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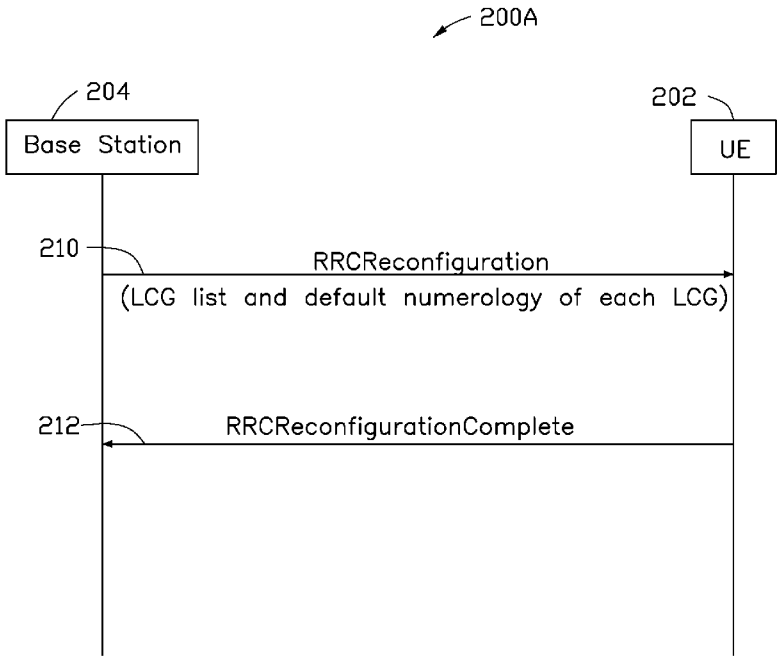


FIG. 2A

(57) Abstract: A user equipment (UE) includes one or more non-transitory computer-readable media having computer-executable instructions embodied thereon, at least one processor coupled to the one or more non-transitory computer-readable media, and configured to execute the computer-executable instructions to receive a logical channel group (LCG) list having a plurality of logical channels in one or more LCGs, where grouping of the plurality of logical channels is based at least in part on a mapping policy between each of the plurality of logical channels and one or more numerology factors. The at least one processor is further configured to execute the computer-executable instructions to request for a numerology-specific uplink radio resource for one of the one or more LCGs through a buffer status report (BSR), wherein the BSR includes a LCG ID identifying the one of the one or more LCGs.

WO 2018/228507 A1

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EVOLVED BUFFER STATUS REPORT SUPPORTING MULTIPLE NUMEROLOGY FACTORS

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] The present application claims the benefit of and priority to a provisional U.S. Patent Application Serial No. 62/519,392 filed June 14, 2017, entitled "EVOLVED BUFFER STATUS REPORT SUPPORTING MULTIPLE NUMEROLOGY FACTORS," Attorney Docket No. US70921 (hereinafter referred to as "US70921 application"). The disclosure of the US70921 application is hereby incorporated fully by reference into the present application.

FIELD

[0002] The present disclosure generally relates to wireless communication methods, and more particularly, to evolved buffer status report (BSR) that supports multiple numerology factors.

BACKGROUND

[0003] In fourth generation (4G) wireless communication systems (e.g., long term evolution (LTE), evolved LTE (eLTE), or LTE-Advanced (LTE-A)), a base station (e.g., evolved Node B (eNB)) can allocate orthogonal resources (e.g., time and frequency) to user equipment's (UEs) under its coverage, so that the UEs can share the radio resource (e.g., uplink/downlink) simultaneously. That is, the radio resource allocated by the base station to a specific UE cannot be used by other UEs. When a UE has uplink data that needs to be transmitted, the UE needs to request an allocation of uplink radio resource from the base station. The uplink radio resource requesting procedure is referred to as a buffer status report (BSR). For example, the BSR is transmitted from the UE to the base station, and contains information on the amount of data in each logical channel group that is ready for uplink transmission in the UE's buffers.

[0004] In the next generation (e.g., 5G) wireless communication networks, also referred to as New Radio (NR), a logical channel may be mapped to different numerologies (e.g., multiple TTIs and/or sub-carrier spacings and/or cyclic prefix). In order to support diverse use cases, (e.g., enhanced mobile broadband (eMBB), massive machine type communications (mMTC), and ultra-reliable low latency communications (URLLC)), which have a greater variety of quality of service (QoS) requirements than the 4G wireless networks, the physical layer of a UE in NR wireless

networks needs to be more flexible to support multiple numerologies.

[0005] A numerology with a shorter TTI length would be more helpful in reducing latency as compared to a numerology with a longer TTI length. However, a numerology with a longer TTI length could be useful for resource efficiency aspects for other use cases.

[0006] For example, URLLC with ultra-low latency requirements may benefit from transmitting data with short TTIs, while eMBB communications may focus on achieving high throughputs and not so stringent on short TTI requirements. Since the UE may perform several applications simultaneously in an NR network, with each application generating data for transmission with different QoS requirements and different TTIs, it is desirable for a single MAC layer to support one or more numerologies, and a radio bearer/logical channel that can be mapped to multiple numerologies (e.g., TTI durations).

[0007] Since a logical channel can be mapped to multiple numerologies in NR, the BSR by a UE can provide more precise information in the radio resource allocation request. Moreover, the conventional BSR and related behaviors (e.g., BSR retransmission, periodic BSR reporting and scheduling request (SR) triggering) in the legacy LTE systems need to be modified to support multiple numerology factors.

[0008] Hence, it is desirable for the radio resource allocation procedure, for example, performed by the base station to take into account of the UE's specific needs or demands when allocating radio resource to the UE in order to improve the overall efficiency of the radio resource utilization.

[0009] In addition, in the current LTE system, the buffer status is reporting on a logical channel group (LCG) basis, which accumulates resource requests from all of the logical channels (LCHs) belonging to the LCG. However, since the numerology mapping for each LCH can be different, it is desirable to have a new BSR format for reporting buffer status on a LCH basis in order to have more precise reporting.

SUMMARY

[0010] The present disclosure is directed to evolved buffer status report supporting multiple numerology factors.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Figure 1A is a diagram illustrating a grouping policy, according to an exemplary implementation of the present application.

[0012] Figure 1B is a diagram illustrating another grouping policy, according to an exemplary implementation of the present application.

[0013] Figure 1C is a diagram illustrating another grouping policy, according to an exemplary implementation of the present application.

[0014] Figure 2A is a diagram illustrating a default numerology determination method by a gNB, according to an exemplary implementation of the present application.

[0015] Figure 2B is a diagram illustrating a default numerology determination method by a UE, according to an exemplary implementation of the present application.

[0016] Figure 2C is a diagram illustrating a coordinated default numerology determination method, according to an exemplary implementation of the present application.

[0017] Figure 3A is an example of a numerology configuration with a UE-specific NSSN assignment, according to an exemplary implementation of the present application.

[0018] Figure 3B is an example of a numerology configuration with a Cell-specific assignment, or an NSSN assignment having identical/uniform NSSN throughout an entire NR wireless network system, according to an exemplary implementation of the present application.

[0019] Figure 4A is a diagram illustrating a short BSR CE with a default numerology indicator, according to an exemplary implementation of the present application.

[0020] Figure 4B is a diagram illustrating a long BSR control element with default numerology indicators - Type I, according to an exemplary implementation of the present application.

[0021] Figure 4C is a diagram illustrating a long BSR control element with default numerology indicators - Type II, according to an exemplary implementation of the present application.

[0022] Figure 4D is a diagram illustrating a LCH BSR CE with a default numerology indicator, according to an exemplary implementation of the present application.

[0023] Figure 5A is a diagram illustrating a short BSR CE with an NSSN, according to an exemplary implementation of the present application.

[0024] Figure 5B is a diagram illustrating a long BSR CE with NSSNs, according to an exemplary implementation of the present application.

[0025] Figure 5C is a diagram illustrating a LCH BSR CE with a numerology indicator, according to an exemplary implementation of the present application.

[0026] Figure 5D is a diagram illustrating a LCH BSR CE with multiple numerology indicators, according to an exemplary implementation of the present application.

[0027] Figure 6A is a diagram illustrating a short BSR CE with a numerology indicator and a 2-bit ratio of numerology, according to an exemplary implementation of the present application.

[0028] Figure 6B is a diagram illustrating a long BSR CE with numerology indicators and corresponding ratios of numerology, according to an exemplary implementation of the present application.

[0029] Figure 6C is a diagram illustrating a long BSR CE with numerology indicators and corresponding ratios of numerology, according to an exemplary implementation of the present application.

[0030] Figure 7A is a diagram illustrating a LCH BSR CE with a single NSSN and a 2-bit ratio of numerology, according to an exemplary implementation of the present application.

[0031] Figure 7B is a diagram illustrating a LCH BSR CE with a single NSSN and a 3-bit ratio of numerology, according to an exemplary implementation of the present application.

[0032] Figure 8A is a diagram illustrating a LCH BSR CE with multiple NSSNs and multiple 2-bit ratios of numerology, according to an exemplary implementation of the present application.

[0033] Figure 8B is a diagram illustrating a LCH BSR CE with multiple NSSNs and multiple 3-bit ratios of numerology, according to an exemplary implementation of the present application.

[0034] Figure 9A is a diagram illustrating a LCH BSR CE with three NSSNs and three 2-bit ratios of numerology, according to an exemplary implementation of the present application.

[0035] Figure 9B is a diagram illustrating a LCH BSR CE with three NSSNs and three 3-bit ratios of numerology, according to an exemplary implementation of the present application.

[0036] Figure 10 is a diagram illustrating a BSR retransmission diagram with a BSR retransmission timer and a scheduling request timer, according to an exemplary implementation of the present application.

[0037] Figure 11 is a diagram illustrating a BSR retransmission flow diagram with a BSR retransmission timer and a scheduling request timer, according to an exemplary implementation of the present application.

[0038] Figure 12 is a diagram illustrating a two-step random access procedure for BSR, according to an exemplary implementation of the present application.

[0039] Figure 13 is a block diagram illustrating a radio communication equipment, in accordance with an exemplary implementation of the present application.

DETAILED DESCRIPTION

[0040] The following description contains specific information pertaining to exemplary implementations in the present disclosure. The drawings in the present disclosure and their accompanying detailed description are directed to merely exemplary implementations. However, the present disclosure is not limited to merely these exemplary implementations. Other variations and implementations of the present disclosure will occur to those skilled in the art. Unless noted otherwise, like or corresponding elements among the figures may be indicated by like or corresponding reference numerals. Moreover, the drawings and illustrations in the present disclosure are generally not to scale, and are not intended to correspond to actual relative dimensions.

[0041] For the purpose of consistency and ease of understanding, like features are identified (although, in some examples, not shown) by numerals in the exemplary figures. However, the features in different implementations may be differed in other respects, and thus shall not be narrowly confined to what is shown in the figures.

[0042] The description uses the phrases "in one implementation," or "in some implementations," which may each refer to one or more of the same or different implementations. The term "coupled" is defined as connected, whether directly or indirectly through intervening components, and is not necessarily limited to physical connections. The term "comprising," when utilized, means "including, but not necessarily limited to"; it specifically indicates open-ended inclusion or membership in the so-described combination, group, series and the equivalent.

[0043] Additionally, for the purposes of explanation and non-limitation, specific details, such as functional entities, techniques, protocols, standard, and the like are set forth for providing an understanding of the described technology. In other examples, detailed description of well-known methods, technologies, system, architectures, and the like are omitted so as not to obscure the description with unnecessary details.

[0044] Persons skilled in the art will immediately recognize that any network function(s) or algorithm(s) described in the present disclosure may be implemented by hardware, software or a combination of software and hardware. Described functions may correspond to modules may be software, hardware, firmware, or any combination thereof. The software implementation may comprise computer executable instructions stored on computer readable medium such as memory or other type of storage devices. For example, one or more microprocessors or general purpose

computers with communication processing capability may be programmed with corresponding executable instructions and carry out the described network function(s) or algorithm(s). The microprocessors or general purpose computers may be formed of applications specific integrated circuitry (ASIC), programmable logic arrays, and/or using one or more digital signal processor (DSPs). Although some of the exemplary implementations described in this specification are oriented to software installed and executing on computer hardware, nevertheless, alternative exemplary implementations implemented as firmware or as hardware or combination of hardware and software are well within the scope of the present disclosure.

[0045] The computer readable medium includes but is not limited to random access memory (RAM), read only memory (ROM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), flash memory, compact disc read-only memory (CD ROM), magnetic cassettes, magnetic tape, magnetic disk storage, or any other equivalent medium capable of storing computer-readable instructions.

[0046] A radio communication network architecture (e.g., a long term evolution (LTE) system, a LTE-Advanced (LTE-A) system, or a LTE-Advanced Pro system) typically includes at least one base station, at least one user equipment (UE), and one or more optional network elements that provide connection towards a network. The UE communicates with the network (e.g., a core network (CN), an evolved packet core (EPC) network, an Evolved Universal Terrestrial Radio Access network (E-UTRAN), a Next-Generation Core (NGC), 5G Core Network (5GC), or an internet), through a radio access network (RAN) established by the base station.

[0047] It should be noted that, in the present application, a UE may include, but is not limited to, a mobile station, a mobile terminal or device, a user communication radio terminal. For example, a UE may be a portable radio equipment, which includes, but is not limited to, a mobile phone, a tablet, a wearable device, a sensor, or a personal digital assistant (PDA) with wireless communication capability. The UE is configured to receive and transmit signals over an air interface to one or more cells in a radio access network.

[0048] A base station may include, but is not limited to, a node B (NB) as in the UMTS, an evolved node B (eNB) as in the LTE-A, a radio network controller (RNC) as in the UMTS, a base station controller (BSC) as in the GSM/GERAN, an NG-eNB as in an E-UTRA base station in connection with the 5GC, a next generation node B (gNB) as in the 5G-RAN, and any other apparatus capable of controlling radio communication and managing radio resources within a cell.

The base station may connect to serve the one or more UEs through a radio interface to the network.

[0049] A base station may be configured to provide communication services according to at least one of the following radio access technologies (RATs): Worldwide Interoperability for Microwave Access (WiMAX), Global System for Mobile communications (GSM, often referred to as 2G), GSM EDGE radio access Network (GERAN), General Packet Radio Service (GRPS), Universal Mobile Telecommunication System (UMTS, often referred to as 3G) based on basic wideband-code division multiple access (W-CDMA), high-speed packet access (HSPA), LTE, LTE-A, eLTE (evolved LTE), New Radio (NR, often referred to as 5G), and/or LTE-A Pro. However, the scope of the present application should not be limited to the above mentioned protocols.

[0050] The base station is operable to provide radio coverage to a specific geographical area using a plurality of cells forming the radio access network. The base station supports the operations of the cells. Each cell is operable to provide services to at least one UE within radio coverage of the cell. More specifically, each cell (often referred to as a serving cell) provides services to serve one or more UEs within the cell's radio coverage, (e.g., each cell schedules the downlink and optionally uplink resources to at least one UE within the cell's radio coverage for downlink and optionally uplink packet transmissions). The base station can communicate with one or more UEs in the radio communication system through the plurality of cells. A cell may allocate sidelink (SL) resources for supporting proximity service (ProSe). Each cell may have overlapped coverage areas with other cells.

[0051] As discussed above, the frame structure for NR is to support flexible configurations for accommodating various next generation (e.g., 5G) communication requirements, such as eMBB, mMTC, and URLLC, while fulfilling high reliability, high data rate and low latency requirements. The orthogonal frequency-division multiplexing (OFDM) technology as agreed in 3GPP may serve as a baseline for NR waveform. The scalable OFDM numerology, such as the adaptive sub-carrier spacing, the channel bandwidth, and the Cyclic Prefix (CP) may be also used. Additionally, two coding schemes are considered for NR: (1) low-density parity-check (LDPC) code and (2) Polar Code. The coding scheme adaption may be configured based on the channel conditions and/or the service applications.

[0052] Moreover, it is also considered that in a transmission time interval TX of a single NR frame, a downlink (DL) transmission data, a guard period, and an uplink (UL) transmission

data should at least be included, where the respective portions of the DL transmission data, the guard period, the UL transmission data should also be configurable, for example, based on the network dynamics of NR. In addition, sidelink resource may also be provided in a NR frame to support ProSe services.

[0053] Exemplary implementations of the present application relate to evolved BSR mechanisms which can be applied when multiple numerologies are supported and a LCH is configured with multiple numerologies, each having multiple numerology factors. The evolved BSR mechanisms may include logical channel grouping, BSR transmission, BSR retransmission, and scheduling request. Examples of numerology factors may include, but are not limited to, TTI length, subcarrier spacing (SCS), and of cyclic prefix (CP) length. It should be noted that the BSR transmission/retransmission and SR procedures can be logically extended to implementations in which a logical channel is configured with other numerology factor(s).

[0054] **Case 1: Logical Channel Grouping**

[0055] In one exemplary implementation of the present application, a UE may report its buffer status on a logical channel group (LCG) basis. A base station (e.g., a next generation Node B (gNB)) may group the UE's logical channels into several LCGs, and transmit a LCG list to the UE, for example, through a downlink RRC message (e.g., RRCReconfiguration message). The LCG list may include a list of LCHs belonging to each LCG. In contrast to conventional BSR procedures, the grouping policy for the evolved BSR mechanism allows the base station (e.g., gNB) to consider the mapping between numerologies and logical channels. Since the numerologies mapped by each logical channel can be different, exemplary implementations of the present application present three grouping policies as follows.

[0056] **Case 1.1: Grouping Policies**

[0057] As shown in Figures 1A and 1B, a base station (e.g., gNB) may group the logical channels of a UE based on the numerologies to which the logical channels each map. In Figure 1A, in grouping policy 100A, LCH 1 and LCH 2 both map to numerologies 1 and 3 (e.g., N1 and N3) in a MAC layer. LCH 3 and LCH 4 both map to numerologies 3 and 4 (e.g., N3 and N4) in the MAC layer. Thus, the base station may group LCH 1 and LCH 2 together in LCG 1 since the numerologies (e.g., N1 and N3) to which LCH 1 and LCH 2 are map are identical. The base station may also group LCH 3 and LCH 4 together in LCG 3 since the numerologies (e.g., N3 and N4) to which LCH 3 and LCH 4 are map are identical.

[0058] As shown in Figure 1B, in grouping policy 100B, LCH 1 maps to N1 and N2. LCH 2 maps to N2 and N3. LCH 3 maps to N1 and N4. LCH 4 maps to N3 and N4. In one implementation, the base station may group LCH 1 and LCH 2 together in LCG 1 since LCH 1 and LCH 2 both map to N2, although LCH 1 and LCH 2 also map to N1 and N3, respectively. The base station may group LCH 3 and LCH 4 together in LCG 2 since LCH 3 and LCH 4 both map to N4, although LCH 3 and LCH 4 also map to N1 and N3, respectively. In another implementation, the base station may group LCH 1 and LCH 3 together in one LCG since they both map to N1, and group LCH 2 and LCH 4 together in another LCG since they both map to N3. It is noted that in Figures 1A and 1B, the base station performs grouping based on the numerologies mapped to by each logical channel.

