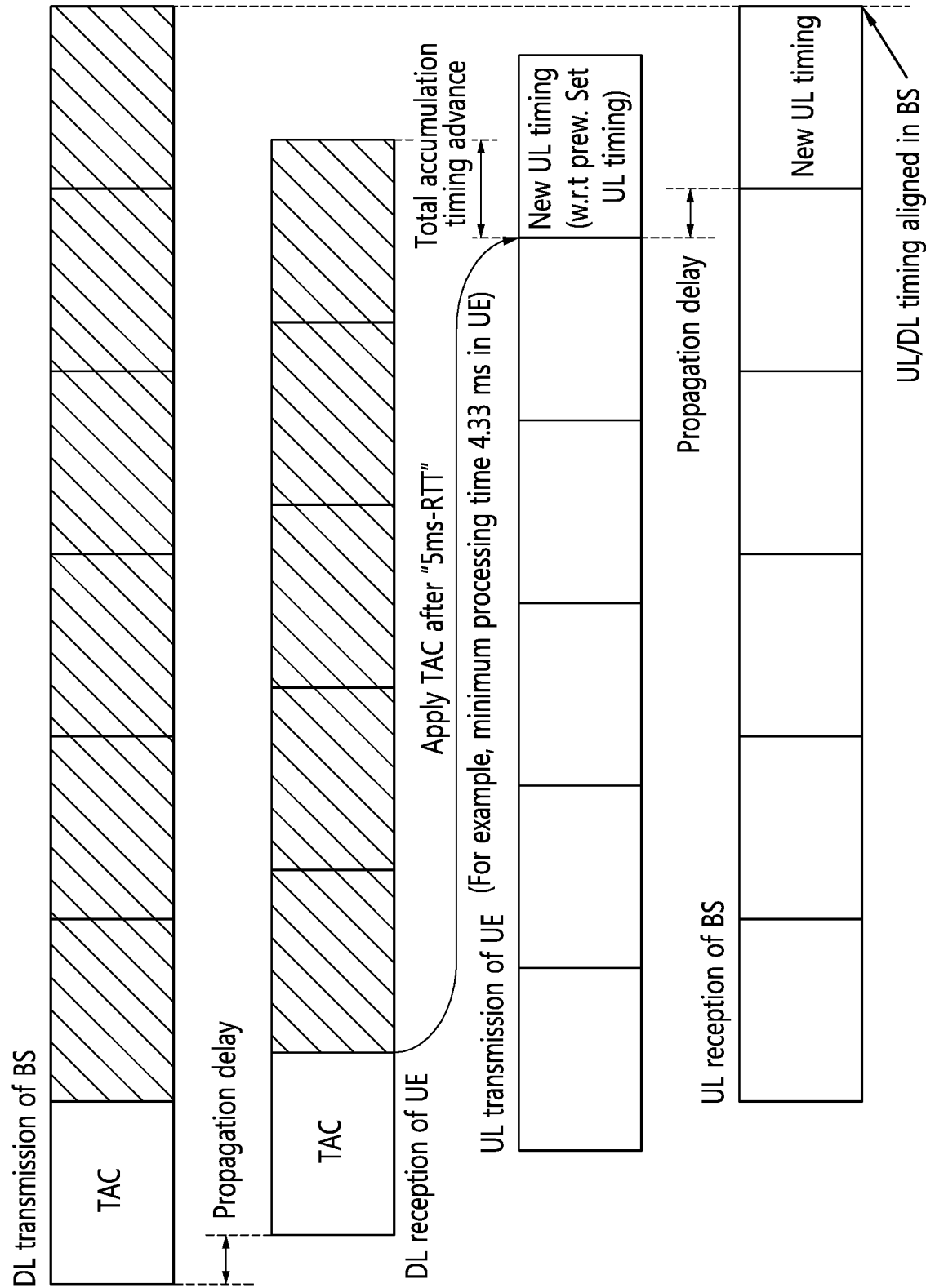
[Fig. 4]



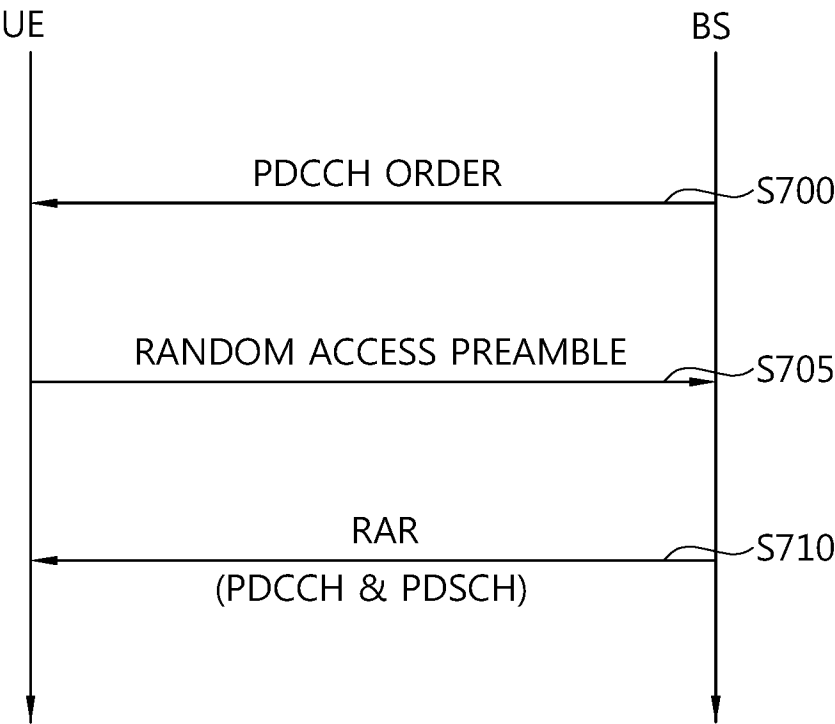
[Fig. 5]



