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(54) Title: CONFIGURATION RELEASE

(57) Abstract: A wireless device receives, from a first base station, a first radio resource control release message comprising a first configured grant configuration of a first cell for a radio resource control non-connected state of the wireless device. The wireless device transmits, via a second cell, a second radio resource control message comprising a release indication for the first configured grant configuration.

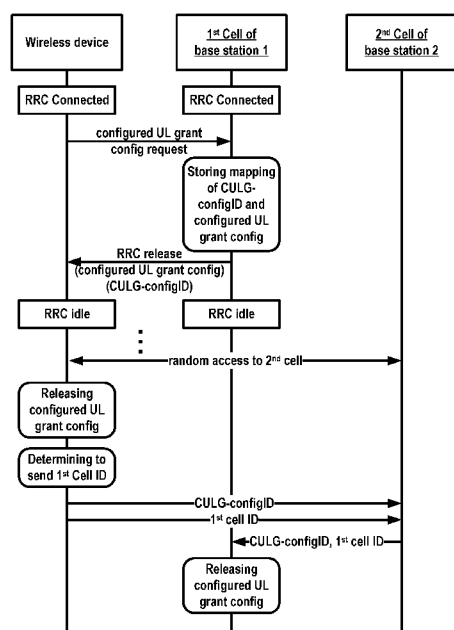


FIG. 22

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TITLE

Configuration Release

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 63/058,134, filed 29 July 2020, which is hereby incorporated by reference in its entirety.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0002] Examples of several of the various embodiments of the present disclosure are described herein with reference to the drawings.
- [0003] FIG. 1A and FIG. 1B illustrate example mobile communication networks in which embodiments of the present disclosure may be implemented.
- [0004] FIG. 2A and FIG. 2B respectively illustrate a New Radio (NR) user plane and control plane protocol stack.
- [0005] FIG. 3 illustrates an example of services provided between protocol layers of the NR user plane protocol stack of FIG. 2A.
- [0006] FIG. 4A illustrates an example downlink data flow through the NR user plane protocol stack of FIG. 2A.
- [0007] FIG. 4B illustrates an example format of a MAC subheader in a MAC PDU.
- [0008] FIG. 5A and FIG. 5B respectively illustrate a mapping between logical channels, transport channels, and physical channels for the downlink and uplink.
- [0009] FIG. 6 is an example diagram showing RRC state transitions of a UE.
- [0010] FIG. 7 illustrates an example configuration of an NR frame into which OFDM symbols are grouped.
- [0011] FIG. 8 illustrates an example configuration of a slot in the time and frequency domain for an NR carrier.
- [0012] FIG. 9 illustrates an example of bandwidth adaptation using three configured BWPs for an NR carrier.
- [0013] FIG. 10A illustrates three carrier aggregation configurations with two component carriers.
- [0014] FIG. 10B illustrates an example of how aggregated cells may be configured into one or more PUCCH groups.
- [0015] FIG. 11A illustrates an example of an SS/PBCH block structure and location.
- [0016] FIG. 11B illustrates an example of CSI-RSs that are mapped in the time and frequency domains.

- [0017] FIG. 12A and FIG. 12B respectively illustrate examples of three downlink and uplink beam management procedures.
- [0018] FIG. 13A, FIG. 13B, and FIG. 13C respectively illustrate a four-step contention-based random access procedure, a two-step contention-free random access procedure, and another two-step random access procedure.
- [0019] FIG. 14A illustrates an example of CORESET configurations for a bandwidth part.
- [0020] FIG. 14B illustrates an example of a CCE-to-REG mapping for DCI transmission on a CORESET and PDCCH processing.
- [0021] FIG. 15 illustrates an example of a wireless device in communication with a base station.
- [0022] FIG. 16A, FIG. 16B, FIG. 16C, and FIG. 16D illustrate example structures for uplink and downlink transmission.
- [0023] FIG. 17 illustrates an example of an RRC connection reestablishment procedure.
- [0024] FIG. 18 illustrates an example of an RRC connection resume procedure.
- [0025] FIG. 19 illustrates an example of a configured grant.
- [0026] FIG. 20 illustrates an example of a user plane configured grant and a control plane configured grant.
- [0027] FIG. 21 illustrates an example of releasing configured grant (CG) configuration parameters.
- [0028] FIG. 22 illustrates an example of an enhanced CG release procedure.
- [0029] FIG. 23 illustrates an example of an enhanced CG release procedure for a failure to resume an RRC connection.
- [0030] FIG. 24 illustrates an example of a CG release in CU DU architecture.
- [0031] FIG. 25 illustrates an example of a CG configuration request comprising a cell identity.