[0059] As shown in Figure 1C, in grouping policy 100C, a base station (e.g., gNB) may group the logical channels from the perspective of the numerologies. That is, each numerology may have its own LCG. For example, for each numerology, all of the logical channels that map to the numerology are grouped to a LCG. As shown in Figure 1C, LCH 1 maps to N1 and N2. LCH 2 maps to N2 and N3. LCH 3 maps to N1 and N4. LCH 4 maps to N3 and N4. The base station may group LCH 1 and LCH 3 together in LCG 1 since they both map to N1. The base station may group LCH 1 and LCH 2 together in LCG 2 since they both map to N2. The base station may group LCH 2 and LCH 4 together in LCG 3 since they both map to N3. The base station may group LCH 3 and LCH 4 together in LCG 4 since they both map to N4. It is noted that in Figure 1C, a logical channel may belong to more than one LCG, if the logical channel is mapped to more than one numerology. Thus, the BSR for each LCG is counting based on the amount of data that needs to be transmitted on the corresponding numerology. It is noted that in Figure 1C, the base station performs grouping from each numerology's perspective.

[0060] It should be noted that the multiple grouping policies shown in Figures 1A-1C can be applied to a UE simultaneously. Moreover, in Figures 1A and 1B, a default numerology within each LCG can also be determined and set, since not every numerology's radio resource (e.g., uplink radio resource) and configuration for the LCG is needed all the time. The UE can usually request the default numerology's radio resource (e.g., uplink radio resource) and request radio resource for other numerologies only when needed. Moreover, in order to reduce signaling overhead on numerology indications between the UE and the base station (e.g., gNB), each LCH/LCG can be pre-configured with a default numerology among all the numerologies the

LCH/LCG may map to.

[0061] Case 1.2: Default Numerology Determination

[0062] Figures 2A, 2B and 2C show three methods for default numerology determination. Figure 2A is a diagram illustrating a default numerology determination method by a gNB, according to an exemplary implementation of the present application. As shown in Figure 2A, in method 200A, in action 210, base station 204 (e.g., a gNB) performs grouping of the LCHs to form a LCG list, determines/configures a default numerology for each LCG, and transmits the determination/configuration to UE 202, for example, through a downlink RRC message (e.g., an *RRCReconfiguration* message). In action 212, UE 202 sends an acknowledgement or a non-acknowledgement, for example, through an uplink RRC message (e.g., an *RRCReconfigurationComplete* message). Thus, in method 200A, base station 204 determines the default numerology for each LCG.

[0063] Figure 2B is a diagram illustrating a default numerology determination method by a UE, according to an exemplary implementation of the present application. As shown in Figure 2B, in method 200B, in action 220, base station 204 (e.g., a gNB) performs grouping of the LCHs to form a LCG list, and transmits the LCG list to UE 202, for example, through a downlink RRC message (e.g., an *RRCReconfiguration* message). In action 222, UE 202 then determines/configures a default numerology for each LCG, and transmits a default numerology of each LCG to base station 204, for example, through an uplink RRC message (e.g., an *RRCReconfigurationComplete* message). Thus, in method 200B, UE 202 determines the default numerology for each LCG.

[0064] Figure 2C is a diagram illustrating a coordinated default numerology determination method, according to an exemplary implementation of the present application. As shown in Figure 2C, in method 200C, in action 230, UE 202 provides assisting information or a default numerology preference for each LCH/LCG to base station 204 (e.g., a gNB) to aid base station 204 in making determination of a default numerology for each LCH/LCG. In Figure 2C, UE 202 provides the assisting information and/or default numerology preference of each LCH or LCG to base station 204. The assisting information may include QoS requirements of each LCH/LCG and traffic pattern. Upon receiving the assisting information and/or default numerology preference from UE 202, in action 232, base station 204 performs grouping of the LCHs to form a LCG list based on one or more grouping policies, determines/configures a default numerology for each LCH/LCG

based on the assisting information and/or default numerology preference, and transmits the LCH/LCG list and the default numerology for each LCH/LCG to UE 202, for example, through a downlink RRC message (e.g., an *RRCReconfiguration* message). In action 234, UE 202 sends an acknowledgement or a non-acknowledgement, for example, through an uplink RRC message (e.g., an *RRCReconfigurationComplete* message). Thus, in method 200C, UE 202 coordinates with base station 204 to determine the default numerology for each LCG. In method 200C, base station 204 makes the final decisions on which grouping policy(ies) to adopt and the default numerology for each LCG.

[0065] **Case 1.3: Numerology Configuration**

[0066] When a base station (e.g., gNB) configures a UE's logical channels, the corresponding numerology configurations for the logical channels can also be provided, for example, through the RRC signaling. For example, the numerology configurations for the logical channels can be transmitted from the base station to the UE through the *RRCReconfiguration* message, which contains a *CellGroupConfig* information element. The numerology configuration of each logical channel can be independently configured.

[0067] As illustrated in Figures 3A and 3B, a base station (e.g., gNB) configures each logical channel with settings on a number of numerology factors, including but not limited to SCS, CP and TTI. It is noted that all of the numerology factors can be optionally contained in the numerology configuration. Other numerology factors (e.g., including numerology factors that may be incorporated into the NR standards in the future) can also be included in the RRC message by adding more parameters. In Figure 3A, the base station (e.g., gNB) can also indicate which set of numerology factors is used as the default numerology for the LCH and/or the LCG to which the LCH belongs, in the numerology configuration.

[0068] Since a logical channel can be mapped to multiple numerologies, the base station can configure multiple sets of numerology factors for each individual logical channel. The base station can also assign a numerology set sequence number (NSSN) to each set of numerology configuration. The NSSN can be transmitted together with downlink control information (DCI) from the base station to the UE to indicate or provide the numerologies of the scheduled uplink radio resource.

[0069] The NSSN assignment can be UE-specific, Cell-specific, or identical/uniform throughout an entire NR wireless network system. When the NSSN assignment is UE-specific,

the NSSN is only valid within each LCH or LCG toward a specific UE. When the NSSN assignment is Cell-specific, the NSSN is uniquely mapped to a combination of configurations on the numerology factors within a specific cell. When the NSSN assignment is identical/uniform throughout an entire NR wireless network system, the NSSN is uniquely mapped to a combination of configurations on the numerology factors within an entire NR wireless network system.

[0070] Figure 3A is an example of a numerology configuration with a UE-specific NSSN assignment, according to an exemplary implementation of the present application. In diagram 300A, each numerology configuration set has multiple numerology factors and their corresponding settings.

[0071] Figure 3B is an example of a numerology configuration with a Cell-specific assignment, or an NSSN assignment having identical/uniform NSSN throughout an entire NR wireless network system, according to an exemplary implementation of the present application. For example, a base station directly configures each LCH with a NSSN that has a fixed mapping to a combination of configurations on the numerology factors as shown in diagram 300B without the numerology factor(s) setting. The mapping between each NSSN and the corresponding detailed configuration on each numerology factor can be predefined or broadcast by the base station via system information (SI), for example.

[0072] When a UE is performing handover from a serving cell or base station (e.g., a serving gNB) to a target cell or base station (e.g., a target gNB), the default numerology configurations can be forward from the serving cell or base station to the target cell or base station in the handover preparation stage, such as during a handover request message transmission from the serving base station to the target base station. For UE-specific NSSN assignment and Cell-specific NSSN assignment cases, the serving cell or base station may need to forward all of the configurations of default numerology to the target cell or base station. But for the case of NSSN identical/uniform throughout an entire NR wireless network system, the serving cell or base station may only need to forward the NSSN of default numerology to the serving cell or base station.

[0073] **Case 2: BSR Transmission**

[0074] When a UE transmits a BSR to a base station (e.g., a gNB), the UE may either implicitly or explicitly notify the base station its numerology preference(s) for a requested uplink resource. In LTE, based on the number of LCGs contained in a BSR control element (CE), the BSR CE can be categorized as long BSR CEs and short BSR CEs.

[0075] According to exemplary implementations of the present application, since the more detailed information the base station can gather/accumulate, the better precision on resource allocation for each numerology that the base station can achieve, a new BSR CE category, in addition to long BSR CE and short BSR CE, is introduced in the present application. The new BSR CE category is called LCH BSR CE. The LCH BSR CE contains the resource request corresponding to a single logical channel.

[0076] A BSR CE can include various fields. Different categories of BSR CEs may include different fields and/or different combinations. Table-1 below shows various combinations of BSR CE formats, and their corresponding MAC sub-headers. In some BSR CE formats, the default numerology is pre-configured. In other BSR CE formats, the default numerology is not pre-configured.

Table-1: The Fields within a Buffer Status Report Control Element.

BSR CE Field	BSR CE Field Description
LCG ID	The Logical Channel Group ID identifies the group of logical channel(s) which buffer status is being reported. The length of the field may be, for example, 3 bits. The number of bits for this field is dependent on the number of logical channels.
Buffer Size #*X*	The Buffer Size field #*X* identifies the total amount of data available across all logical channels of a logical channel group *X*, similar to the definition in LTE. The length of the Buffer Size field #*X* field can be, for example, 8 bits.
Buffer Size*x*	The Buffer Size$_X$ identifies the total amount of data available for numerology *X* within a logical channel. The length of the Buffer Size$_X$ field can be, for example, 8 bits.
D	The default numerology indicator, D, indicates whether the numerology of the requested uplink resource is limited to default numerology or not. The length of the D field can be, for example, 1 bit.

NSSN	The NSSN identifies the numerology preference for a LCG/LCH. The length of the NSSN field can be multiple bits (e.g., 8 bits). The length of the NSSN field can be defined by the base station (e.g., gNB).
NSSN # *X*	The NSSN #*X* identifies the numerology preference for LCG *X*. The length of the NSSN #*X* field can be multiple bits (e.g., 8 bits). The length of the NSSN #*X* field can be defined by the base station (e.g., gNB).
NSSN$_X$	The NSSN$_X$ identifies the *x*th numerology preference for a LCH. The length of the NSSN$_X$ field can be multiple bits (e.g., 8 bits). The length of the NSSN$_X$ field can be defined by the base station (e.g., gNB).
RN	The Ratio of Numerology identifies the numerology set that UE prefers for all or a portion (e.g., a ratio) of the requested uplink resources for each LCG/LCH. The length of the RN field can be, for example, 2 bits. As the number of bits used in the RN field increases, the finer granularity of reporting can be achieved.
RN #*X*	The RN #*X* identifies the numerology set that UE prefers for all or a portion (e.g., a ratio) of the requested uplink resources for LCG *X*. The length of the RN #*X* field can be multiple bits (e.g., 2 bits). As the number of bits used in the RN #*X* field increases, the finer granularity of reporting can be achieved.
RN$_X$	The RN$_X$ identifies the *x*th numerology set that UE prefers for all or a portion (e.g., a ratio) of the requested uplink resources for a LCH. The length of the RN$_X$ field can be multiple bits (e.g., 2 bits). As the number of bits used in the RN$_X$ field increases, the finer granularity of reporting can be achieved.
LCID	The LCID identifies which resource is requested by which logical channel.

R	The R identifies one or more reserve bits reserved for future usage.

[0077] Case 2.1: Pre-Configured Default Numerology with Explicit Numerology Preference Indication

[0078] When a UE is pre-configured with a default numerology, and when the UE reports a BSR to a base station, a flag bit (e.g., a default numerology indicator, *D*, field in the MAC sub-header) can be applied by the UE to indicate whether the numerology of the requested uplink resource is limited to the default numerology or not. The flag bit can be placed within a BSR CE.

[0079] As shown in Figure 4A, when a UE is reporting a short BSR CE or truncated BSR CE (e.g., only reporting for a single LCG), a flag bit (e.g., D field) can be placed within the short BSR CE. Figure 4A illustrates a short BSR CE 400A with a default numerology indicator, according to an exemplary implementation of the present application. In Figure 4A, since only one LCG's buffer status is reported, the short BSR CE includes a LCG ID in Octet 1, where the LCG ID occupies 3 bits. Also, the default numerology indicator D is included in Octet 1, which means that the numerology of the requested uplink resource is limited to the default numerology. Octet 1 also includes multiple reserve bits (e.g., R), which occupy 4 bits in Octet 1. As shown in Figure 4A, the short BSR CE also includes Octet 2 reporting the buffer size for the LCG.

[0080] As shown in Figures 4B and 4C, when a UE is reporting a long BSR CE (e.g., reporting for multiple LCGs), each LCG may include its own flag bit within the long BSR CE. Figure 4B illustrates a long BSR control element with default numerology indicators - Type I, according to an exemplary implementation of the present application. As shown in Figure 4B, in a long BSR CE 400B, the flag bit for each LCG may be placed together in Octet 1, while the buffer size for each corresponding LCG is placed in a separate octet in the long BSR CE (e.g., Buffer size #0 through Buffer size #7 being placed in Octet 2 through Octet 9, respectively). Figure 4C illustrates a long BSR control element with default numerology indicators - Type II, according to an exemplary implementation of the present application. As shown in Figure 4C, in another implementation, the flag bit for each LCG may be placed in a separate octet along with the corresponding LCG's buffer size field as shown in Figure 4C. In Figure 4C, in a long BSR CE 400C, the buffer size for LCG_0 (e.g., Buffer Size #0) occupies 7 bits in Octet 1, and 1 bit in Oct 2. The buffer size for LCG_1 (e.g., Buffer Size #1) occupies 6 bits in Octet 2, and 2 bits in Oct 3. The buffer size for LCG_2 (e.g., Buffer Size #2) occupies 5 bits in Octet 3, and 3 bits in Oct 4, and so

on. The flag bit for each LCG may be placed in front of its corresponding buffer size. For example, the default numerology indicator for LCG_0 (e.g., D_0) is placed in Octet 1 and in front of Buffer Size #0. Similarly, the default numerology indicator for LCG_1 (e.g., D_1) is placed in Octet 2 and in front of Buffer Size #1, and so on. As shown in Figure 4C, the default numerology indicator for LCG_7 (e.g., D_7) is placed in Octet 8 and in front of Buffer Size #7 in Octet 9.

[0081] If a flag bit(s) is not set up, it implies that the uplink resource the UE is requesting does not have any restriction or limitation on numerology (e.g., not subject to default numerology). It is noted that, in Figures 4B and 4C, since the long BSR CE is used, the LCG IDs are not necessary since all of the LCGs including their default numerology indicators and buffer sizes are included in the long BSR CE.

[0082] Figure 4D illustrates an exemplary format of a LCH BSR CE with a default numerology indicator, according to an exemplary implementation of the present application. In Figure 4D, a UE is reporting resource request for a single logical channel. In Figure 4D, a LCH BSR CE 400D includes a LCID in Octet 1, where the LCID indicates which logical channel sent the BSR. In the present exemplary implementation, the LCID occupies 4 bits in Octet 1. Also, the default numerology indicator D is included in Octet 1, which means that the numerology of the requested uplink resource is limited to the default numerology. Octet 1 also includes multiple reserve bits (e.g., R), which occupy 3 bits in Octet 1. As shown in Figure 4D, the LCH BSR CE also includes Octet 2 which includes the buffer size, where the buffer size indicates the amount of data available for the logical channel as identified by the LCID.

[0083] **Case 2.2: No Default Numerology Pre-Configured with Explicit Numerology Preference Indication**

[0084] As shown in Figures 5A and 5B, when a default numerology is not pre-configured, a UE may include one or more numerology indicators (e.g., NSSNs) to inform a base station the numerology corresponding to each LCG explicitly in the BSR CE. Each LCG has its own numerology indicator.

[0085] Figure 5A illustrates a short BSR CE with an NSSN, according to an exemplary implementation of the present application. As shown in Figure 5A, when a UE is reporting a short BSR CE or truncated BSR CE (e.g., only reporting for a single LCG), an NSSN can be placed within the short BSR CE. Figure 5A illustrates a short BSR CE 500A with a numerology indicator (e.g., an NSSN). In Figure 5A, since only a single LCG's buffer status is reported, the short BSR

CE 500A includes a LCG ID in Octet 1, where the LCG ID occupies 3 bits. The rest of Octet 1 is occupied by 5 reserve bits (e.g., R). In the short BSR CE 500A, an NSSN is included in Octet 2. In addition, the short BSR CE 500A also includes Octet 3 reporting a buffer size for the LCG.

[0086] Figure 5B illustrates a long BSR CE with NSSNs, according to an exemplary implementation of the present application. In Figure 5B, a long BSR CE 500B includes buffer status reports for all of the LCGs (including the NSSNs for the corresponding LCGs) at the same time. As shown in Figure 5B, when a UE is reporting a long BSR CE (e.g., reporting for multiple LCGs), each LCG may include its own numerology indicator (e.g., NSSN #*X*) within the long BSR CE. As shown in Figure 5B, NSSN #0 occupies Octet 1, while the buffer size for the corresponding LCG_0 (e.g., Buffer Size #0) is placed in Octet 2. NSSN #1 occupies Octet 3, while the buffer size for the corresponding LCG_1 (e.g., Buffer Size #1) is placed in Octet 4. It is noted that in Figure 5B, since the long BSR CE is used, the LCG IDs are not necessary since all of the LCGs including their numerology indicators (NSSNs) and buffer sizes are included in the long BSR CE 500B.

[0087] Figure 5C illustrates an exemplary format of a LCH BSR CE with a single numerology indicator (e.g., NSSN), according to an exemplary implementation of the present application. In Figure 5C, a UE is reporting resource request for a single logical channel. In Figure 5C, a LCH BSR CE 500C includes a LCID in Octet 1, where the LCID indicates which logical channel sent the BSR. In the present exemplary implementation, the LCID occupies 4 bits in Octet 1. The remaining bits in Octet 1 are occupied by reverse bits (e.g., R). The numerology indicator, NSSN, is included in Octet 2, where the NSSN indicates the preferred numerology for the logical channel having the LCID specified in Octet 1. As shown in Figure 5C, the LCH BSR CE 500C also includes Octet 3 reporting the buffer size, where the buffer size indicates the amount of data available for the logical channel having the LCID specified in Octet 1.