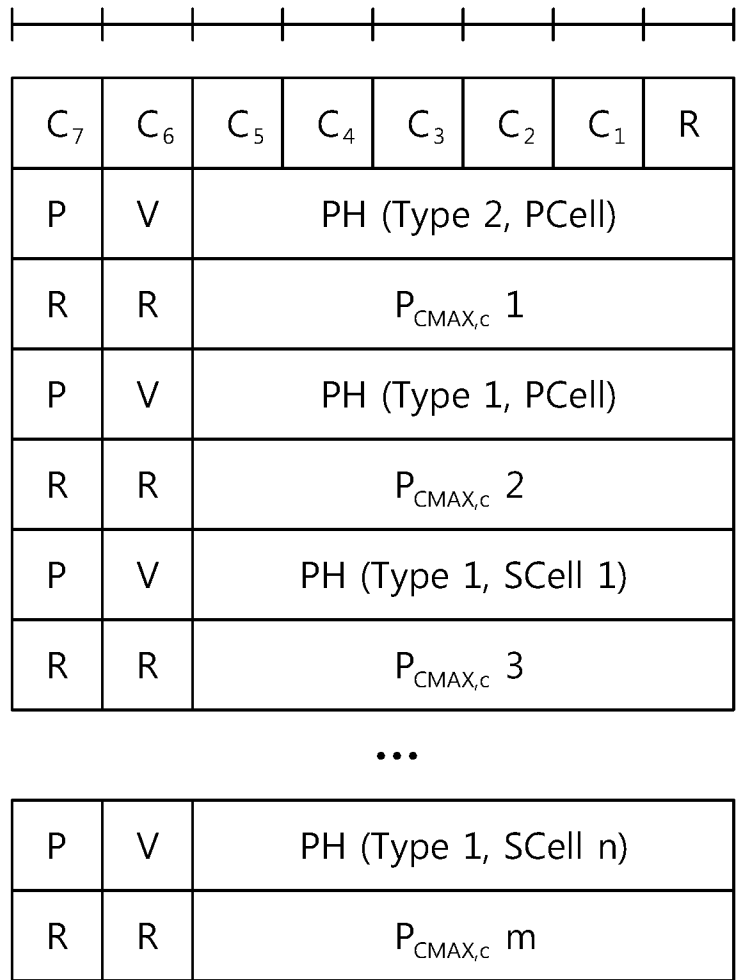
[Fig. 6]



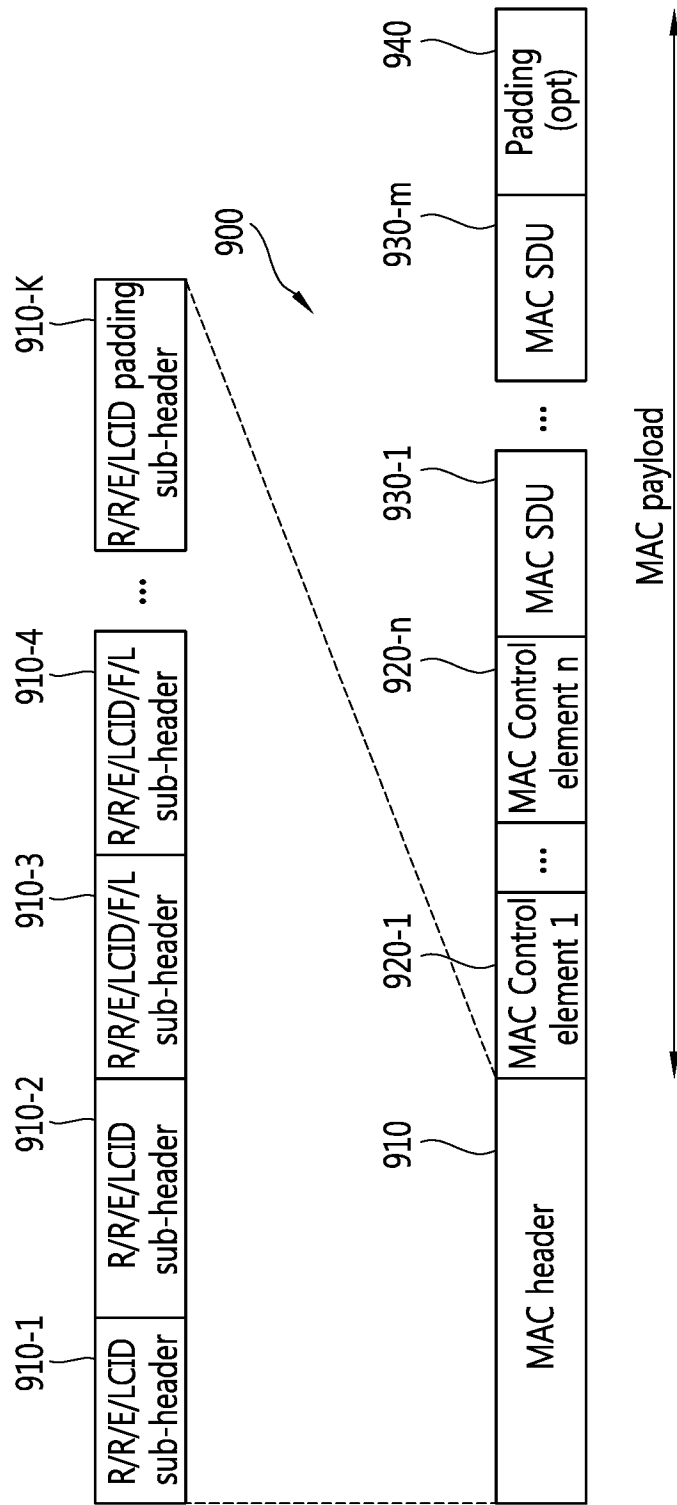
[Fig. 7]