DETAILED DESCRIPTION

- [0032] In the present disclosure, various embodiments are presented as examples of how the disclosed techniques may be implemented and/or how the disclosed techniques may be practiced in environments and scenarios. It will be apparent to persons skilled in the relevant art that various changes in form and detail can be made therein without departing from the scope. In fact, after reading the description, it will be apparent to one skilled in the relevant art how to implement alternative embodiments. The present embodiments should not be limited by any of the described exemplary embodiments. The embodiments of the present disclosure will be described with reference to the accompanying drawings. Limitations,

features, and/or elements from the disclosed example embodiments may be combined to create further embodiments within the scope of the disclosure. Any figures which highlight the functionality and advantages, are presented for example purposes only. The disclosed architecture is sufficiently flexible and configurable, such that it may be utilized in ways other than that shown. For example, the actions listed in any flowchart may be re-ordered or only optionally used in some embodiments.

[0033] Embodiments may be configured to operate as needed. The disclosed mechanism may be performed when certain criteria are met, for example, in a wireless device, a base station, a radio environment, a network, a combination of the above, and/or the like. Example criteria may be based, at least in part, on for example, wireless device or network node configurations, traffic load, initial system set up, packet sizes, traffic characteristics, a combination of the above, and/or the like. When the one or more criteria are met, various example embodiments may be applied. Therefore, it may be possible to implement example embodiments that selectively implement disclosed protocols.

[0034] A base station may communicate with a mix of wireless devices. Wireless devices and/or base stations may support multiple technologies, and/or multiple releases of the same technology. Wireless devices may have some specific capability(ies) depending on wireless device category and/or capability(ies). When this disclosure refers to a base station communicating with a plurality of wireless devices, this disclosure may refer to a subset of the total wireless devices in a coverage area. This disclosure may refer to, for example, a plurality of wireless devices of a given LTE or 5G release with a given capability and in a given sector of the base station. The plurality of wireless devices in this disclosure may refer to a selected plurality of wireless devices, and/or a subset of total wireless devices in a coverage area which perform according to disclosed methods, and/or the like. There may be a plurality of base stations or a plurality of wireless devices in a coverage area that may not comply with the disclosed methods, for example, those wireless devices or base stations may perform based on older releases of LTE or 5G technology.

[0035] In this disclosure, “a” and “an” and similar phrases are to be interpreted as “at least one” and “one or more.” Similarly, any term that ends with the suffix “(s)” is to be interpreted as “at least one” and “one or more.” In this disclosure, the term “may” is to be interpreted as “may, for example.” In other words, the term “may” is indicative that the phrase following the term “may” is an example of one of a multitude of suitable possibilities that may, or may not, be employed by one or more of the various embodiments. The terms “comprises” and “consists of”, as used herein, enumerate one or more components of the element being described. The term “comprises” is interchangeable with “includes” and does

not exclude unenumerated components from being included in the element being described. By contrast, “consists of” provides a complete enumeration of the one or more components of the element being described. The term “based on”, as used herein, should be interpreted as “based at least in part on” rather than, for example, “based solely on”. The term “and/or” as used herein represents any possible combination of enumerated elements. For example, “A, B, and/or C” may represent A; B; C; A and B; A and C; B and C; or A, B, and C.