[0088] Figure 5D illustrates a LCH BSR CE with multiple numerology indicators (e.g., NSSNs), according to an exemplary implementation of the present application. In one exemplary implementation, the BSR format is used when a UE needs to request uplink radio resource for a single LCH with multiple numerologies in order to be more precise for each numerology. In Figure 5D, the UE is reporting resource request for a single logical channel. In Figure 5D, a LCH BSR CE 500D includes a LCID in Octet 1, where the LCID indicates which logical channel sent the BSR. In the present exemplary implementation, the LCID occupies 4 bits in Octet 1. The remaining bits in Octet 1 are occupied by reverse bits (e.g., R). The UE indicates the amount of

uplink radio resource needed by adding the corresponding NSSN and Buffer Size field for each of the numerologies. The number of NSSNs and Buffer Size fields depend on the number of numerologies the UE requests. Thus, the number of octets in the LCH BSR CE 500D may vary.

[0089] Figure 6A illustrates a short BSR CE 600A with a numerology indicator and a ratio of numerology, according to an exemplary implementation of the present application. Figure 6B illustrates a long BSR CE 600B with numerology indicators and corresponding 2-bit ratios of numerology, according to an exemplary implementation of the present application. Figure 6C illustrates a long BSR CE 600C with numerology indicators and corresponding 3-bit ratios of numerology, according to an exemplary implementation of the present application. As illustrated in Figures 6A, 6B, and 6C, a BSR CE may include an extra field, RN (Ratio of Numerology) for indicating the numerology that the UE prefers for all or a portion of the requested uplink resource for a LCG or for all of the LCGs. For example, the UE can follow a ratio table defined and configured by a base station (e.g., gNB) to indicate the ratio. In one implementation, if 2 bits are applied for indicating the ratio in the RN field, "00" may indicate that 25% of the requested uplink resource for the corresponding LCG is limited to the preferred numerology and the remaining percentage of the requested uplink resource does not have any limitation. Similarly, "01", "10", and "11" may indicate that 50%, 75%, and 100%, respectively, of the requested uplink resource for the corresponding LCG is limited to the preferred numerology and the remaining percentage of the requested uplink resource does not have any limitation. The more bits used for indicating the ratio, the finer the granularity that the ratio can be indicated. Also, the UE can use the RN to indicate that it only expects/needs uplink radio resource on specific numerology(ies). RN may occupy 3 bits as shown in Figures 6C, 7B, 8B, and 9B, for example.

[0090] Figure 7A illustrates a LCH BSR CE 700A with a single NSSN and a 2-bit RN. In Figure 7A, a UE is reporting resource request for a single logical channel. In Figure 7A, the LCH BSR CE includes a LCID in Octet 1, where the LCID indicates which logical channel sent the BSR. In the present exemplary implementation, the LCID occupies 4 bits in Octet 1. Octet 1 also includes an RN occupying 2 bits. The rest of Octet 1 is occupied by 2 reserve bits (e.g., R). The LCH BSR CE includes Octet 2 having an NSSN that indicates the preferred numerology for the LCH identified by the LCID in Octet 1. The LCH BSR CE also includes Octet 3 which includes a buffer size, where the buffer size indicates the amount of data available for the LCH identified by the LCID in Octet 1. The RN in Octet 1 indicates a percentage (e.g., 25%, 50%, 75%, and

100%) of the total buffer size that the UE desires the uplink radio resource to have with the preferred numerology. Figure 7B illustrates a LCH BSR CE 700B with a single NSSN and a 3-bit ratio of numerology, according to an exemplary implementation of the present application. Different from Figure 7A, the NSSN in Figure 7B occupies 3 bits in Octet 1, while the remaining bit of Octet 1 is occupied by 1 reserve bit (e.g., R). Having a 3-bit NSSN allows the UE to achieve a finer granularity for the ratio of numerology (e.g., 12.5%, 25%, 37.5%, 50%, 62.5%, 75%, 87.5%, and 100%).

[0091] Figure 8A illustrates a LCH BSR CE with multiple NSSNs and multiple 2-bit ratios of numerology, according to an exemplary implementation of the present application. In Figure 8A, the LCH BSR CE format is used when a UE needs to request uplink radio resource for a single LCH having multiple numerologies. As illustrated in Figure 8A, in the LCH BSR CE 800A, the UE may indicate the total amount of uplink radio resource on all of the numerologies by a Buffer Size field. Also, the UE may indicate the amount of uplink radio resource requested on each numerology by having multiple RNs and NSSNs. The number of NSSNs and the RNs fields are the same as the number of numerologies, respectively, that the UE requests. Thus, the length of the LCH BSR CE 800A may vary based on the number of numerologies the LCH prefers to configure. Figure 8B illustrates a LCH BSR CE 800B with multiple NSSNs and multiple 3-bit ratios of numerology, according to an exemplary implementation of the present application. It should be noted that, in Figures 8A and 8B, the total the sum of the percentages reflected by the corresponding RNs should be less than or equal to 100%.

[0092] Figure 9A illustrates an exemplary format of a LCH BSR CE 900A with three NSSNs and three 2-bit ratios of numerology, according to an exemplary implementation of the present application. Figure 9B illustrates an exemplary format of a LCH BSR CE 900B with three NSSNs and three 3-bit ratios of numerology, according to an exemplary implementation of the present application.

[0093] According to exemplary implementations of the present application, a UE may use the LCID field in the MAC sub-header to indicate the format of the transmitted BSR CE. Table-2 shows a list of LCIDs and their corresponding BSR formats, according to an exemplary implementation of the present application. It is noted that the values of the LCIDs shown in Table-2 are intend for illustration purpose only, as other values and total number to bits may be used for the LCIDs.

Table-2: Examples of Values of LCID

LCID	BSR Format
000000	Short BSR control element with default numerology indication
000001	Long BSR control element with default numerology indication - Type I
000010	Long BSR control element with default numerology indication - Type II
000011	LCH BSR control element with default numerology indication
000100	Short BSR control element with NSSN
000101	Long BSR control element with NSSN
000110	LCH BSR control element with single NSSN
000111	LCH BSR control element with multiple NSSN
001000	Short BSR control element with NSSN and RN
001001	Long BSR control element with NSSN and RN (2bits)
001010	Long BSR control element with NSSN and RN (3bits)
001011	LCH BSR control element with single NSSN and RN (2bits)
001100	LCH BSR control element with single NSSN and RN (3bits)
001101	LCH BSR control element with multiple NSSN and RN (2bits)
001110	LCH BSR control element with multiple NSSN and RN (3bits)

[0094] Case 2.3: Pre-Configured Default Numerology with Implicit Numerology Preference Indication

[0095] Similar as Case 2.1 above, a UE may notify a base station (e.g., gNB) whether the request uplink resource is limited to default numerology or not. Different from Case 2.1, instead of using a default numerology indicator (e.g., D), the UE in the present implementation uses a predefined logical channel ID (LCID) in the BSR message (e.g., LCID within the corresponding sub-header for the BSR) for the base station to distinguish whether the request uplink resource is limited to default numerology or not. For example, the LCID may be applied in a short BSR

message containing a single LCG.

[0096] Case 2.4: No Default Numerology Pre-Configured with Implicit Numerology Preference Indication

[0097] In this exemplary implementation, a base station (e.g., gNB) may configure a physical uplink shared channel (PUSCH) for each numerology. Thus, each numerology has its own PUSCH allocated by the base station. A UE may implicitly notify the base station its preferred numerology through the specific PUSCH by which the UE transmits the BSR message. For example, when a UE needs uplink radio resource having a specific numerology, the UE may transmit a BSR message through a PUSCH that specifically corresponds to the UE's preferred numerology to notify the base station about the UE's preferred numerology. It should be noted that the UE may also include a numerology indicator in a BSR message for requesting uplink resource having other numerologies.

[0098] Case 3: BSR Retransmission

[0099] Figure 10 illustrates a BSR retransmission diagram 1000 with a BSR retransmission (Retx) timer and a scheduling request timer, according to an exemplary implementation of the present application. Figure 11 illustrates a BSR retransmission flow diagram with a BSR retransmission timer and a scheduling request timer, according to an exemplary implementation of the present application. As shown in Figures 10 and 11, a BSR retransmission timer is configured to overcome a situation where a UE had sent a BSR message but has not received any uplink resource after a predetermined time set be the BSR retransmission timer (retxBSR-Timer). In such case, the UE is allowed to trigger a BSR retransmission after the retxBSR-Timer is expired. In the case of numerology preference mechanism described in Case 2.4 above is applied, the UE may request uplink radio resource having a specific numerology by transmitting a BSR message on a specific PUSCH that corresponds to the preferred numerology. In one exemplary implementation, since the data ready for transmission has been already queued in the buffer for a while (e.g., longer that predetermined time of the retxBSR-Timer), it may be beneficial for the UE to trigger BSR retransmission in any numerology/OFDM symbol which has shorter/shortest TTI duration to reduce reporting latency. This procedure may apply to a portion of the logical channels. For example, the base station can configure an across numerology restriction mask for one or more logical channels that have permission to retransmit BSRs in other numerologies.

[00100] In another implementation, by configuring a *SR_direct* mask for a specific

LCH/LCG, the base station (e.g., gNB) may configure/limit the specific LCH/LCG to perform scheduling request (SR) transmission directly, if the waiting time on a SR resource is shorter than the resource on BSR retransmission. For example, the *SR_direct* mask can be configured within a downlink RRC message (e.g., *RRCReconfiguration*).

[00101] As shown in Figure 11, flow chart 1100 starts with action 1102. In action 1104, there is uplink data for a logical channel becomes available for transmission in the buffer (either RLC entity or in the PDCP entity). In action 1106, the UE triggers a regular BSR procedrue. In action 1108, if the logical channel is configured with Scheduling Request prohibit timer (SR-ProhibitTimer, T_{SR}), the UE starts or restart the SR-ProhibitTimer.

[00102] In action 1110, the UE waits for uplink resource grant for devierling BSR message (MAC control element). If the UE is granted UL resources for new transmission for this TTI, the UE transmits the BSR message in action 1112. Then, the UE starts or restarts a BSR message retransmission timer (retxBSR-Timer, T_{retx}) configured by the base station (e.g., gNB) in action 1114. The flow chart 1110 proceeds from action 1114 to action 1116 to increment the TTI to TTI+1.

[00103] If the UE is not granted with any UL resources for new transmission for this TTI, the UE may trigger an SR procedure in action 1120, if the BSR has been triggered, and the T_{SR} is not running or has expried in action 1118. If the T_{SR} is not expried, then, the flow chart 1110 proceeds from action 1118 to action 1116 to increment the TTI to TTI+1.

[00104] In action 1122, if the BSR tretransmission timer (T_{retx}) is expired, then the flow chart 1100 proceeds to action 1124, where the UE retransmits the BSR in another numerology. In action 1122, if the BSR tretransmission timer (T_{retx}) has not expired, then the flow chart 1100 proceeds to action 1110, where the UE waits for UL resources to be granted by the base station. The flow chart 1100 ends with action 1126.

[00105] **Case 4: Scheduling Request (SR)**

[00106] **Case 4.1: Masking Specific LCH for Triggering Random Access with Small Data Transmission When No BSR Resource Is Granted**

[00107] Figure 12 illustrates a two-step random access procedure for BSR, according to an exemplary implementation of the present application. As shown in flow diagram 1200, once a BSR had been sent from a UE to a base station in action 1202, and no uplink resource is granted by the base station in action 1204, the UE may use a two-step random access (RA) procedure to

transmit its BSR message and/or a small amount of data in its buffer directly to the base station. The UE may include its BSR message in MSG 1 (e.g., a preamble, or a mapping resource). Before using the two-step RA procedure in action 1208, the UE may need to check whether a BSR transmission via a two-step RA mask for a corresponding logical channel is setup/configured by the base station in action 1206. The UE can use two-step RA mask only when the mask for the corresponding logical channel is setup. For example, the two-step RA mask configuration can be transmitted to the UE in a downlink RRC message (e.g., *RRCReconfiguration*). If the mask for the corresponding logical channel is not setup, the UE may use transmit its BSR message to the base station through a scheduling request in action 1210.

[00108] Figure 13 illustrates a block diagram of a node for wireless communication, in accordance with various aspects of the present application. As shown in Figure 13, a node 1300 may include a transceiver 1320, a processor 1326, a memory 1328, one or more presentation components 1334, and at least one antenna 1336. The node 1300 may also include an RF spectrum band module, a base station communications module, a network communications module, and a system communications management module, input/output (I/O) ports, I/O components, and power supply (not explicitly shown in Figure 13). Each of these components may be in communication with each other, directly or indirectly, over one or more buses 1340. In one implementation, the node 1300 may be a UE or a base station that performs various functions described herein, for example, with reference to Figures 1 through 12.

[00109] The transceiver 1320 having a transmitter 1322 and a receiver 1324 may be configured to transmit and/or receive time and/or frequency resource partitioning information. In some implementations, the transceiver 1320 may be configured to transmit in different types of subframes and slots including, but not limited to, usable, non-usable and flexibly usable subframes and slot formats. The transceiver 1320 may be configured to receive data and control channels.

[00110] The node 1300 may include a variety of computer-readable media. Computer-readable media can be any available media that can be accessed by the node 1300 and include both volatile and non-volatile media, removable and non-removable media. By way of example, and not limitation, computer-readable media may comprise computer storage media and communication media. Computer storage media includes both volatile and non-volatile, removable and non-removable media implemented in any method or technology for storage of information such as computer-readable instructions, data structures, program modules or other data.

[00111] Computer storage media includes RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices. Computer storage media does not comprise a propagated data signal. Communication media typically embodies computer-readable instructions, data structures, program modules or other data in a modulated data signal such as a carrier wave or other transport mechanism and includes any information delivery media. The term "modulated data signal" means a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. By way of example, and not limitation, communication media includes wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, RF, infrared and other wireless media. Combinations of any of the above should also be included within the scope of computer-readable media.

[00112] The memory 1328 may include computer-storage media in the form of volatile and/or non-volatile memory. The memory 1328 may be removable, non-removable, or a combination thereof. Exemplary memory includes solid-state memory, hard drives, optical-disc drives, and etc. As illustrated in Figure 13, The memory 1328 may store computer-readable, computer-executable instructions 1332 (e.g., software codes) that are configured to, when executed, cause the processor 1326 to perform various functions described herein, for example, with reference to Figures 1 through 12. Alternatively, the instructions 1332 may not be directly executable by the processor 1326 but be configured to cause the node 1300 (e.g., when compiled and executed) to perform various functions described herein.

[00113] The processor 1326 may include an intelligent hardware device, e.g., a central processing unit (CPU), a microcontroller, an ASIC, and etc. The processor 1326 may include memory. The processor 1326 may process the data 1330 and the instructions 1332 received from the memory 1328, and information through the transceiver 1320, the base band communications module, and/or the network communications module. The processor 1326 may also process information to be sent to the transceiver 1320 for transmission through the antenna 1336, to the network communications module for transmission to a core network.

[00114] One or more presentation components 1334 presents data indications to a person or other device. Exemplary presentation components 1334 include a display device, speaker, printing component, vibrating component, and etc.

[00115] From the above description it is manifest that various techniques can be used for implementing the concepts described in the present application without departing from the scope of those concepts. Moreover, while the concepts have been described with specific reference to certain implementations, a person of ordinary skill in the art would recognize that changes can be made in form and detail without departing from the scope of those concepts. As such, the described implementations are to be considered in all respects as illustrative and not restrictive. It should also be understood that the present application is not limited to the particular implementations described above, but many rearrangements, modifications, and substitutions are possible without departing from the scope of the present disclosure.

CLAIMS

What is claimed is:

1. A user equipment (UE) comprising:

one or more non-transitory computer-readable media having computer-executable instructions embodied thereon;

at least one processor coupled to the one or more non-transitory computer-readable media, and configured to execute the computer-executable instructions to:

receive a logical channel group (LCG) list having a plurality of logical channels in one or more LCGs, wherein grouping of the plurality of logical channels is based at least in part on a mapping policy between each of the plurality of logical channels and one or more numerology factors;

request for a numerology-specific uplink radio resource for one of the one or more LCGs through a buffer status report (BSR), wherein the BSR includes a LCG ID identifying the one of the one or more LCGs.

2. The UE of Claim 1, wherein the one or more numerology factors include transmission time interval (TTI) length, subcarrier spacing (SCS), and cyclic prefix (CP) length.

3. The UE of Claim 1, wherein a first logical channel and a second logical channel of one of the one or more LCG groups share at least one common numerology factor.

4. The UE of Claim 1, wherein the LCG ID includes at least 3 bits.

5. The UE of Claim 1, wherein a buffer size field of the BSR includes at least 8 bits.

6. The UE of Claim 1, wherein the LCG list is provided to the UE through a downlink radio resource control (RRC) message.

7. The UE of Claim 6, wherein the downlink RRC message includes an information element (IE) having a media access control (MAC) layer logical channel configuration for each of the plurality of logical channels.

8. The UE of Claim 1, wherein, when the UE requests for the numerology-specific uplink radio resource for a specific logical channel group, the UE transmits the BSR through a physical uplink shared channel (PUSCH) that corresponds to the numerology.

9. The UE of Claim 1, wherein at least one processor is further configured to execute the computer-executable instructions to:

request for another uplink radio resource for a specific logical channel group through one or more bandwidth parts (BWPs).

10. The UE of Claim 1, wherein the BSR includes a numerology indictor for requesting another uplink radio resource having another numerology.

11. The UE of Claim 8, wherein, when data ready for transmission has been queued in a buffer for longer than a predetermined time, the at least one processor is configured to further execute the computer-executable instructions to retransmit the BSR through a PUSCH that corresponds to a numerology or an orthogonal frequency division modulation (OFDM) symbol that has a shorter TTI length than that of the requested numerology specific uplink radio resource.

12. The UE of Claim 11, wherein the base station configures an across numerology restriction mask for one or more logical channels that have permission to retransmit BSRs through another PUSCH that corresponds to other numerologies.

13. The UE of Claim 1, wherein, when an uplink resource is not granted after the BSR is transmitted, the at least one processor is configured to further execute the computer-executable instructions to perform a two-step random access (RA) procedure to retransmit the BSR.

14. A base station comprising:

one or more non-transitory computer-readable media having computer-executable instructions embodied thereon;

at least one processor coupled to the one or more non-transitory computer-readable media, and configured to execute the computer-executable instructions to:

group a plurality of logical channels into one or more logical channel groups (LCGs);

providing a LCG list to a user equipment(UE), the LCG list having the plurality of logical channels in the one or more LCGs;

receive, from the UE, a buffer status report (BSR), the BSR having a request for a numerology-specific uplink radio resource for one of the one or more LCGs, wherein the BSR includes a LCG ID identifying the one of the one or more LCGs.

15. The base station of Claim 14, wherein the one or more numerology factors include transmission time interval (TTI) length, subcarrier spacing (SCS), and cyclic prefix (CP) length.

16. The base station of Claim 14, wherein a first logical channel and a second logical channel of one of the one or more LCG groups share at least one common numerology factor.