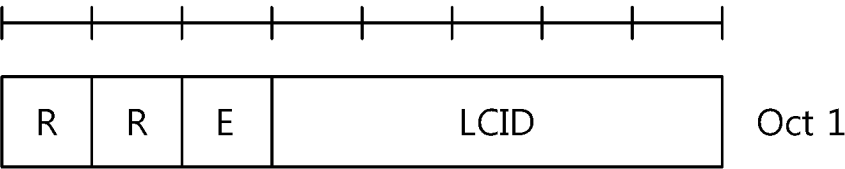
[Fig. 8]



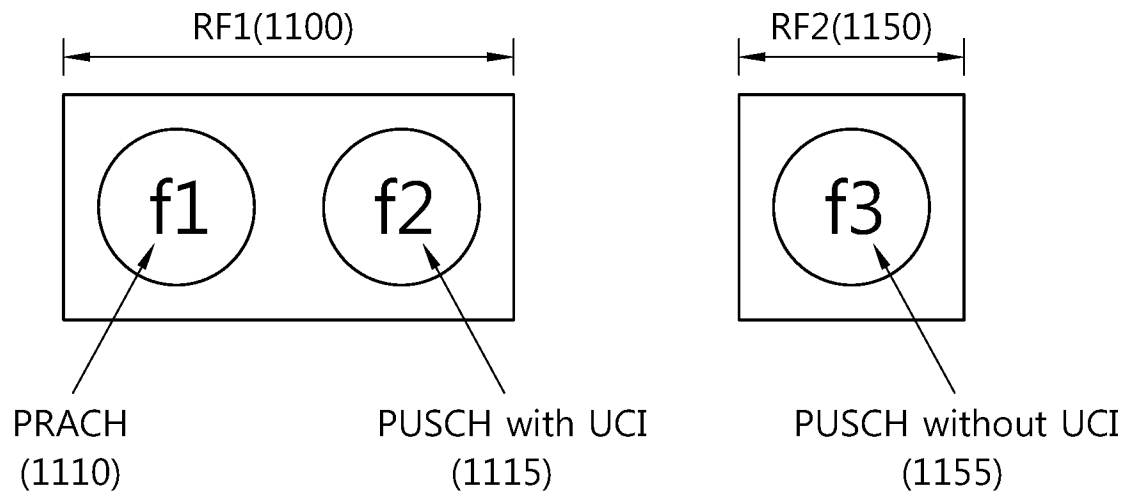
[Fig. 9]



[Fig. 10]

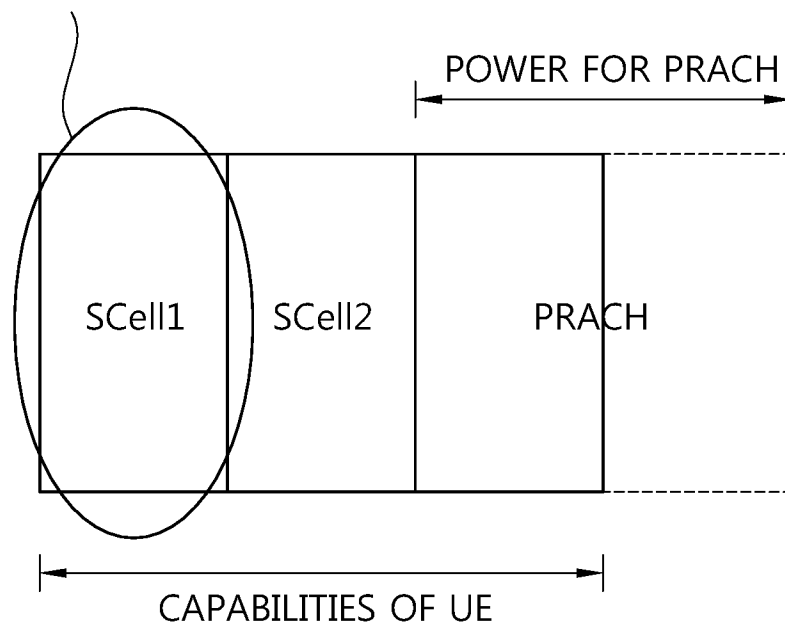


[Fig. 11]