[0036] If A and B are sets and every element of A is an element of B, A is called a subset of B. In this specification, only non-empty sets and subsets are considered. For example, possible subsets of $B = \{\text{cell1}, \text{cell2}\}$ are: $\{\text{cell1}\}$, $\{\text{cell2}\}$, and $\{\text{cell1}, \text{cell2}\}$. The phrase “based on” (or equally “based at least on”) is indicative that the phrase following the term “based on” is an example of one of a multitude of suitable possibilities that may, or may not, be employed to one or more of the various embodiments. The phrase “in response to” (or equally “in response at least to”) is indicative that the phrase following the phrase “in response to” is an example of one of a multitude of suitable possibilities that may, or may not, be employed to one or more of the various embodiments. The phrase “depending on” (or equally “depending at least to”) is indicative that the phrase following the phrase “depending on” is an example of one of a multitude of suitable possibilities that may, or may not, be employed to one or more of the various embodiments. The phrase “employing/using” (or equally “employing/using at least”) is indicative that the phrase following the phrase “employing/using” is an example of one of a multitude of suitable possibilities that may, or may not, be employed to one or more of the various embodiments.

[0037] The term configured may relate to the capacity of a device whether the device is in an operational or non-operational state. Configured may refer to specific settings in a device that effect the operational characteristics of the device whether the device is in an operational or non-operational state. In other words, the hardware, software, firmware, registers, memory values, and/or the like may be “configured” within a device, whether the device is in an operational or nonoperational state, to provide the device with specific characteristics. Terms such as “a control message to cause in a device” may mean that a control message has parameters that may be used to configure specific characteristics or may be used to implement certain actions in the device, whether the device is in an operational or non-operational state.

[0038] In this disclosure, parameters (or equally called, fields, or Information elements: IEs) may comprise one or more information objects, and an information object may comprise one or more other objects. For example, if parameter (IE) N comprises parameter (IE) M, and parameter (IE) M comprises parameter (IE) K, and parameter (IE) K comprises parameter

(information element) J. Then, for example, N comprises K, and N comprises J. In an example embodiment, when one or more messages comprise a plurality of parameters, it implies that a parameter in the plurality of parameters is in at least one of the one or more messages, but does not have to be in each of the one or more messages.

[0039] Many features presented are described as being optional through the use of “may” or the use of parentheses. For the sake of brevity and legibility, the present disclosure does not explicitly recite each and every permutation that may be obtained by choosing from the set of optional features. The present disclosure is to be interpreted as explicitly disclosing all such permutations. For example, a system described as having three optional features may be embodied in seven ways, namely with just one of the three possible features, with any two of the three possible features or with three of the three possible features.

[0040] Many of the elements described in the disclosed embodiments may be implemented as modules. A module is defined here as an element that performs a defined function and has a defined interface to other elements. The modules described in this disclosure may be implemented in hardware, software in combination with hardware, firmware, wetware (e.g. hardware with a biological element) or a combination thereof, which may be behaviorally equivalent. For example, modules may be implemented as a software routine written in a computer language configured to be executed by a hardware machine (such as C, C++, Fortran, Java, Basic, Matlab or the like) or a modeling/simulation program such as Simulink, Stateflow, GNU Octave, or LabVIEWMathScript. It may be possible to implement modules using physical hardware that incorporates discrete or programmable analog, digital and/or quantum hardware. Examples of programmable hardware comprise: computers, microcontrollers, microprocessors, application-specific integrated circuits (ASICs); field programmable gate arrays (FPGAs); and complex programmable logic devices (CPLDs). Computers, microcontrollers and microprocessors are programmed using languages such as assembly, C, C++ or the like. FPGAs, ASICs and CPLDs are often programmed using hardware description languages (HDL) such as VHSIC hardware description language (VHDL) or Verilog that configure connections between internal hardware modules with lesser functionality on a programmable device. The mentioned technologies are often used in combination to achieve the result of a functional module.

[0041] FIG. 1A illustrates an example of a mobile communication network 100 in which embodiments of the present disclosure may be implemented. The mobile communication network 100 may be, for example, a public land mobile network (PLMN) run by a network operator. As illustrated in FIG. 1A, the mobile communication network 100 includes a core network (CN) 102, a radio access network (RAN) 104, and a wireless device 106.