17. The base station of Claim 14, wherein the LCG ID includes at least 3 bits.

18. The base station of Claim 14, wherein a buffer size field of the BSR includes at least 8 bits.

19. The base station of Claim 14, wherein the LCG list is provided to the UE through a downlink RRC message.

20. The base station of Claim 19, wherein the downlink RRC message includes an information element (IE) having a media access control (MAC) layer logical channel configuration for each of the plurality of logical channels.

21. The base station of Claim 14, wherein, when the UE requests for the numerology-specific uplink radio resource for a specific logical channel group, the UE transmits the BSR through a physical uplink shared channel (PUSCH) that corresponds to the numerology.

22. The base station of Claim 14, wherein the BSR includes a numerology indictor for requesting another uplink radio resource having another numerology.

23. The base station of Claim 14, wherein base station configures an across numerology restriction mask for one or more of the plurality of logical channels that have permission to retransmit the BSR through a PUSCH that corresponds other numerologies.

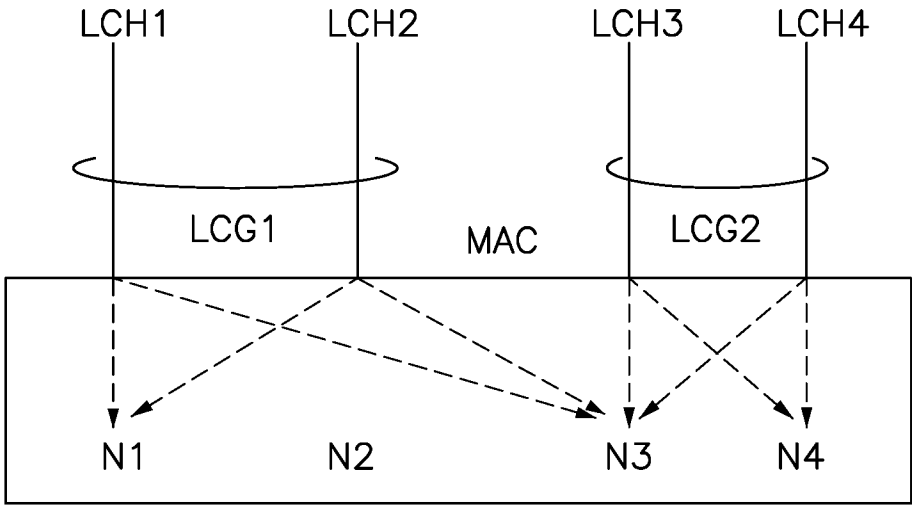

LCH1
LCH2
LCH3
LCH4
LCG1
MAC
LCG2
N1
N2
N3
N4

FIG. 1A

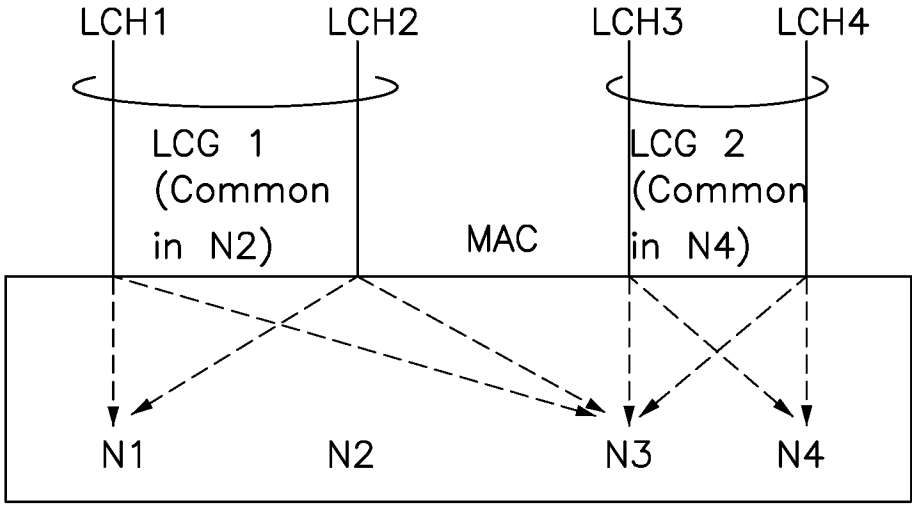
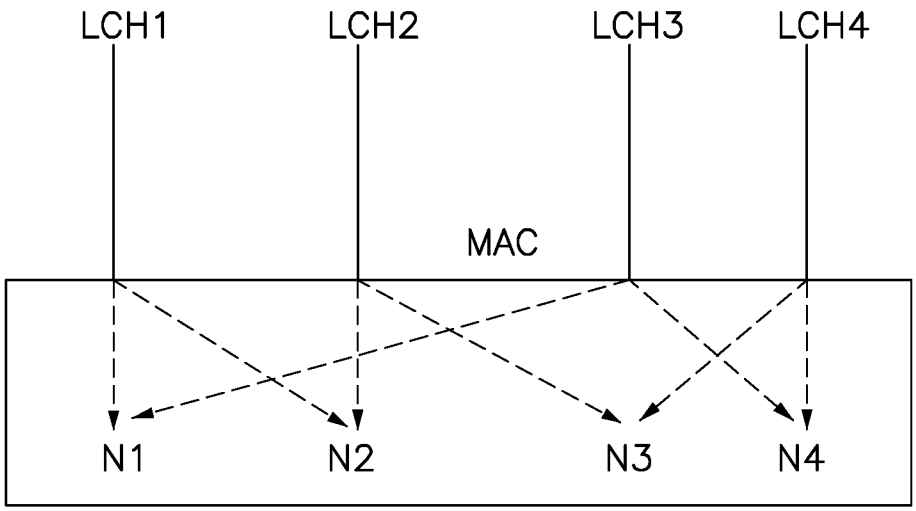

LCH1
LCH2
LCH3
LCH4
LCG 1
(Common
in N2)
MAC
LCG 2
(Common
in N4)
N1
N2
N3
N4

FIG. 1B



LCG 1: {LCH1, LCH3} LCG 3: {LCH2, LCH4}
LCG 2: {LCH1, LCH2} LCG 4: {LCH3, LCH4}

FIG. 1C

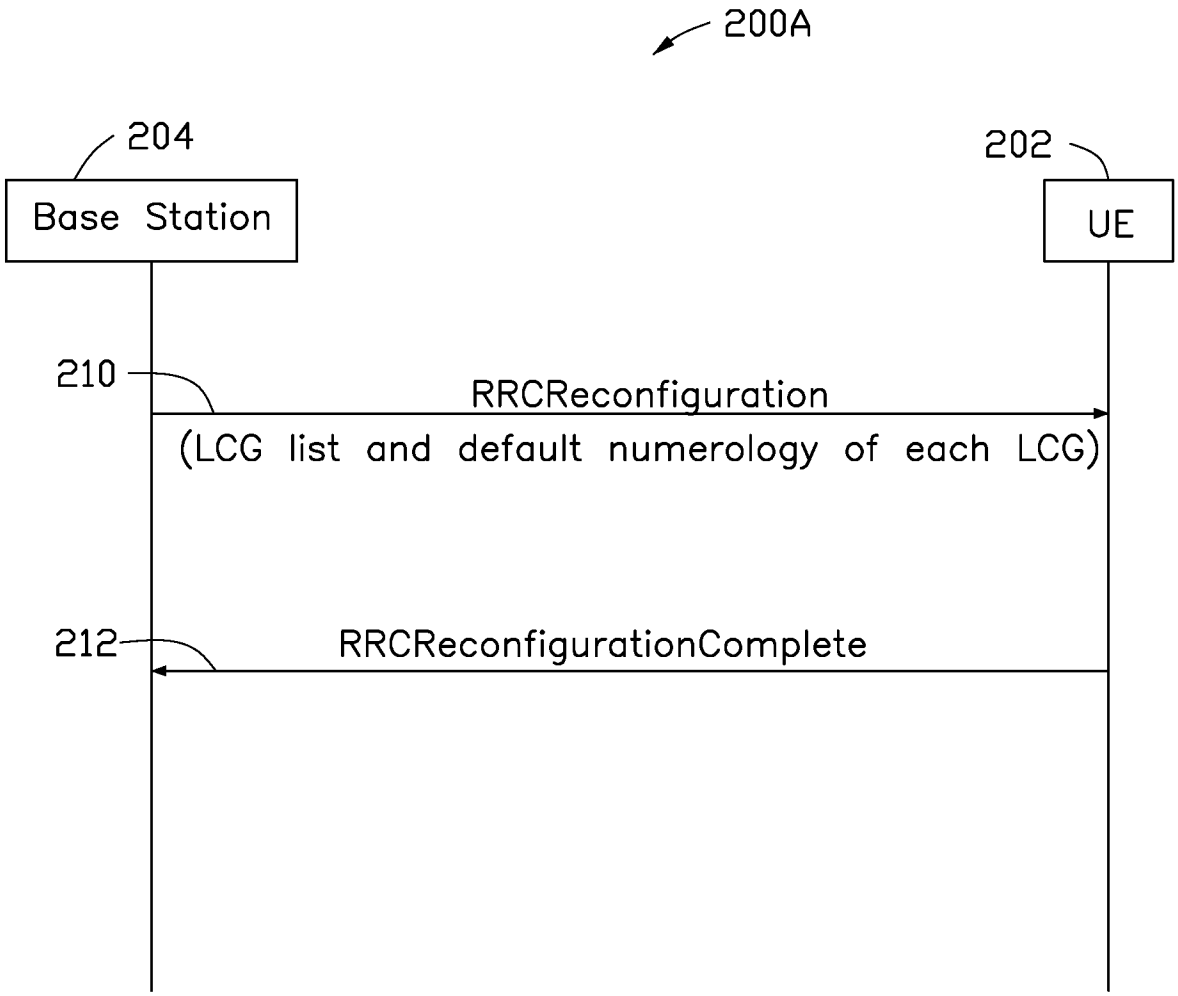

200A
204
Base Station
202
UE
210
RRCReconfiguration
(LCG list and default numerology of each LCG)
212
RRCReconfigurationComplete

FIG. 2A

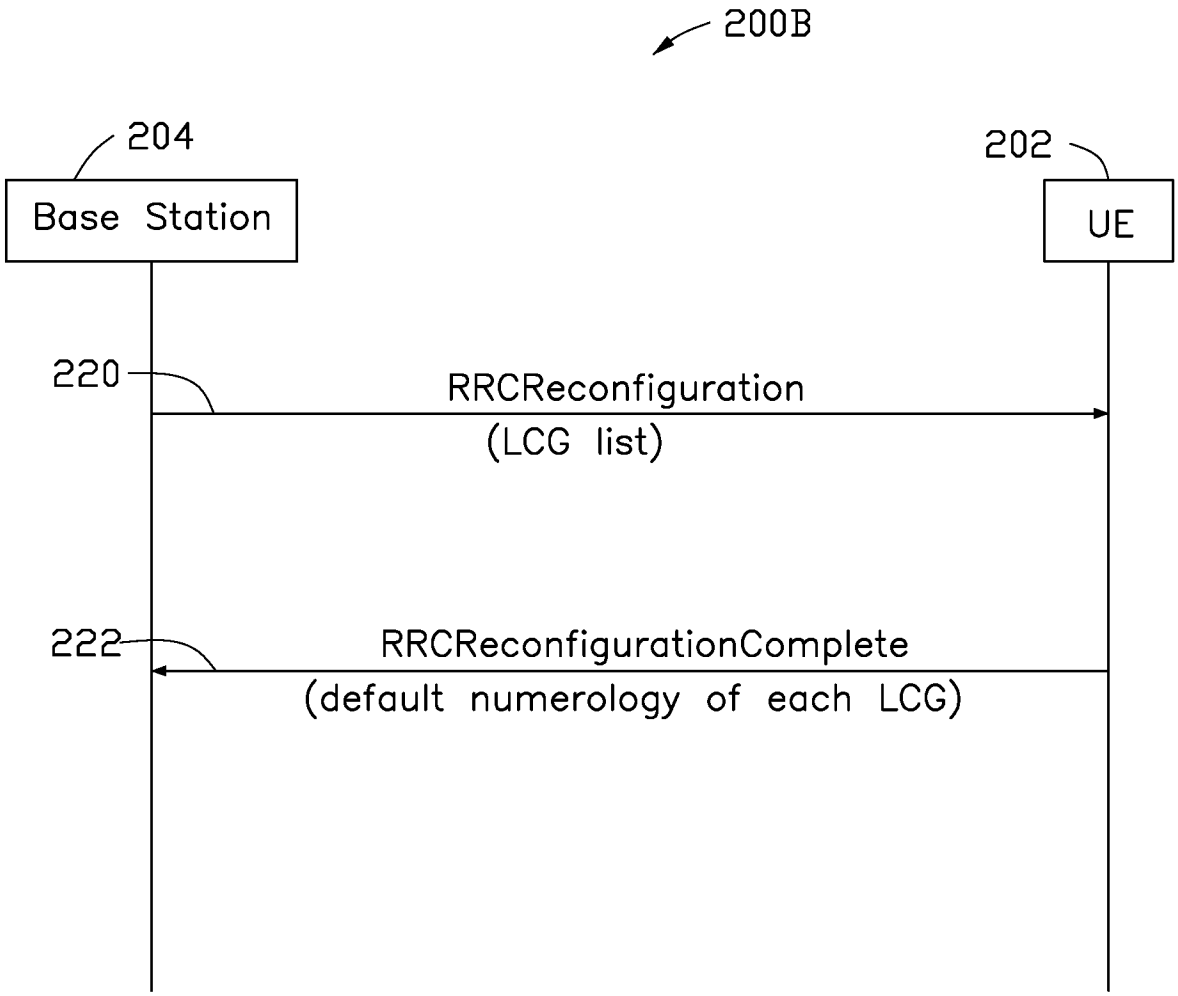

200B
204
Base Station
202
UE
220
RRCReconfiguration
(LCG list)
222
RRCReconfigurationComplete
(default numerology of each LCG)

FIG. 2B

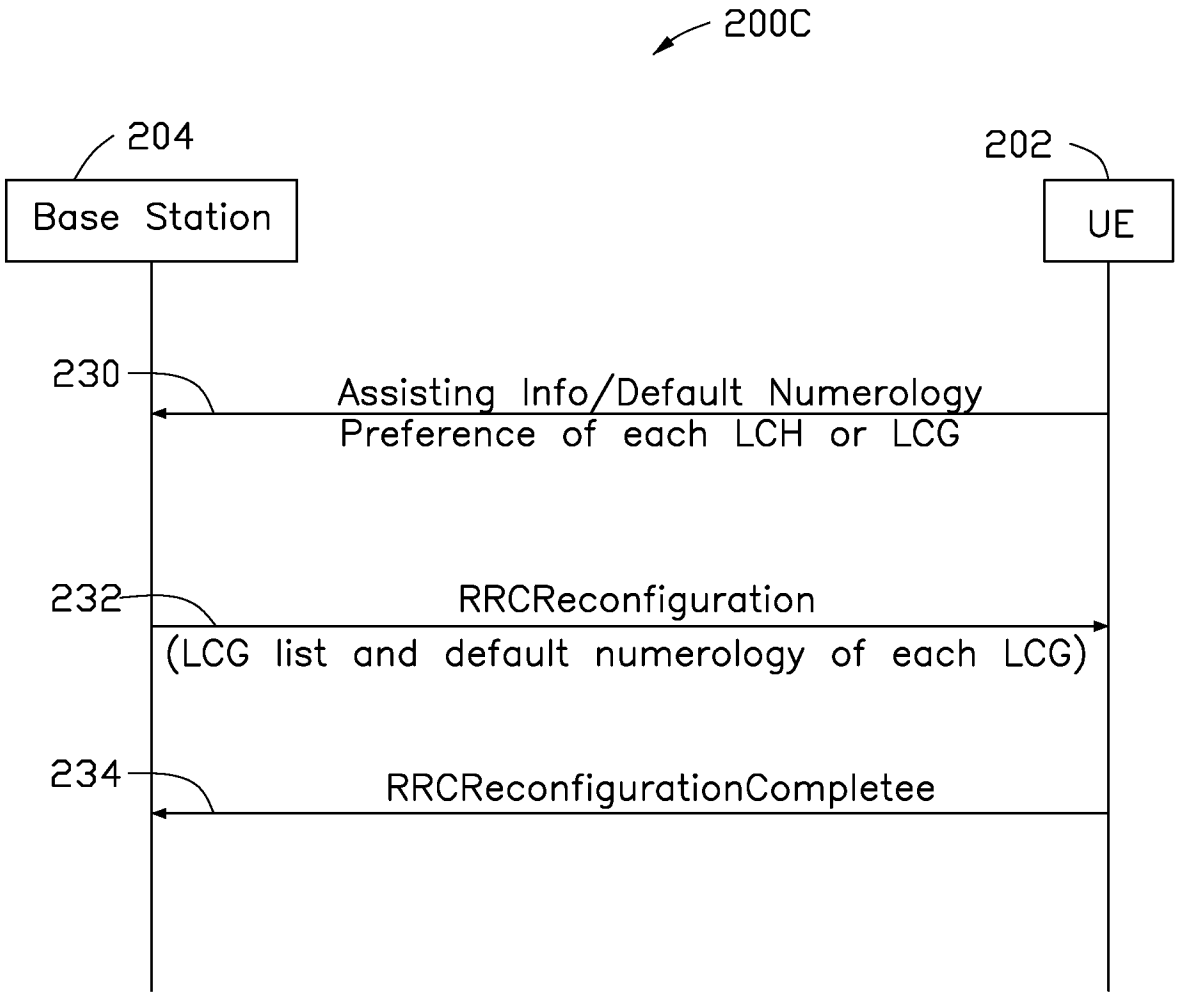

200C
204
Base Station
202
UE
230
Assisting Info/Default Numerology
Preference of each LCH or LCG
232
RRCReconfiguration
(LCG list and default numerology of each LCG)
234
RRCReconfigurationCompletee