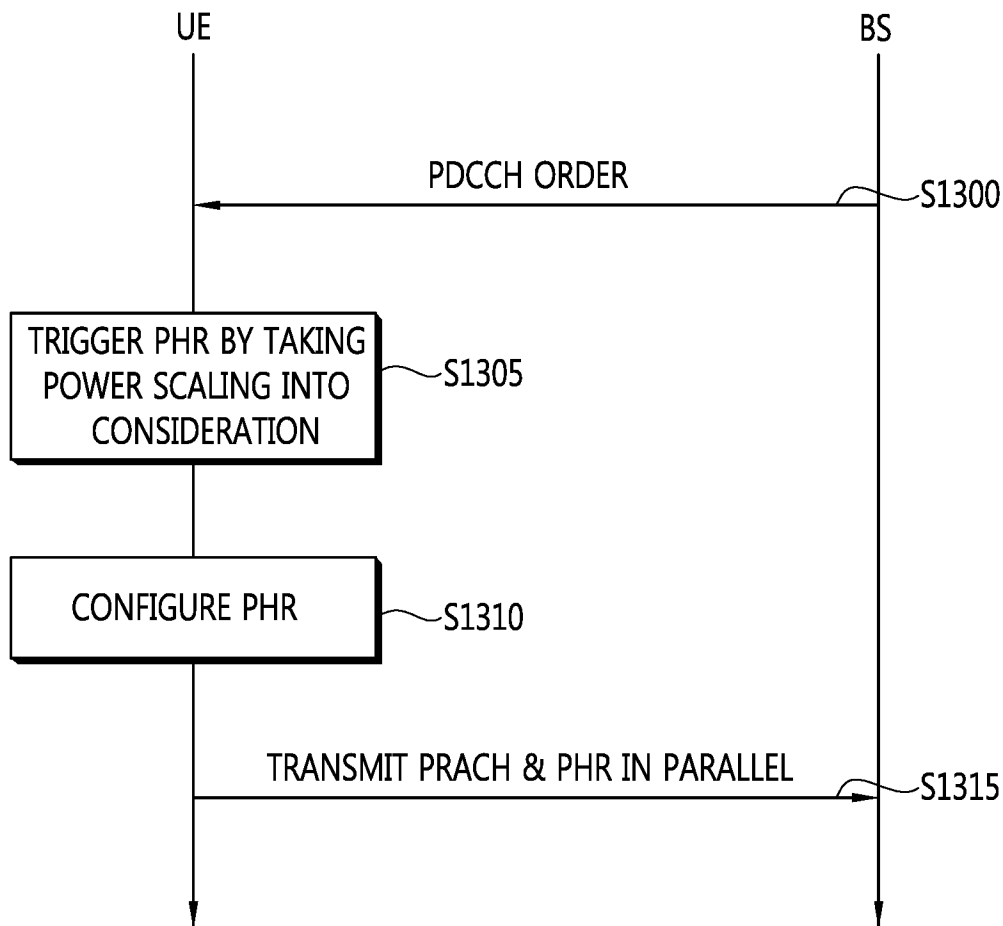


[Fig. 12]