[0042] The CN 102 may provide the wireless device 106 with an interface to one or more data networks (DNs), such as public DN (e.g., the Internet), private DN, and/or intra-operator DN. As part of the interface functionality, the CN 102 may set up end-to-end connections between the wireless device 106 and the one or more DN, authenticate the wireless device 106, and provide charging functionality.

[0043] The RAN 104 may connect the CN 102 to the wireless device 106 through radio communications over an air interface. As part of the radio communications, the RAN 104 may provide scheduling, radio resource management, and retransmission protocols. The communication direction from the RAN 104 to the wireless device 106 over the air interface is known as the downlink and the communication direction from the wireless device 106 to the RAN 104 over the air interface is known as the uplink. Downlink transmissions may be separated from uplink transmissions using frequency division duplexing (FDD), time-division duplexing (TDD), and/or some combination of the two duplexing techniques.

[0044] The term wireless device may be used throughout this disclosure to refer to and encompass any mobile device or fixed (non-mobile) device for which wireless communication is needed or usable. For example, a wireless device may be a telephone, smart phone, tablet, computer, laptop, sensor, meter, wearable device, Internet of Things (IoT) device, vehicle road side unit (RSU), relay node, automobile, and/or any combination thereof. The term wireless device encompasses other terminology, including user equipment (UE), user terminal (UT), access terminal (AT), mobile station, handset, wireless transmit and receive unit (WTRU), and/or wireless communication device.

[0045] The RAN 104 may include one or more base stations (not shown). The term base station may be used throughout this disclosure to refer to and encompass a Node B (associated with UMTS and/or 3G standards), an Evolved Node B (eNB, associated with E-UTRA and/or 4G standards), a remote radio head (RRH), a baseband processing unit coupled to one or more RRHs, a repeater node or relay node used to extend the coverage area of a donor node, a Next Generation Evolved Node B (ng-eNB), a Generation Node B (gNB, associated with NR and/or 5G standards), an access point (AP, associated with, for example, WiFi or any other suitable wireless communication standard), and/or any combination thereof. A base station may comprise at least one gNB Central Unit (gNB-CU) and at least one a gNB Distributed Unit (gNB-DU).

[0046] A base station included in the RAN 104 may include one or more sets of antennas for communicating with the wireless device 106 over the air interface. For example, one or more of the base stations may include three sets of antennas to respectively control three cells (or sectors). The size of a cell may be determined by a range at which a receiver (e.g., a base

station receiver) can successfully receive the transmissions from a transmitter (e.g., a wireless device transmitter) operating in the cell. Together, the cells of the base stations may provide radio coverage to the wireless device 106 over a wide geographic area to support wireless device mobility.

[0047] In addition to three-sector sites, other implementations of base stations are possible. For example, one or more of the base stations in the RAN 104 may be implemented as a sectored site with more or less than three sectors. One or more of the base stations in the RAN 104 may be implemented as an access point, as a baseband processing unit coupled to several remote radio heads (RRHs), and/or as a repeater or relay node used to extend the coverage area of a donor node. A baseband processing unit coupled to RRHs may be part of a centralized or cloud RAN architecture, where the baseband processing unit may be either centralized in a pool of baseband processing units or virtualized. A repeater node may amplify and rebroadcast a radio signal received from a donor node. A relay node may perform the same/similar functions as a repeater node but may decode the radio signal received from the donor node to remove noise before amplifying and rebroadcasting the radio signal.

[0048] The RAN 104 may be deployed as a homogenous network of macrocell base stations that have similar antenna patterns and similar high-level transmit powers. The RAN 104 may be deployed as a heterogeneous network. In heterogeneous networks, small cell base stations may be used to provide small coverage areas, for example, coverage areas that overlap with the comparatively larger coverage areas provided by macrocell base stations. The small coverage areas may be provided in areas with high data traffic (or so-called “hotspots”) or in areas with weak macrocell coverage. Examples of small cell base stations include, in order of decreasing coverage area, microcell base stations, picocell base stations, and femtocell base stations or home base stations.