FIG. 2C

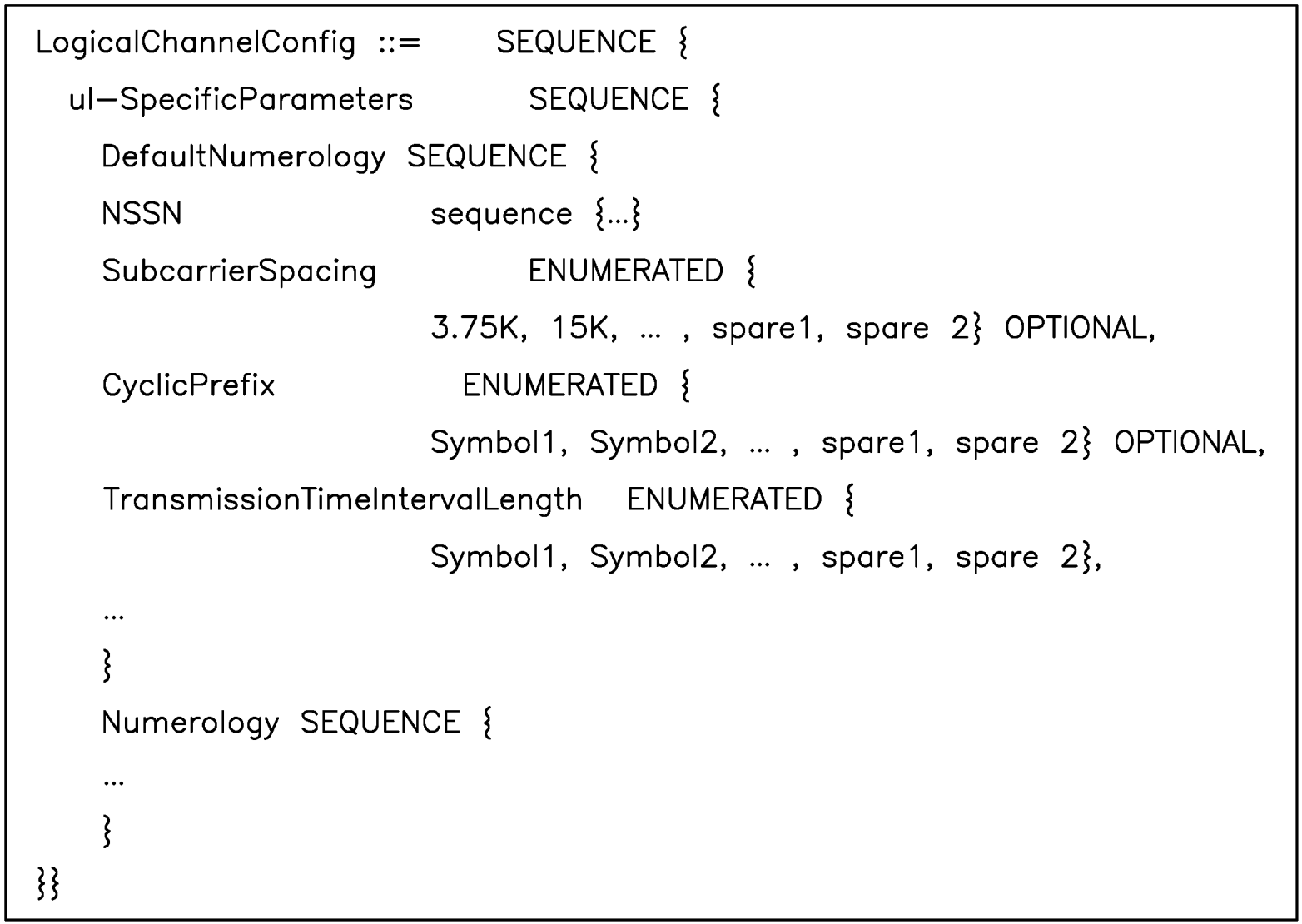

LogicalChannelConfig ::= SEQUENCE {
ul-SpecificParameters SEQUENCE {
DefaultNumerology SEQUENCE {
NSSN sequence {...}
SubcarrierSpacing ENUMERATED {
3.75K, 15K, ... , spare1, spare 2} OPTIONAL,
CyclicPrefix ENUMERATED {
Symbol1, Symbol2, ... , spare1, spare 2} OPTIONAL,
TransmissionTimeIntervalLength ENUMERATED {
Symbol1, Symbol2, ... , spare1, spare 2},
...
}
Numerology SEQUENCE {
...
}
}}
300A

FIG. 3A

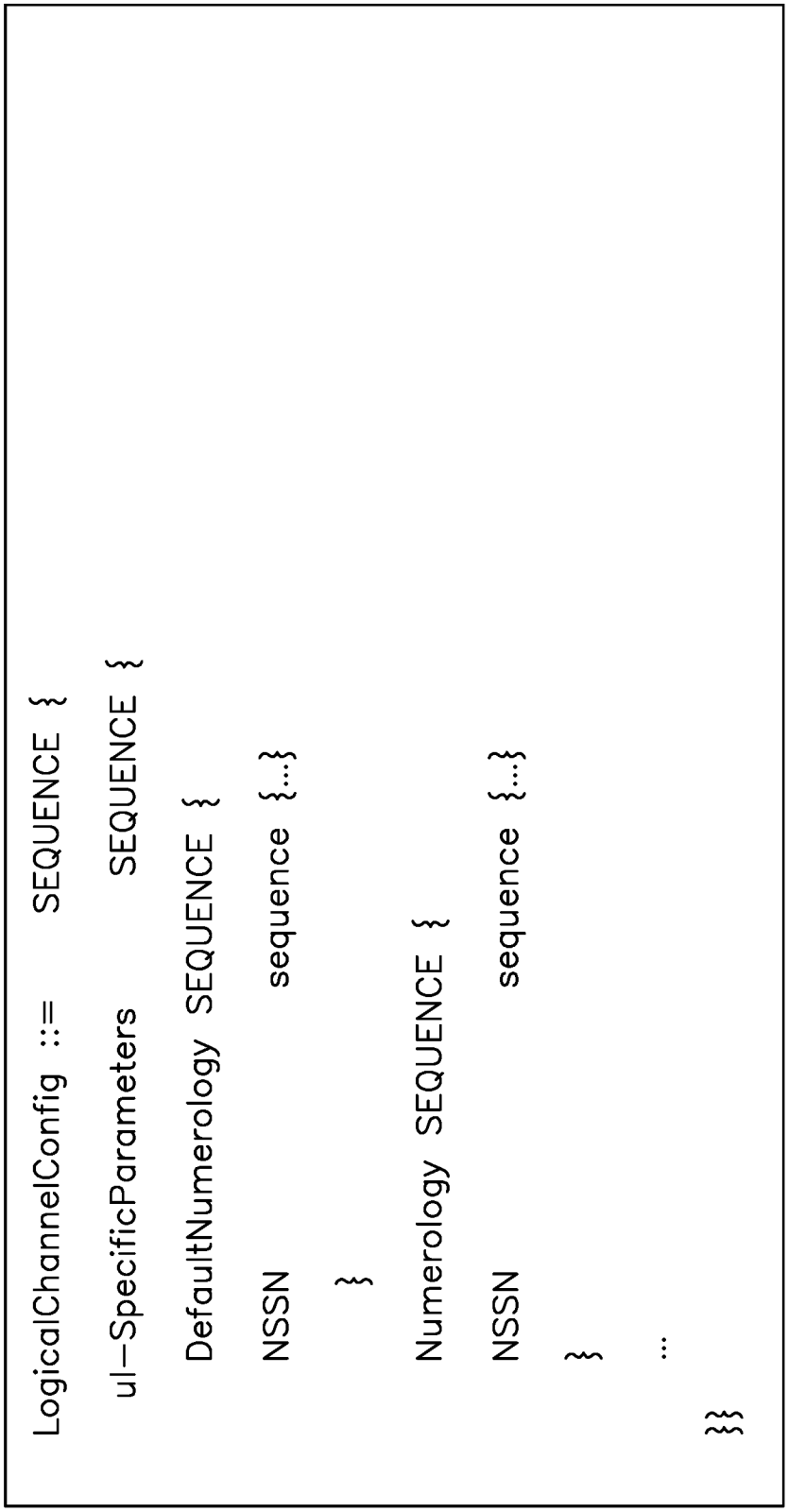

300B
LogicalChannelConfig ::= SEQUENCE {
ul-SpecificParameters SEQUENCE {
DefaultNumerology SEQUENCE {
NSSN sequence {...}
}
Numerology SEQUENCE {
NSSN sequence {...}
}
...
}

FIG. 3B

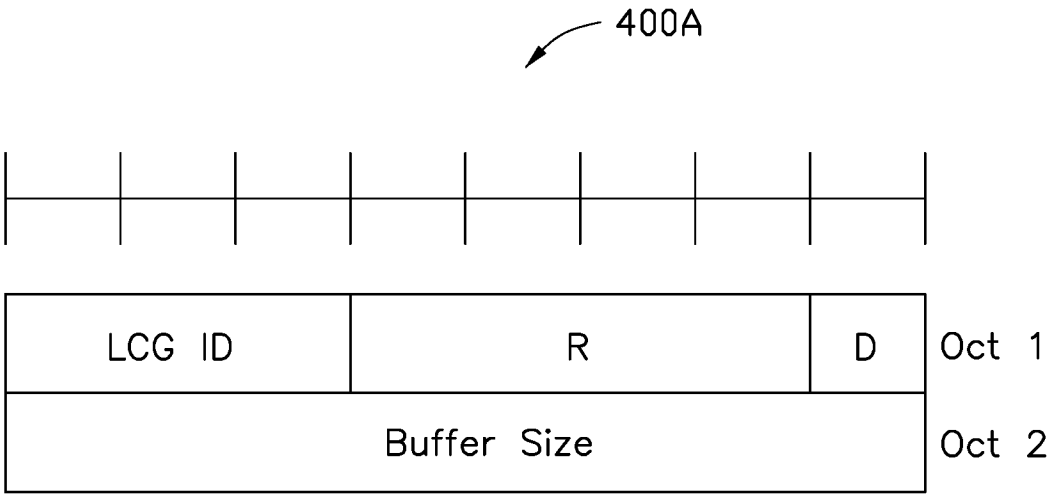
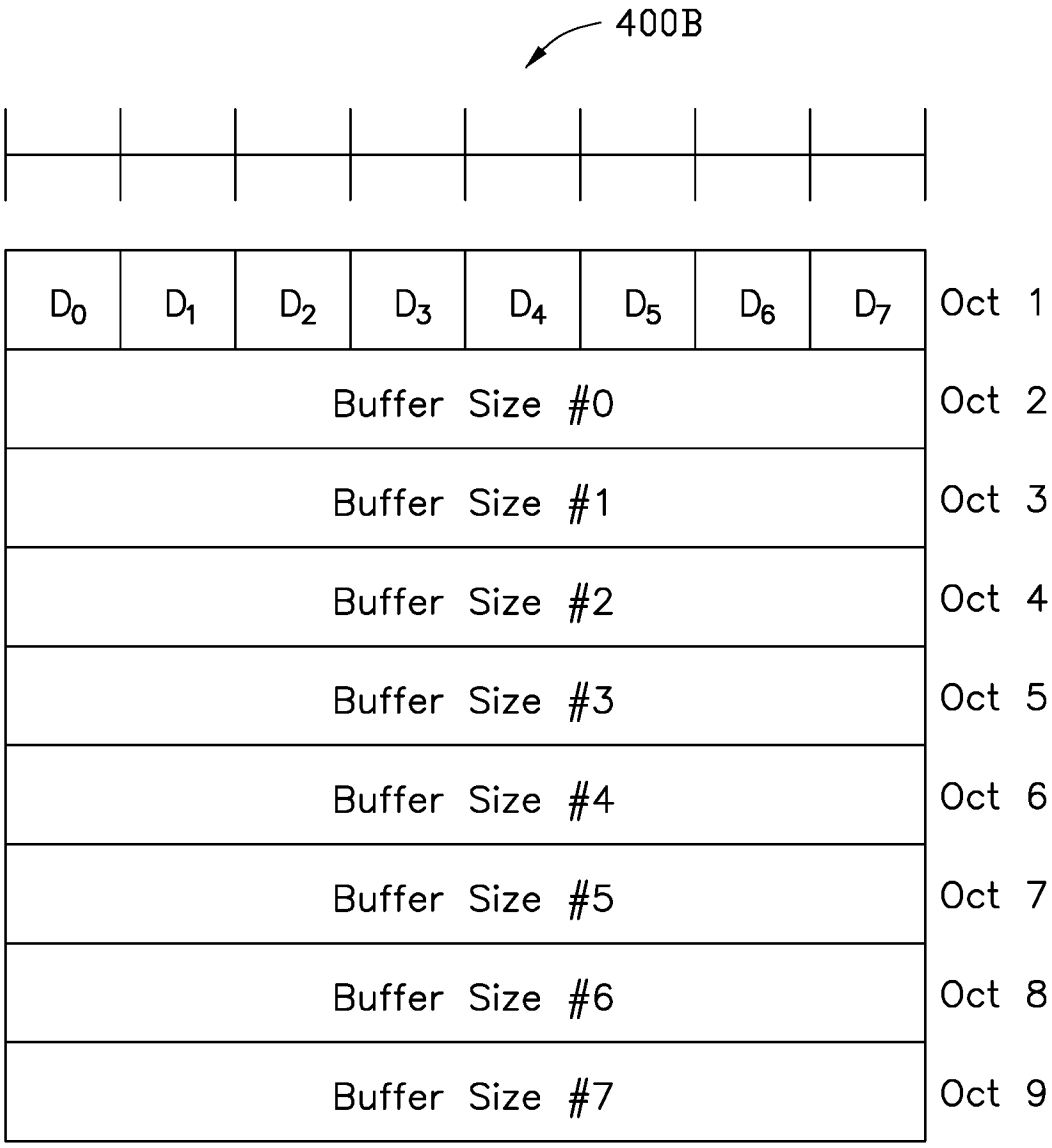
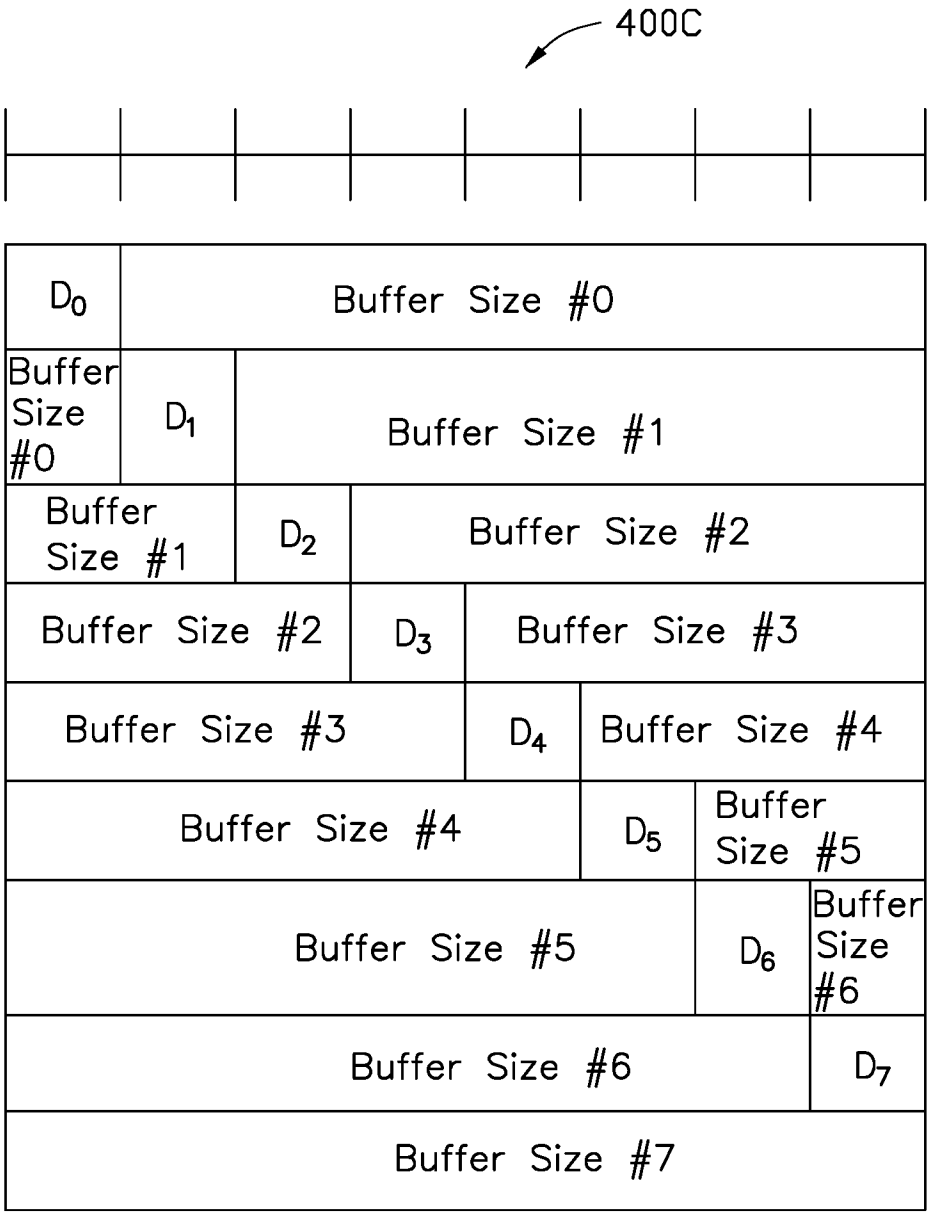


FIG. 4A



Long BSR Control Element 400B
with
Default Numerology Indicators
(Type I)

FIG. 4B



Long BSR Control Element 400C
with
Default Numerology Indicators
(Type II)