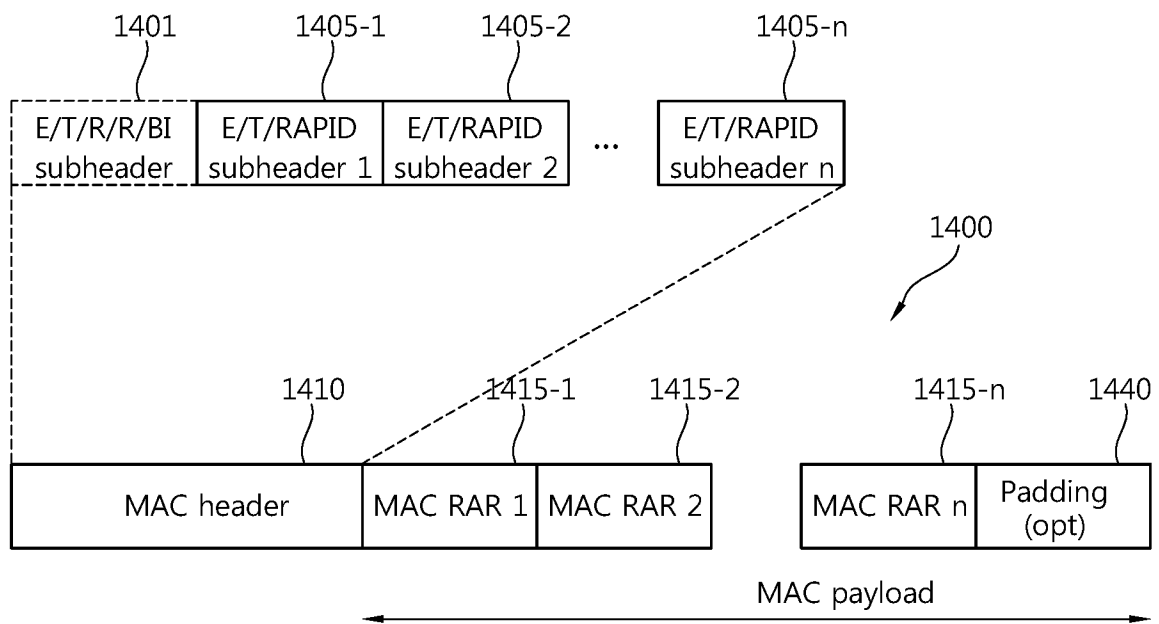
IMPOSSIBLE POWER ASSIGNMENT



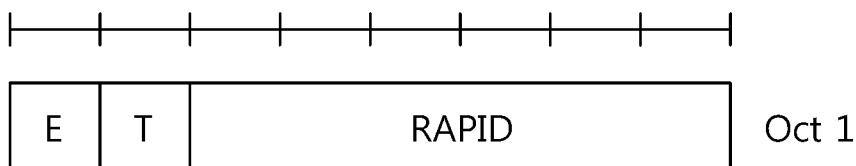
[Fig. 13]



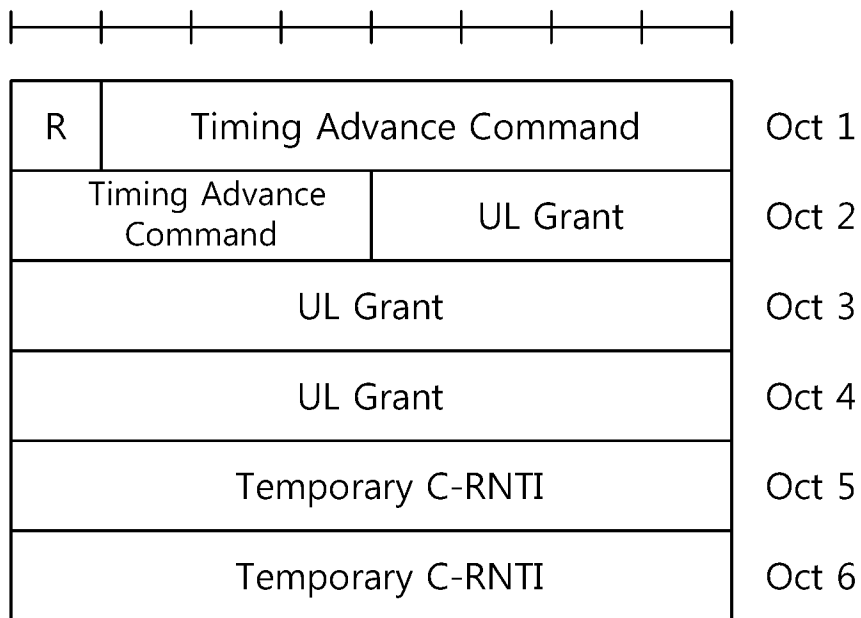
[Fig. 14]



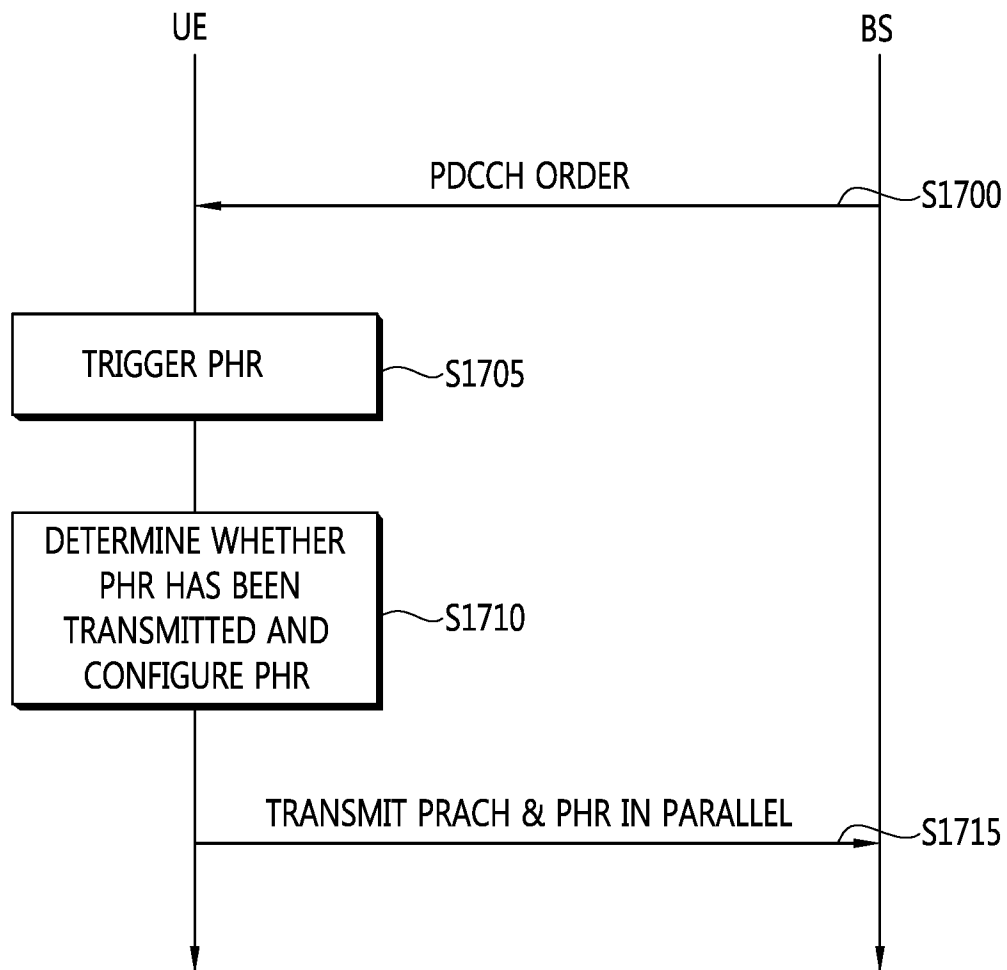
[Fig. 15]