FIG. 4C

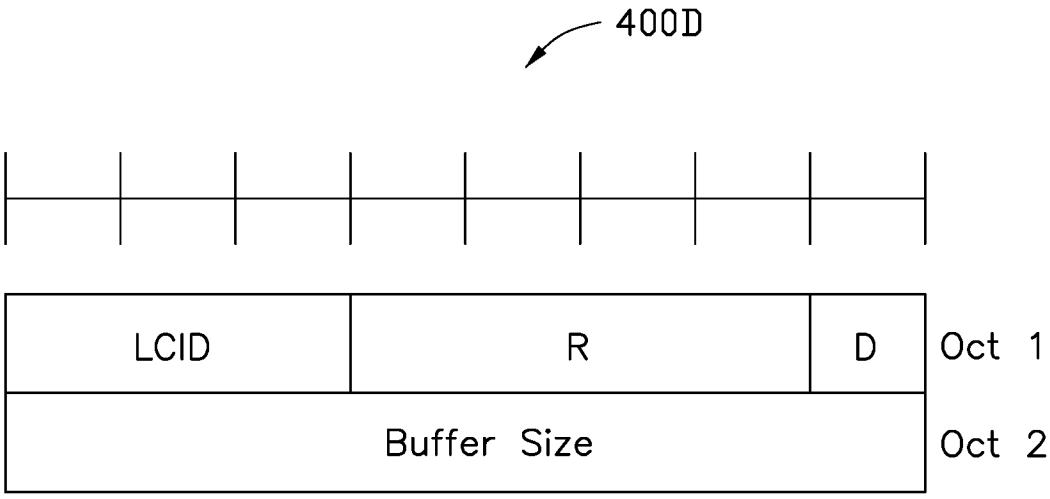


FIG. 4D

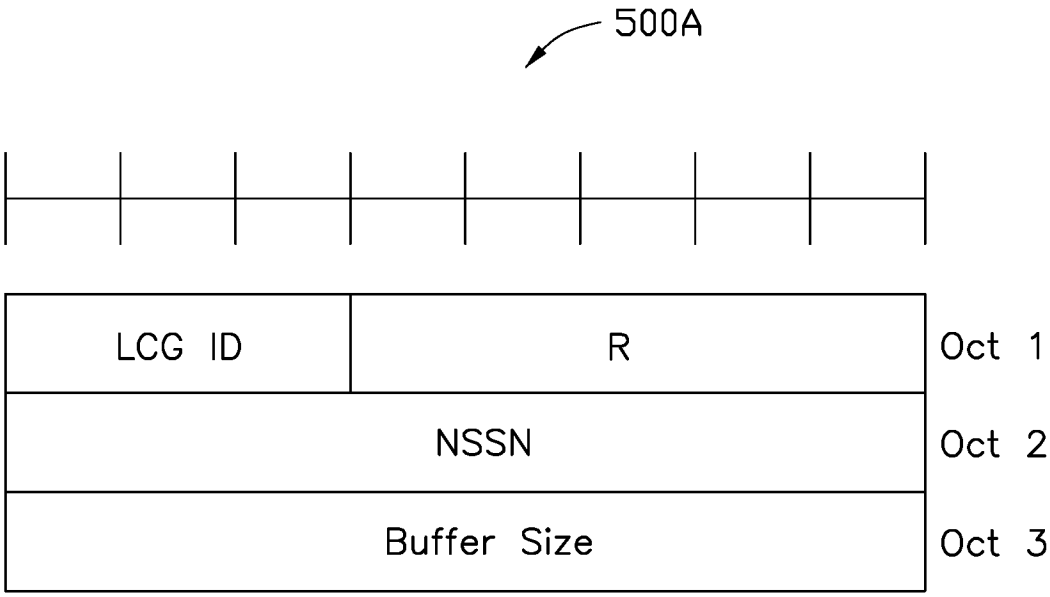


FIG. 5A

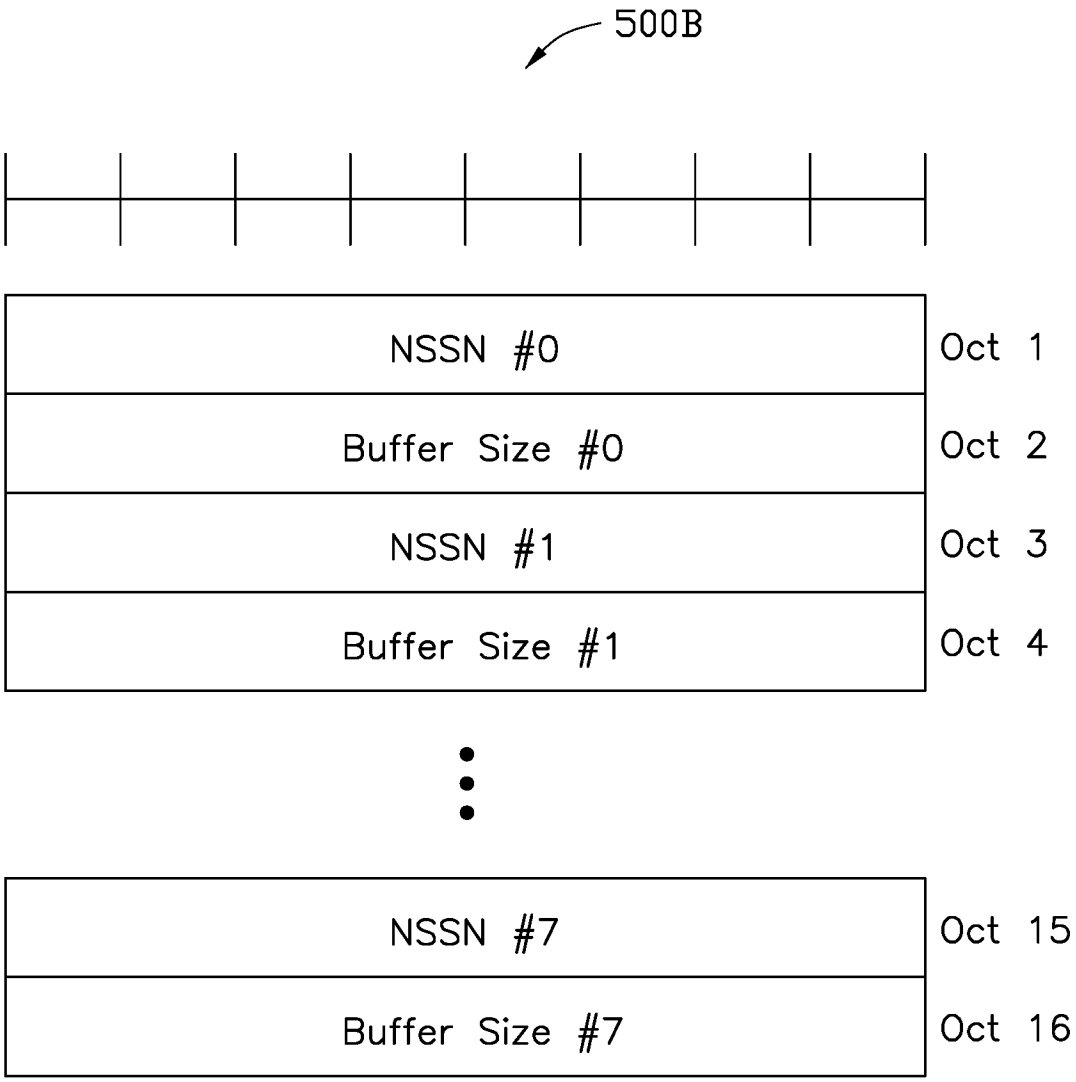

500B
NSSN #0
Oct 1
Buffer Size #0
Oct 2
NSSN #1
Oct 3
Buffer Size #1
Oct 4
NSSN #7
Oct 15
Buffer Size #7
Oct 16

FIG. 5B

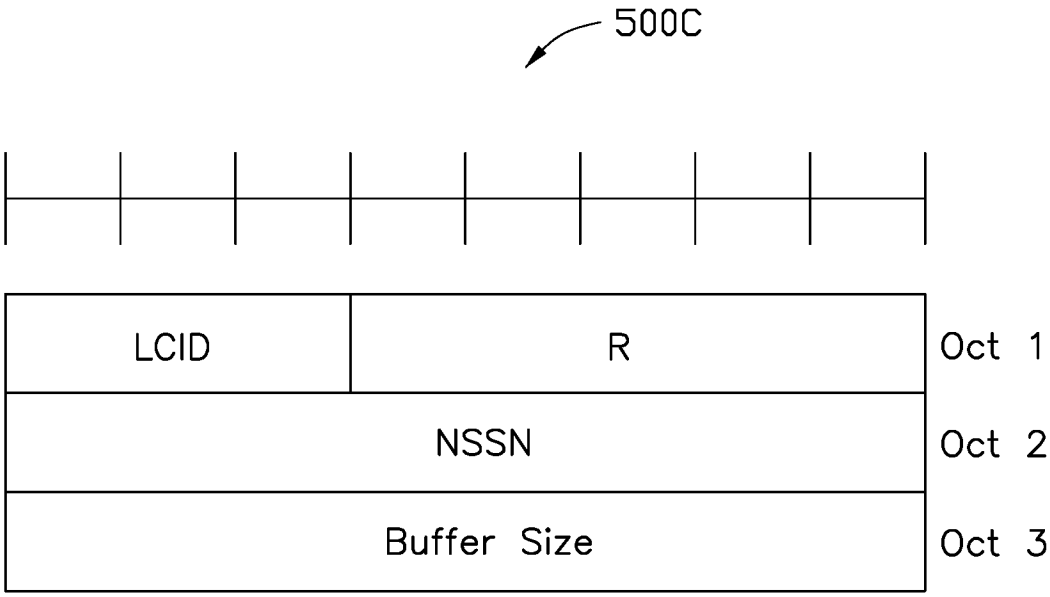


FIG. 5C

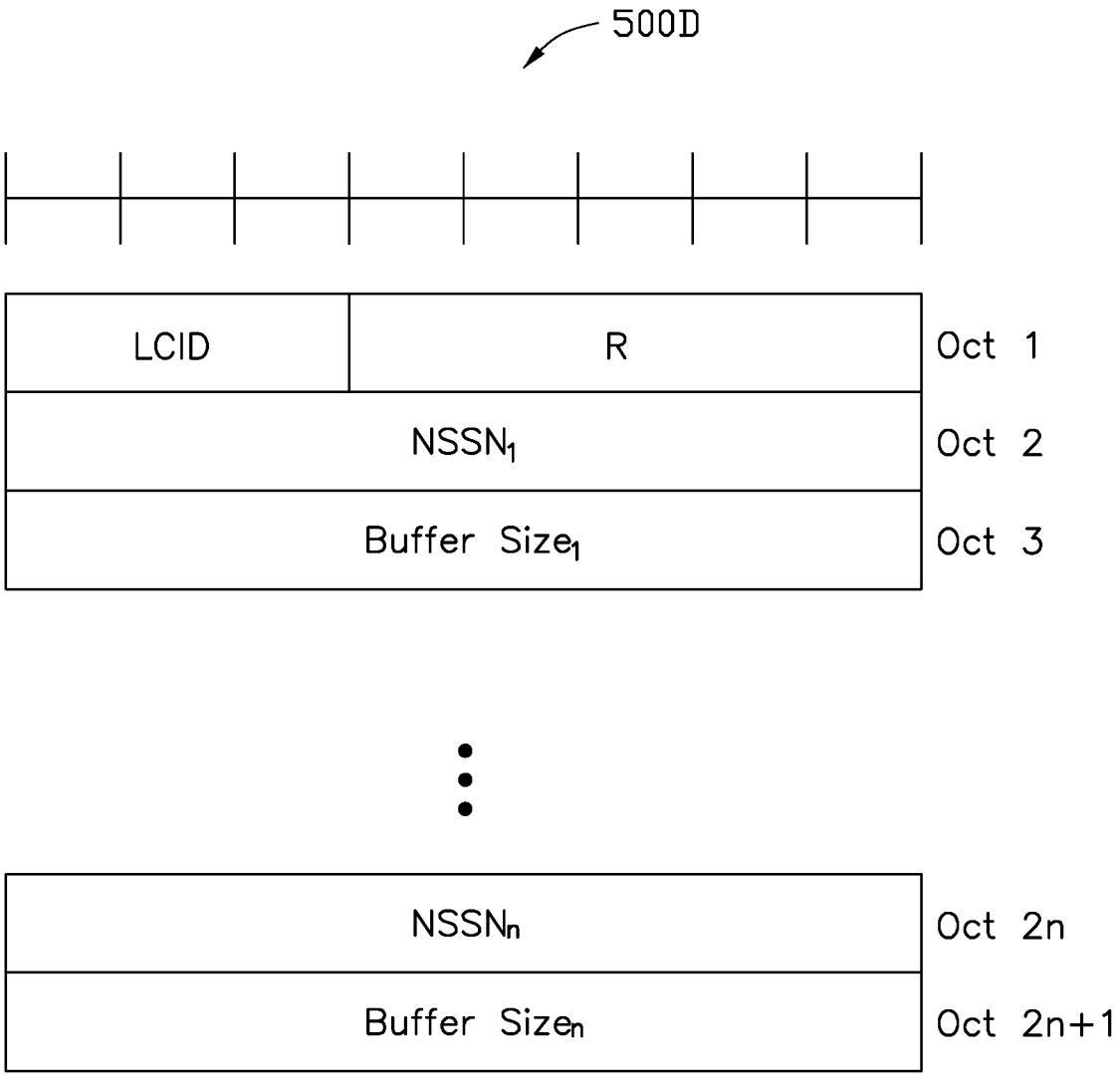

500D
LCID
R
Oct 1
NSSN1
Oct 2
Buffer Size1
Oct 3
NSSNn
Oct 2n
Buffer Sizen
Oct 2n+1

FIG. 5D

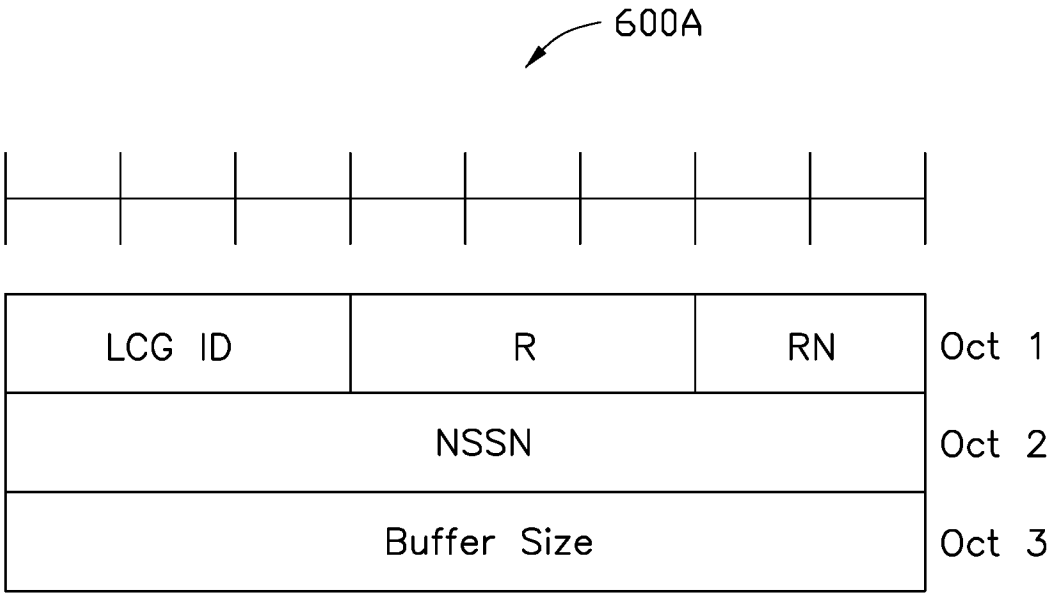


FIG. 6A

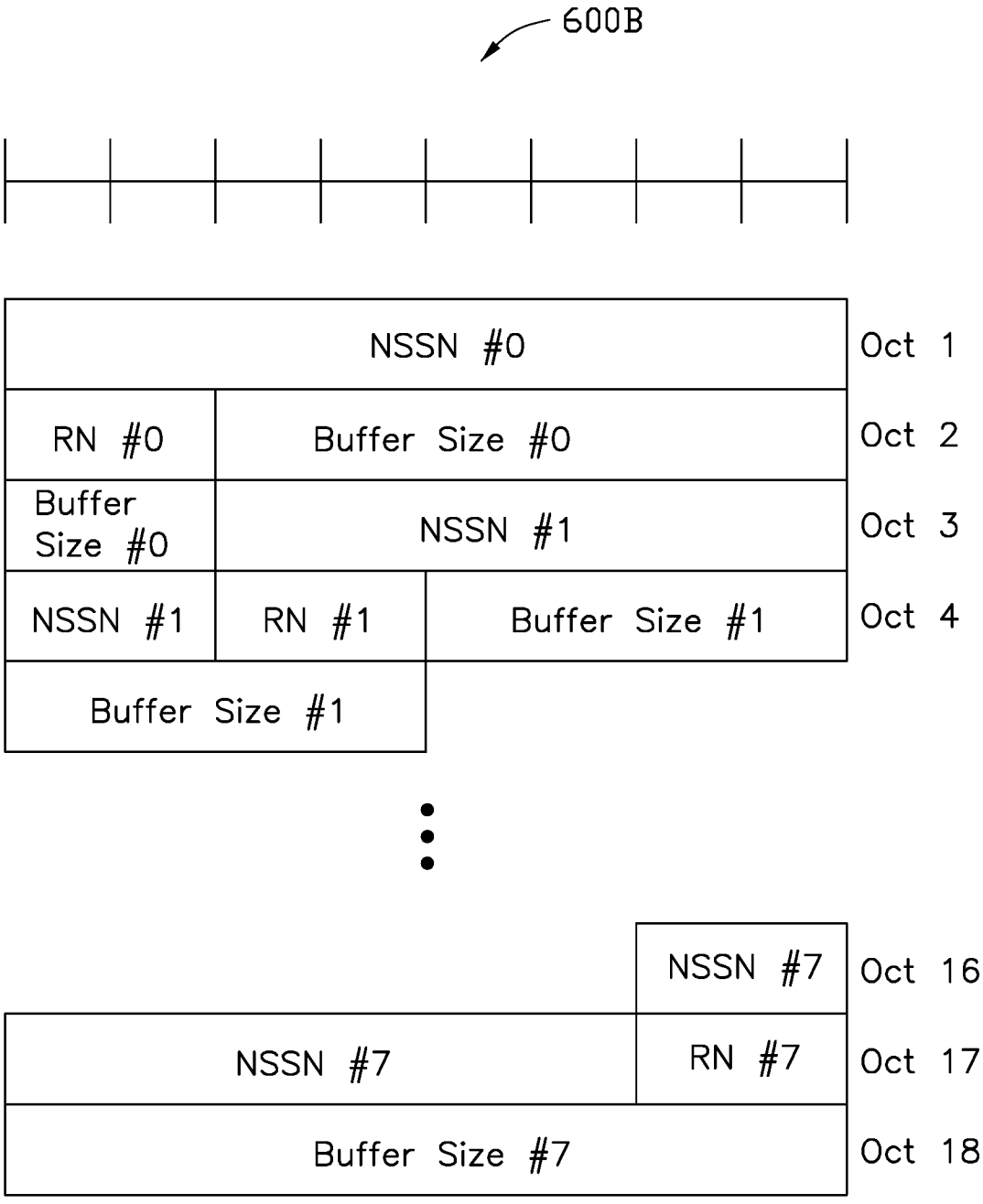

600B
NSSN #0
Oct 1
RN #0
Buffer Size #0
Oct 2
Buffer Size #0
NSSN #1
Oct 3
NSSN #1
RN #1
Buffer Size #1
Oct 4
Buffer Size #1
NSSN #7
Oct 16
NSSN #7
RN #7
Oct 17
Buffer Size #7
Oct 18

FIG. 6B

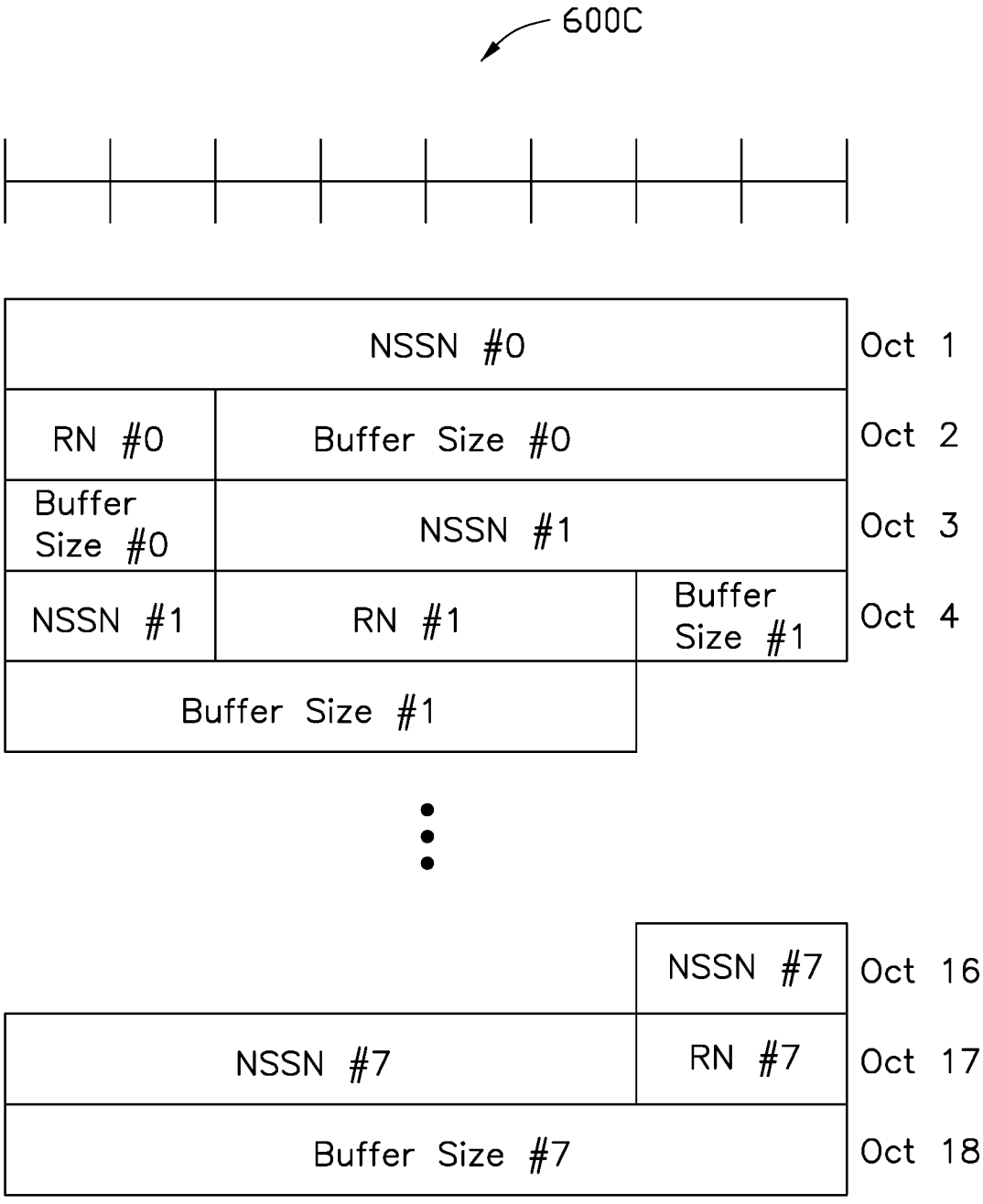

600C
NSSN #0
Oct 1
RN #0
Buffer Size #0
Oct 2
Buffer Size #0
NSSN #1
Oct 3
NSSN #1
RN #1
Buffer Size #1
Oct 4
Buffer Size #1
NSSN #7
Oct 16
NSSN #7
RN #7
Oct 17
Buffer Size #7
Oct 18

FIG. 6C

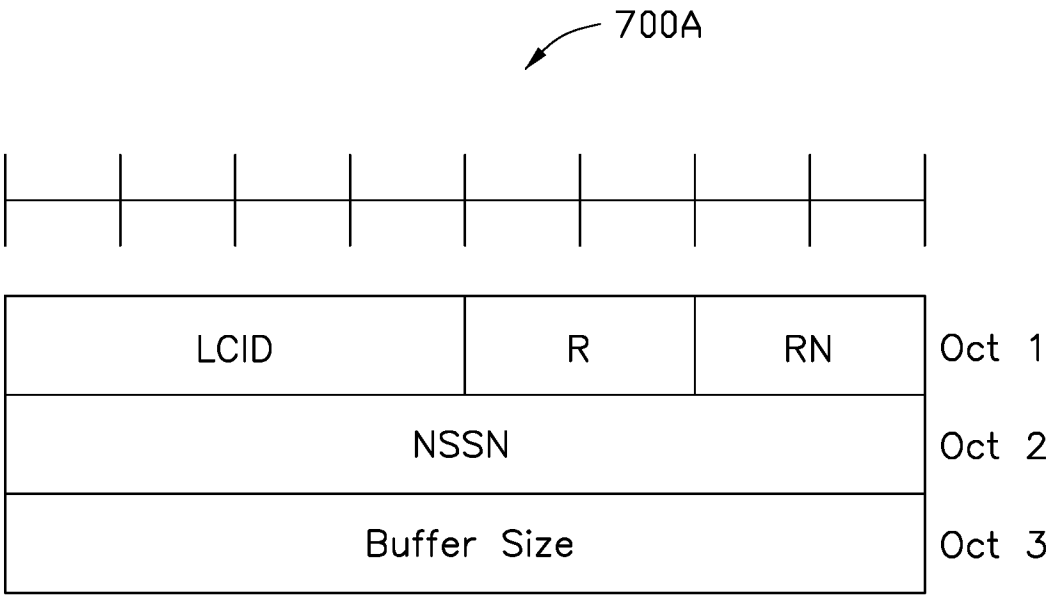

700A
LCID
R
RN
Oct 1
NSSN
Oct 2
Buffer Size
Oct 3

FIG. 7A

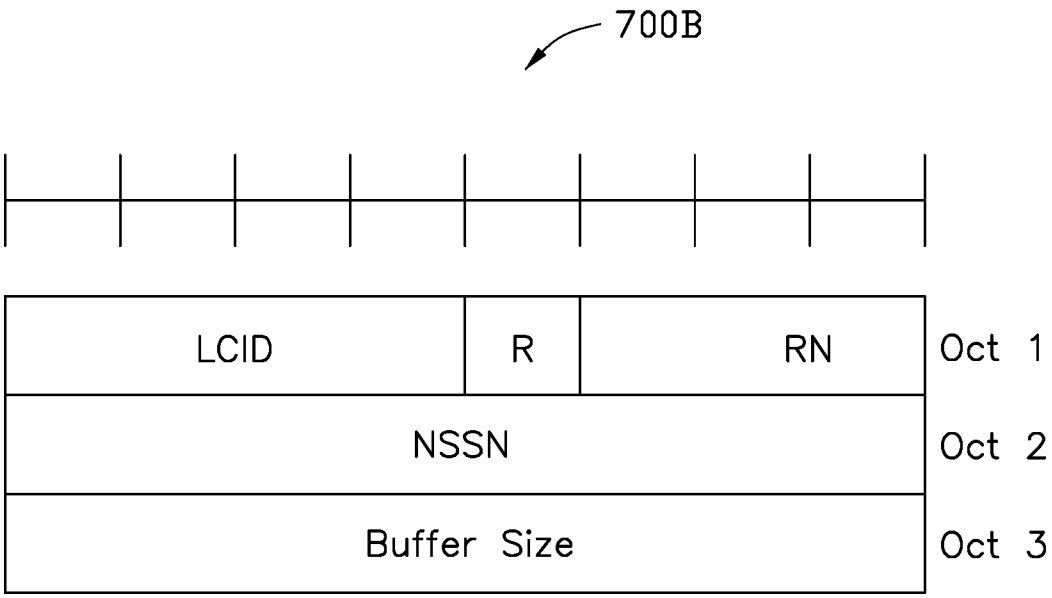
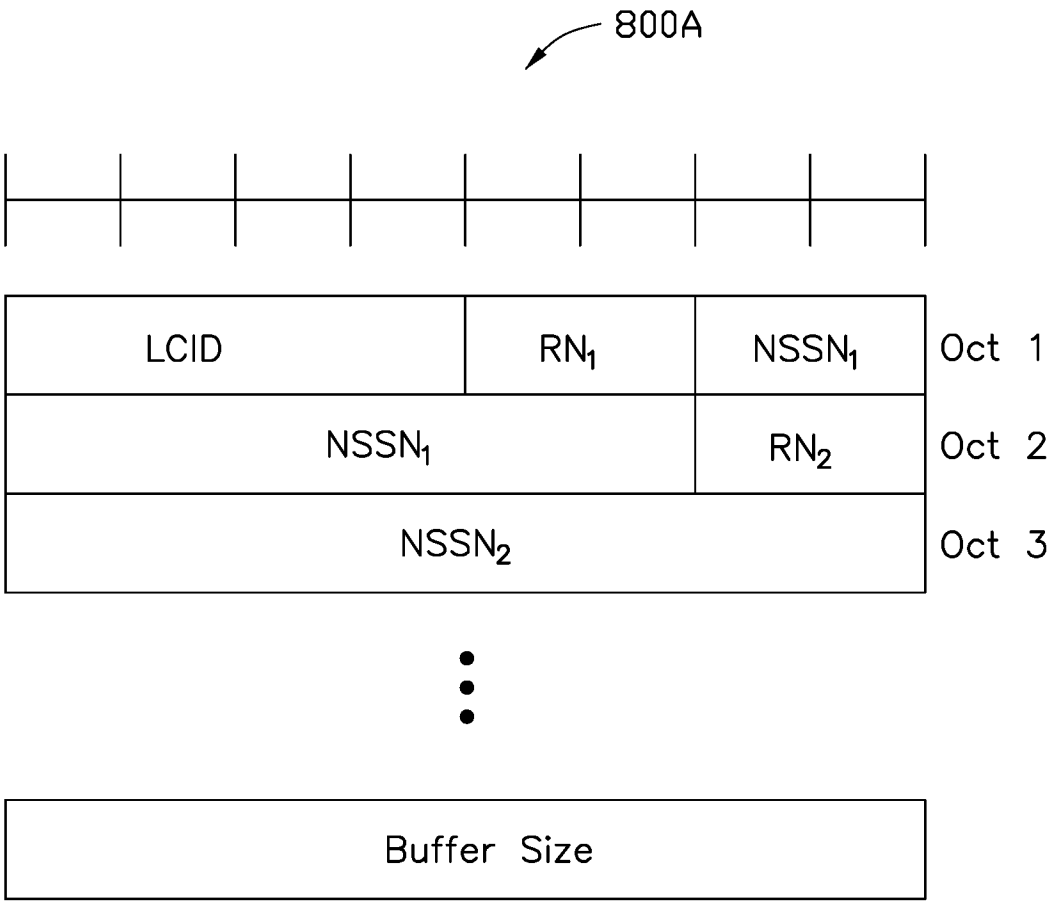
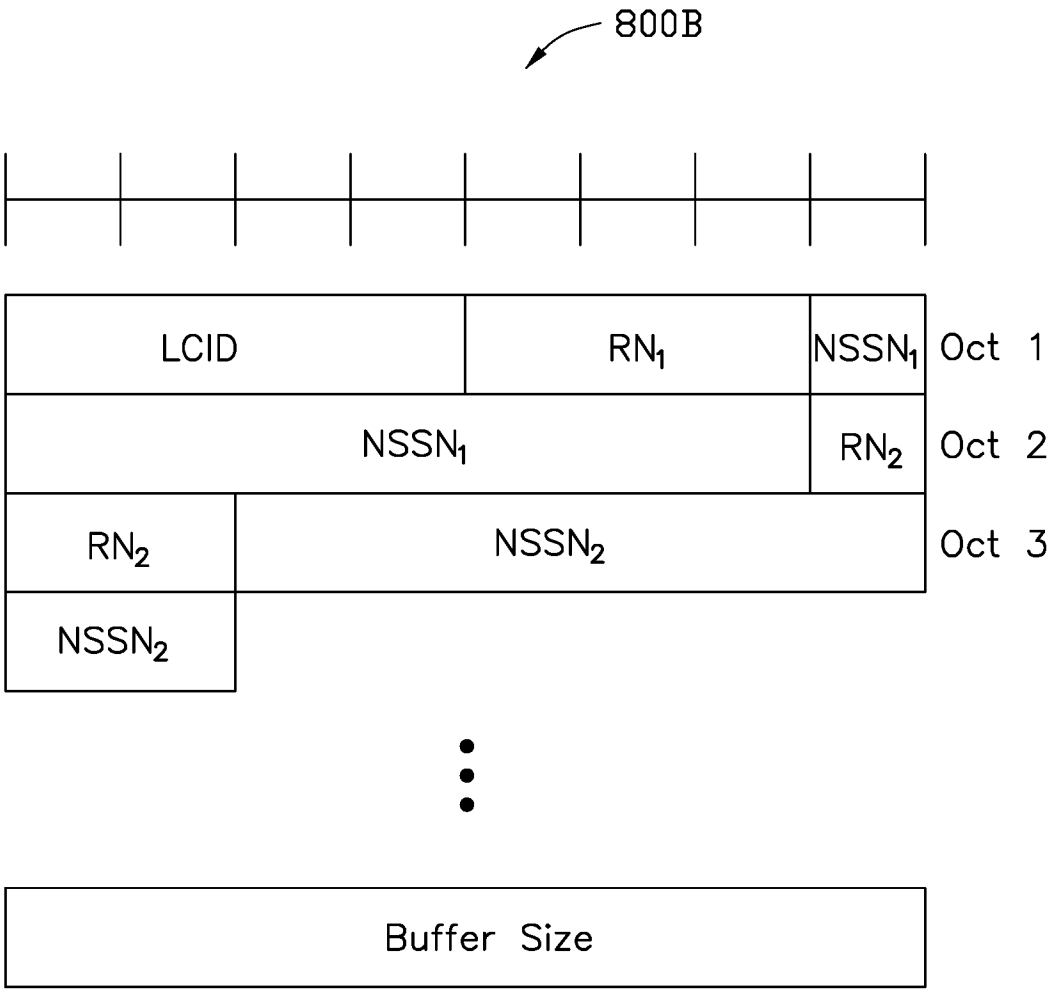

700B
LCID
R
RN
Oct 1
NSSN
Oct 2
Buffer Size
Oct 3

FIG. 7B



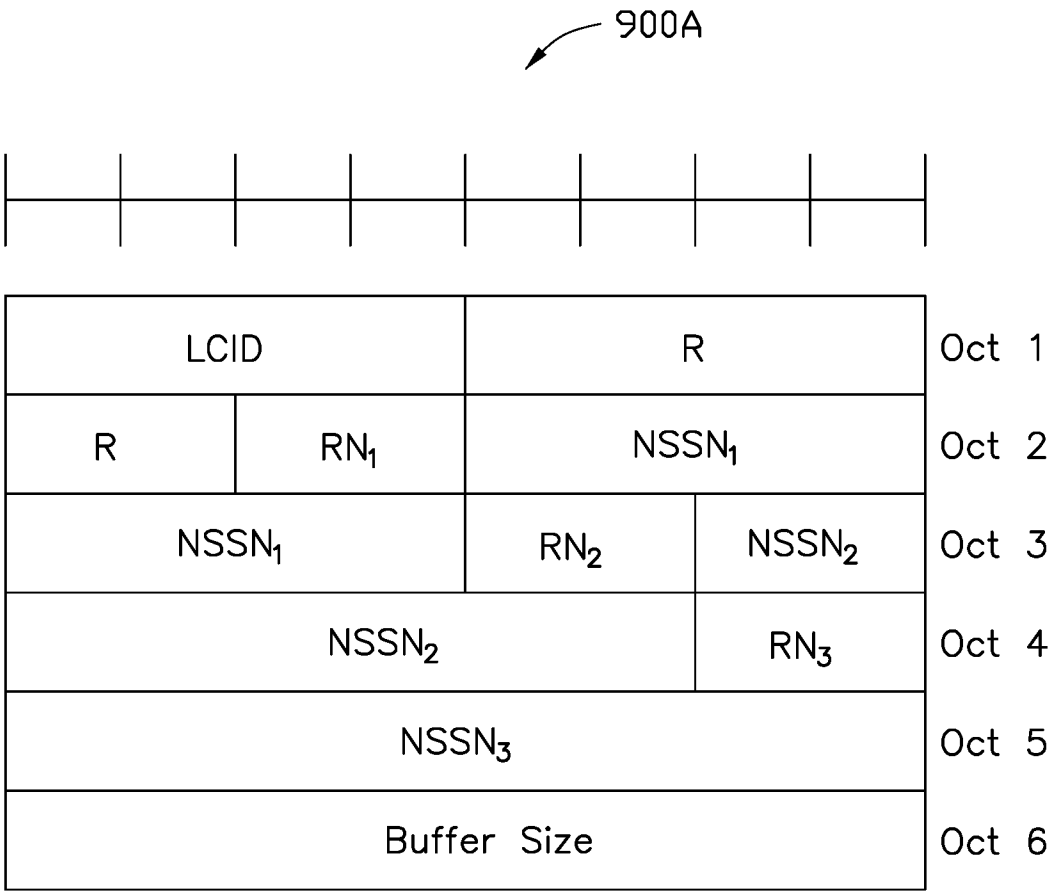
LCH BSR Control Element 800A
with
Multiple NSSNs and Multiple 2-bit RNs