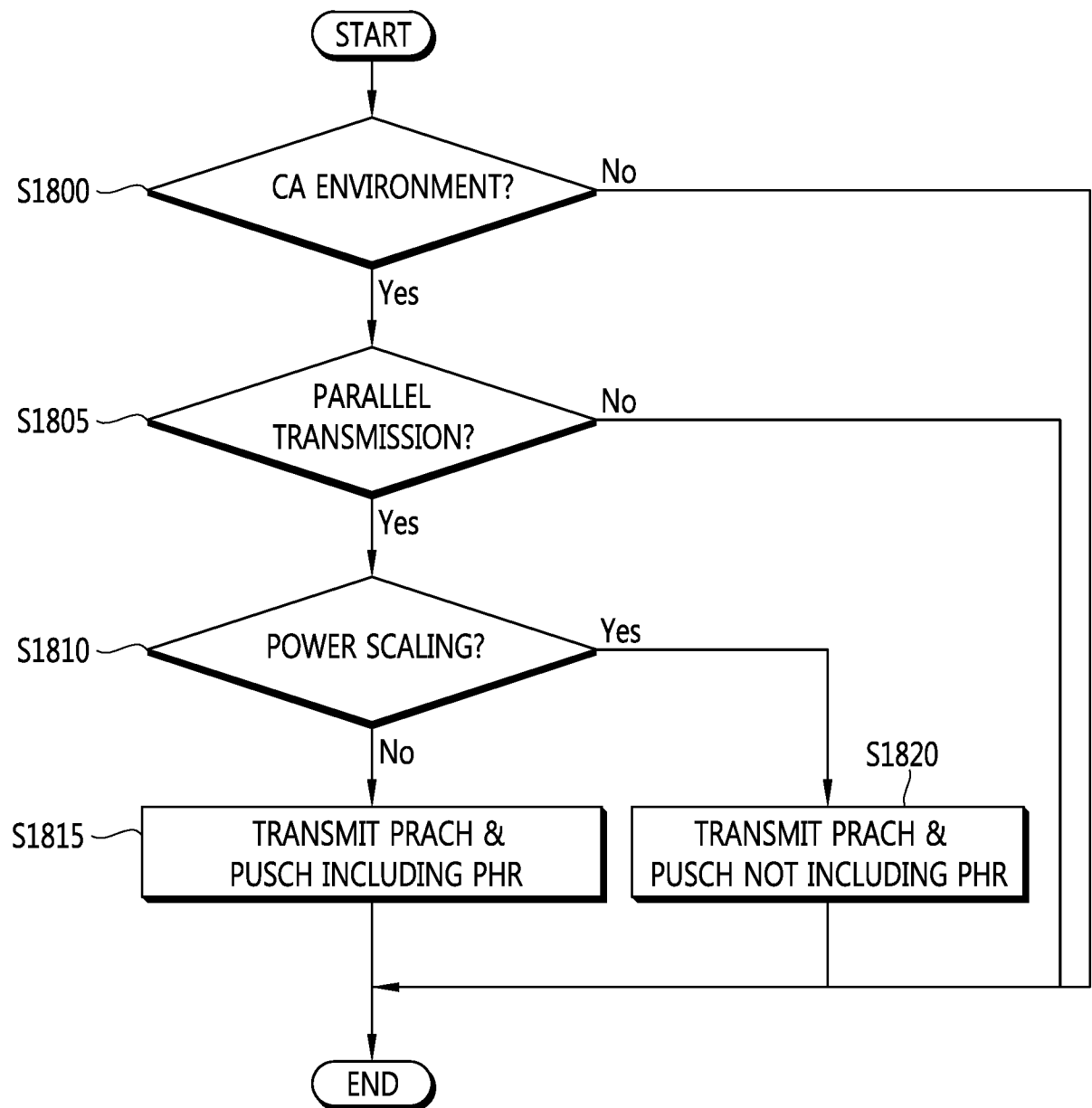
[Fig. 16]