FIG. 8A



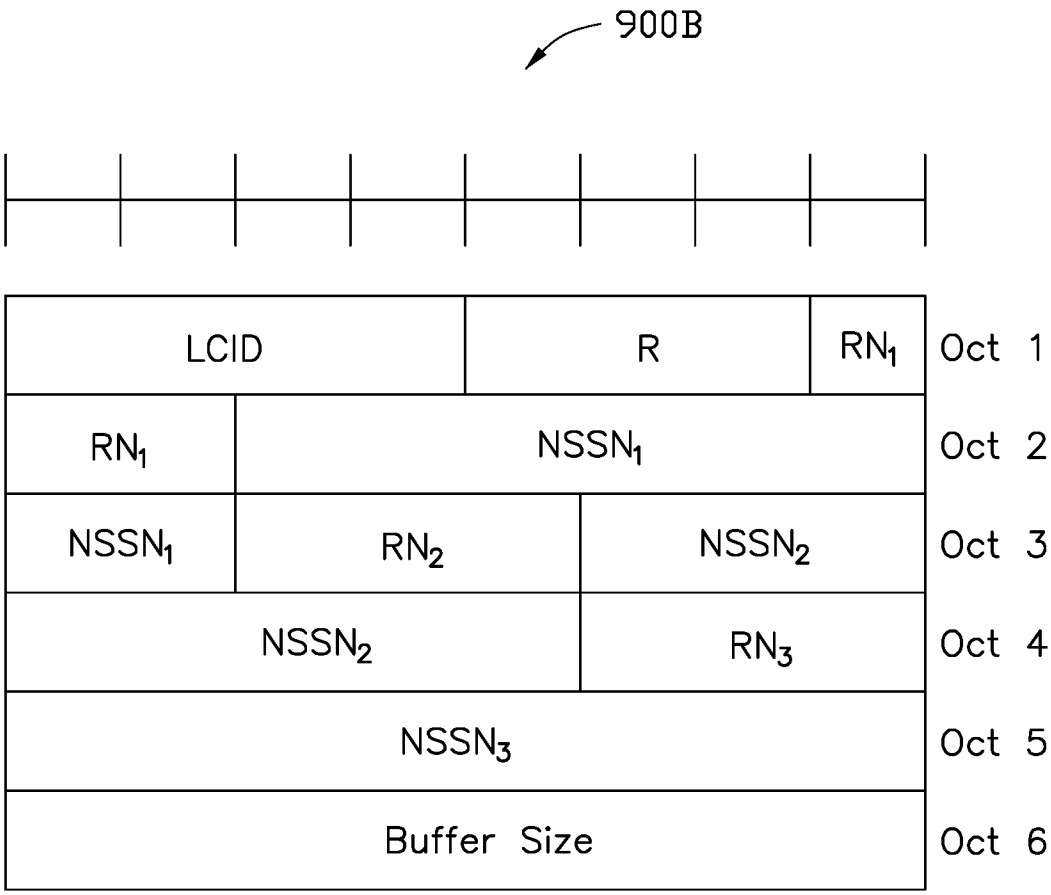
LCH BSR Control Element 800B
with
Multiple NSSNs and Multiple 3-bit RNs

FIG. 8B



LCH BSR Control Element 900A
with
Three NSSNs and Three 2-bit RNs

FIG. 9A



LCH BSR Control Element 900B
with
Three NSSNs and Three 3-bit RNs

FIG. 9B

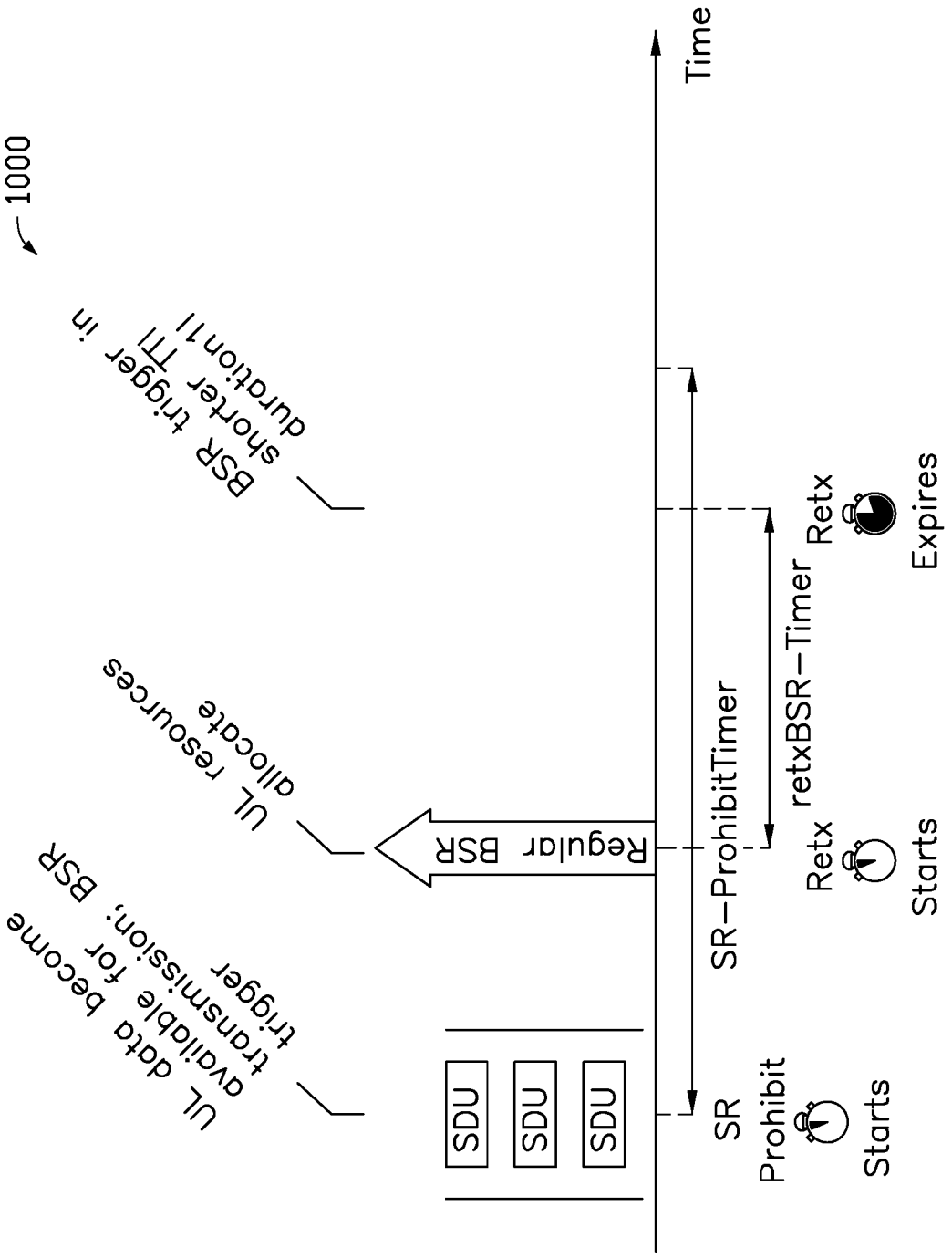

1000
Time
UL data become available for transmission; BSR trigger
SDU
SDU
SDU
SR Prohibit
Starts
SR-ProhibitTimer
retxBSR-Timer
Retx
Starts
Retx
Expires
Regular BSR
UL resources allocate
BSR trigger in shorter TTI duration 11

FIG. 10

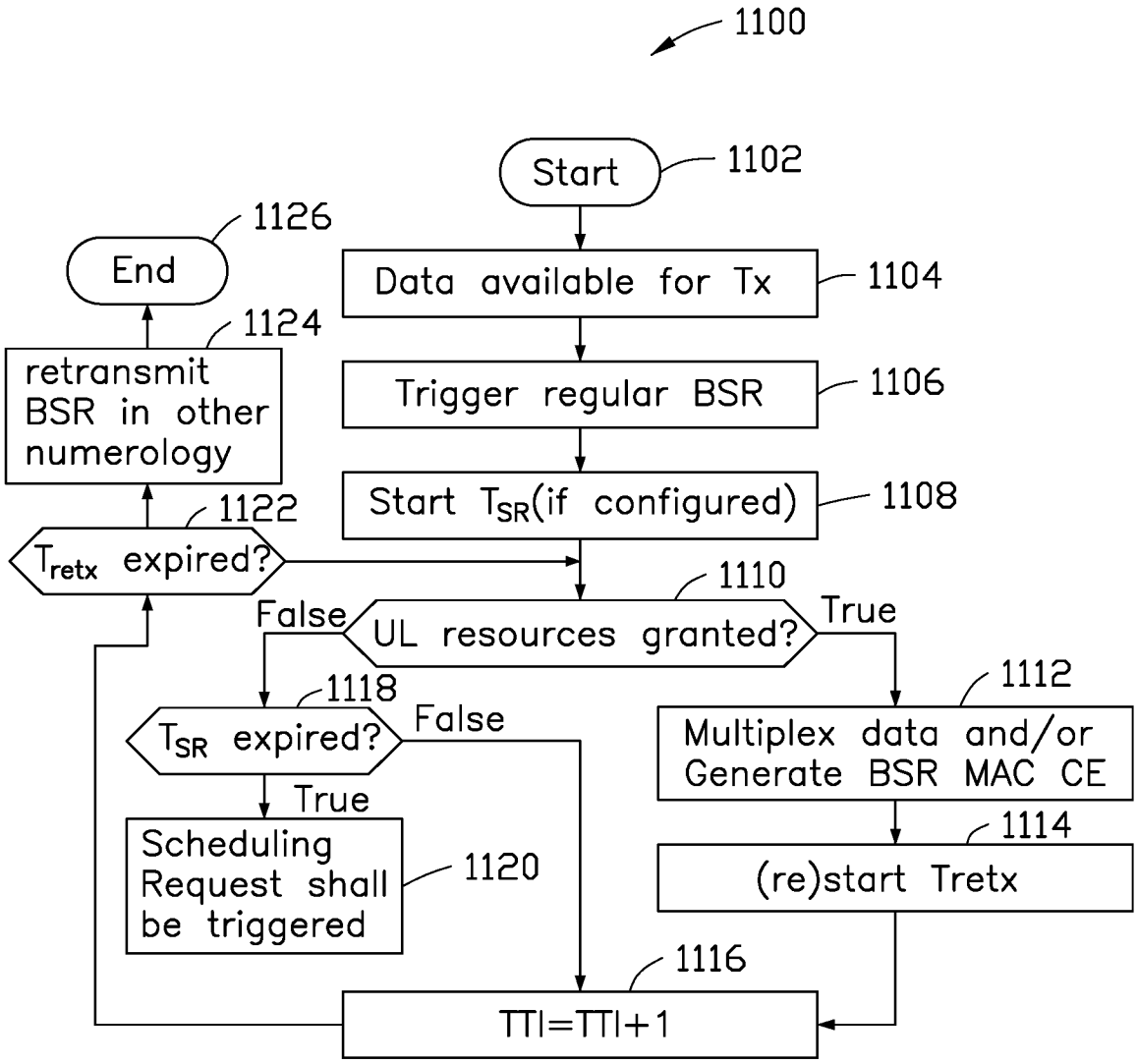

1100
Start
1102
Data available for Tx
1104
Trigger regular BSR
1106
Start T_{SR}(if configured)
1108
1110
UL resources granted?
False
True
1112
Multiplex data and/or Generate BSR MAC CE
1114
(re)start Tretx
1116
TTI=TTI+1
1118
T_{SR} expired?
False
True
Scheduling Request shall be triggered
1120
1122
T_{retx} expired?
1124
retransmit BSR in other numerology
1126
End

FIG. 11

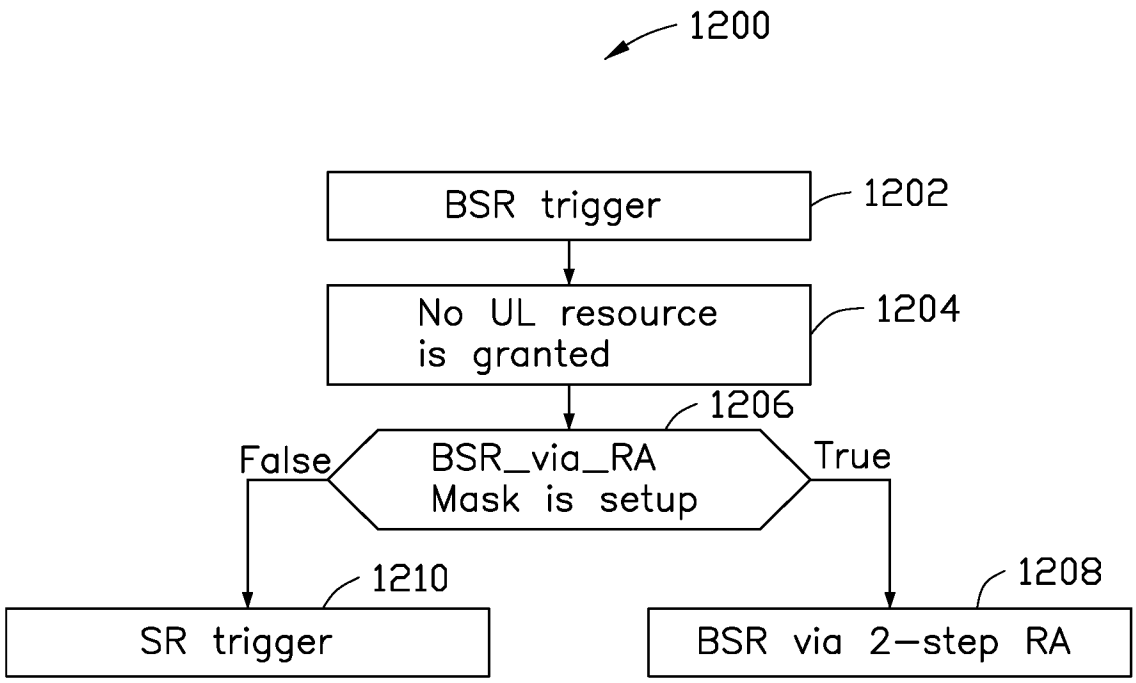

1200
BSR trigger
1202
No UL resource is granted
1204
1206
False
BSR_via_RA Mask is setup
True
1210
1208
SR trigger
BSR via 2-step RA

FIG. 12

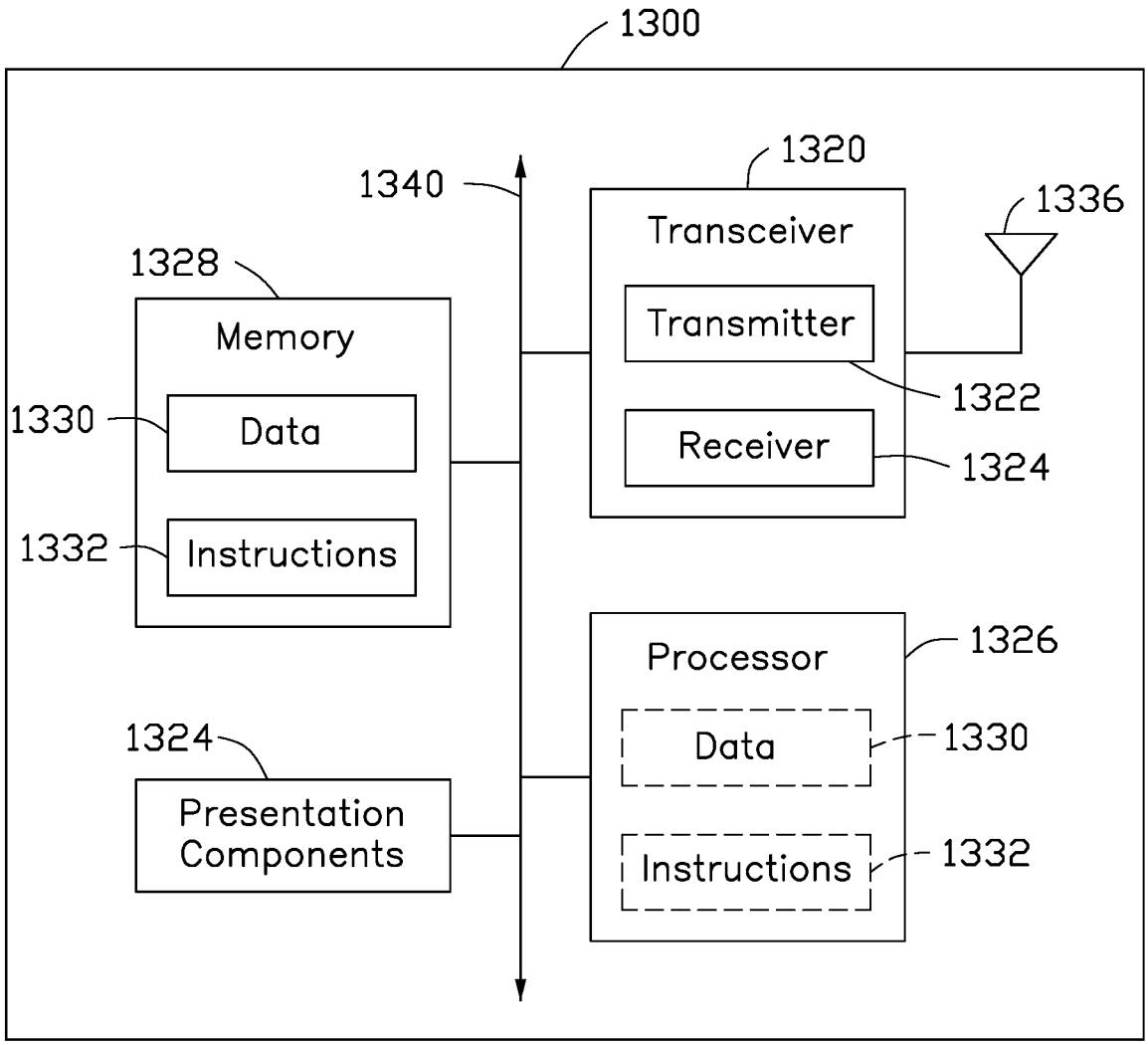

1300
1340
1320
Transceiver
1336
1328
Memory
Transmitter
1330
Data
1322
Receiver
1324
1332
Instructions
Processor
1326
1324
Data
1330
Presentation Components
Instructions
1332

FIG. 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2018/091365

A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/12(2009.01)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; H04L

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

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

CNPAT;WPI;EPODOC;CNKI;3GPP:BSR, list?, numerolog??, TTI, LCG ID, LCGID, spac+, CP, LCH?, LCG?, buffer satus report?, logical channel?, length

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ERICSSON. "Uplink dynamic scheduling in NR, " *3GPP TSG-RAN WG2 #97 Tdoc R2-1700838*, , 17 February 2017 (2017-02-17), section 2.2.2	1-23
A	US 2017099615 A1 (KONINKLIJKE PHILIPS N.V.) 06 April 2017 (2017-04-06) the whole document	1-23
A	WO 2013009635 A2 (INTERDIGITAL PATENT HOLDINGS, INC.) 17 January 2013 (2013-01-17) the whole document	1-23
A	CN 106535246 A (ZTE CORP.) 22 March 2017 (2017-03-22) the whole document	1-23

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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	Date of mailing of the international search report
17 August 2018	**04 September 2018**

Name and mailing address of the ISA/CN	Authorized officer
STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China**	**XU,Hongyan**
Facsimile No. **(86-10)62019451**	Telephone No. **86-(10)-53961670**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2018/091365

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
US	2017099615	A1	06 April 2017	BR	PI1006380	A2	19 June 2018
				WO	2010119390	A1	21 October 2010
				CN	102396192	A	28 March 2012
				JP	2012524443	A	11 October 2012
				KR	20120016240	A	23 February 2012
				RU	2011146324	A	10 June 2013
				US	2012033569	A1	09 February 2012
				TW	201132202	A	16 September 2011
				EP	2420029	A1	22 February 2012
WO	2013009635	A2	17 January 2013	US	2014241265	A1	28 August 2014
				TW	201316796	A	16 April 2013
CN	106535246	A	22 March 2017	WO	2016177221	A1	10 November 2016