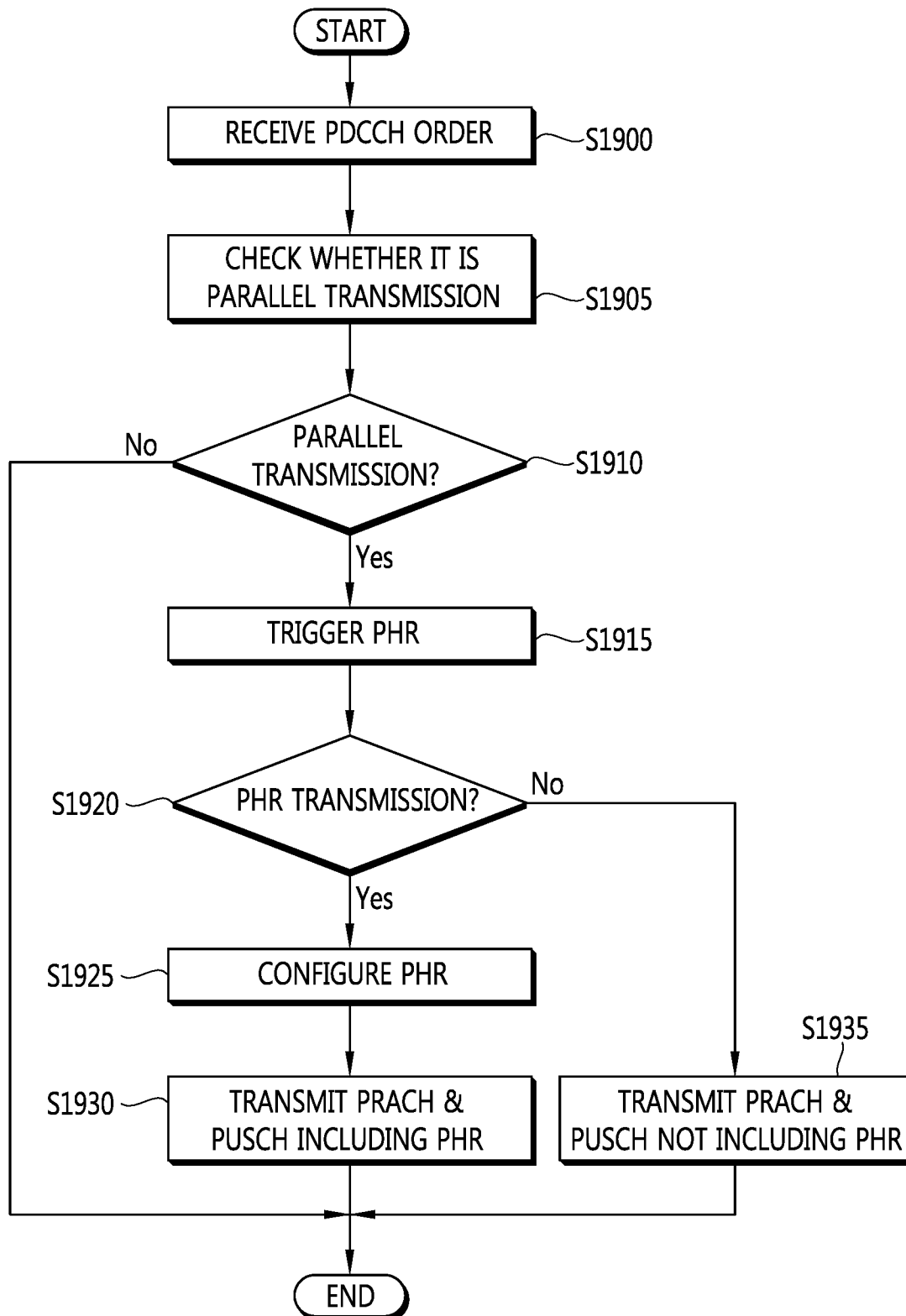
[Fig. 17]



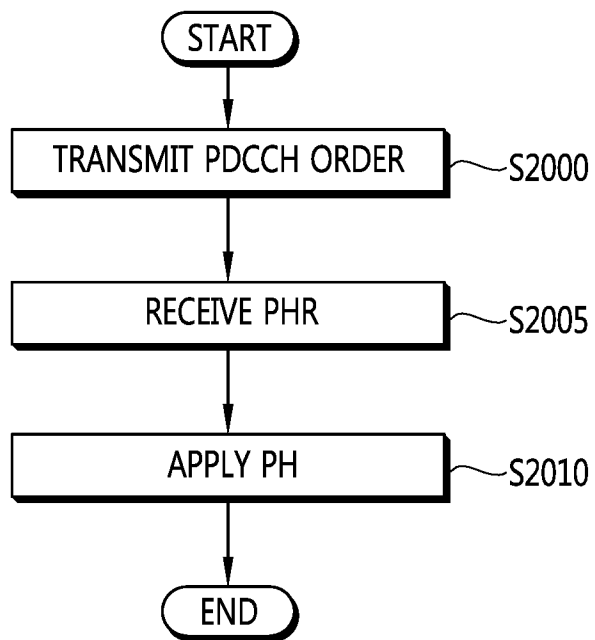
[Fig. 18]



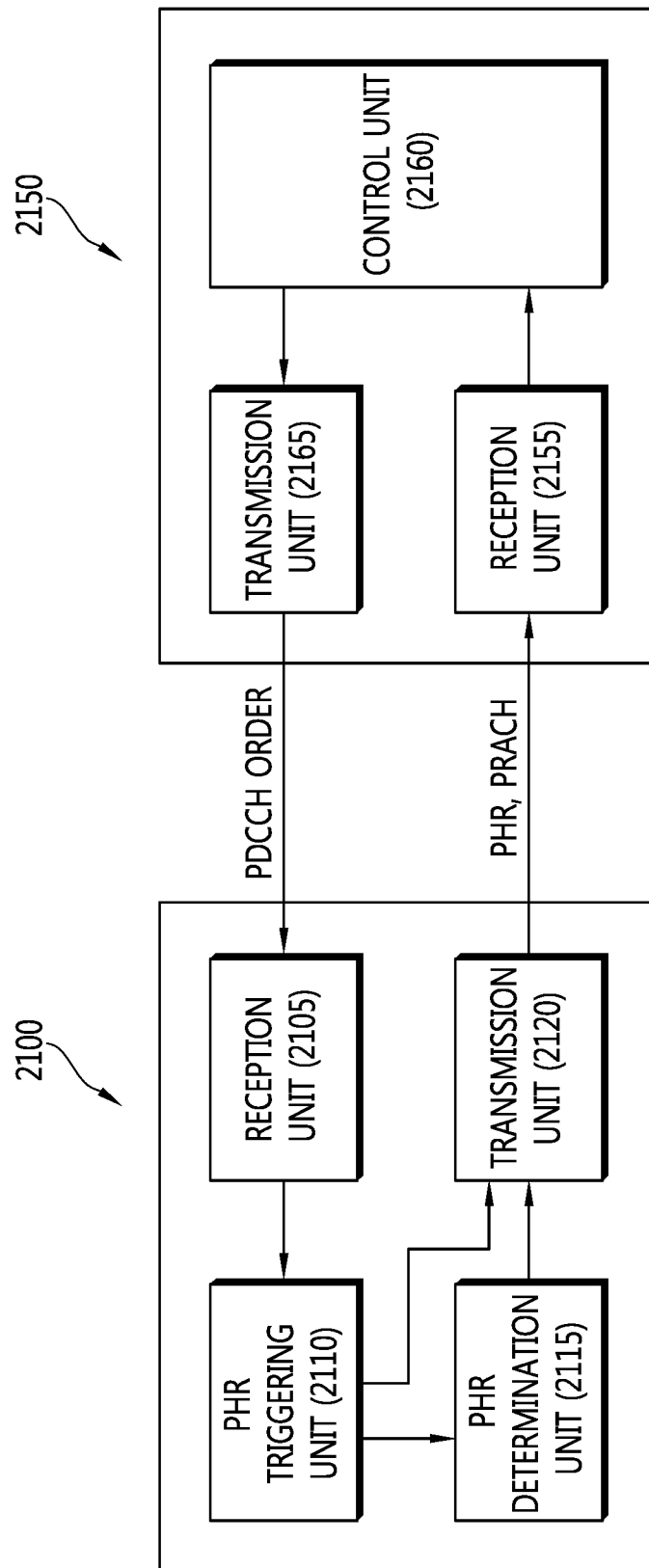
[Fig. 19]



[Fig. 20]



[Fig. 21]



A. CLASSIFICATION OF SUBJECT MATTER**H04W 24/10(2009.01)i, H04J 11/00(2006.01)i, H04B 7/26(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W 24/10; H04W 74/08; H04W 52/36; H04J 11/00; H04W 52/30; H04W 72/04; H04W 52/42; H04B 7/26

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: PHR, power, headroom, PDCCH, PUSCH, PRACH, random access, prohibit, trigger, subframe

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2012-023688 A1 (LG ELECTRONICS INC.) 23 February 2012 See paragraphs [0052]-[0076], [0094], [0118]-[0120], [0136]; claims 1-6; and figure 6.	1-16
A	WO 2011-150361 A1 (QUALCOMM INCORPORATED) 1 December 2011 See paragraphs [0073]-[0077]; claims 1-6; and figures 14a-14f.	1-16
A	WO 2011-056001 A2 (LG ELECTRONICS INC.) 12 May 2011 See paragraphs [0013], [0106]-[0110], [0153]-[0183]; claims 1-7; and figures 1, 7-8.	1-16
A	WO 2011-122904 A2 (SAMSUNG ELECTRONICS CO., LTD.) 6 October 2011 See paragraphs [0019]-[0022], [0035]-[0047]; and figures 1-2.	1-16
A	US 2011-0310986 A1 (HEO, YOUN HYOUNG et al.) 22 December 2011 See paragraphs [0017]-[0023]; claims 1-5; and figures 2-3.	1-16



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

22 August 2013 (22.08.2013)

Date of mailing of the international search report

23 August 2013 (23.08.2013)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR2013/003925

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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