[0049] The Third-Generation Partnership Project (3GPP) was formed in 1998 to provide global standardization of specifications for mobile communication networks similar to the mobile communication network 100 in FIG. 1A. To date, 3GPP has produced specifications for three generations of mobile networks: a third generation (3G) network known as Universal Mobile Telecommunications System (UMTS), a fourth generation (4G) network known as Long-Term Evolution (LTE), and a fifth generation (5G) network known as 5G System (5GS). Embodiments of the present disclosure are described with reference to the RAN of a 3GPP 5G network, referred to as next-generation RAN (NG-RAN). Embodiments may be applicable to RANs of other mobile communication networks, such as the RAN 104 in FIG. 1A, the RANs of earlier 3G and 4G networks, and those of future networks yet to be

specified (e.g., a 3GPP 6G network). NG-RAN implements 5G radio access technology known as New Radio (NR) and may be provisioned to implement 4G radio access technology or other radio access technologies, including non-3GPP radio access technologies.

[0050] FIG. 1B illustrates another example mobile communication network 150 in which embodiments of the present disclosure may be implemented. Mobile communication network 150 may be, for example, a PLMN run by a network operator. As illustrated in FIG. 1B, mobile communication network 150 includes a 5G core network (5G-CN) 152, an NG-RAN 154, and UEs 156A and 156B (collectively UEs 156). These components may be implemented and operate in the same or similar manner as corresponding components described with respect to FIG. 1A.

[0051] The 5G-CN 152 provides the UEs 156 with an interface to one or more DN's, such as public DN's (e.g., the Internet), private DN's, and/or intra-operator DN's. As part of the interface functionality, the 5G-CN 152 may set up end-to-end connections between the UEs 156 and the one or more DN's, authenticate the UEs 156, and provide charging functionality. Compared to the CN of a 3GPP 4G network, the basis of the 5G-CN 152 may be a service-based architecture. This means that the architecture of the nodes making up the 5G-CN 152 may be defined as network functions that offer services via interfaces to other network functions. The network functions of the 5G-CN 152 may be implemented in several ways, including as network elements on dedicated or shared hardware, as software instances running on dedicated or shared hardware, or as virtualized functions instantiated on a platform (e.g., a cloud-based platform).

[0052] As illustrated in FIG. 1B, the 5G-CN 152 includes an Access and Mobility Management Function (AMF) 158A and a User Plane Function (UPF) 158B, which are shown as one component AMF/UPF 158 in FIG. 1B for ease of illustration. The UPF 158B may serve as a gateway between the NG-RAN 154 and the one or more DN's. The UPF 158B may perform functions such as packet routing and forwarding, packet inspection and user plane policy rule enforcement, traffic usage reporting, uplink classification to support routing of traffic flows to the one or more DN's, quality of service (QoS) handling for the user plane (e.g., packet filtering, gating, uplink/downlink rate enforcement, and uplink traffic verification), downlink packet buffering, and downlink data notification triggering. The UPF 158B may serve as an anchor point for intra-/inter-Radio Access Technology (RAT) mobility, an external protocol (or packet) data unit (PDU) session point of interconnect to the one or more DN's, and/or a branching point to support a multi-homed PDU session. The UEs

156 may be configured to receive services through a PDU session, which is a logical connection between a UE and a DN.

[0053] The AMF 158A may perform functions such as Non-Access Stratum (NAS) signaling termination, NAS signaling security, Access Stratum (AS) security control, inter-CN node signaling for mobility between 3GPP access networks, idle mode UE reachability (e.g., control and execution of paging retransmission), registration area management, intra-system and inter-system mobility support, access authentication, access authorization including checking of roaming rights, mobility management control (subscription and policies), network slicing support, and/or session management function (SMF) selection. NAS may refer to the functionality operating between a CN and a UE, and AS may refer to the functionality operating between the UE and a RAN.

[0054] The 5G-CN 152 may include one or more additional network functions that are not shown in FIG. 1B for the sake of clarity. For example, the 5G-CN 152 may include one or more of a Session Management Function (SMF), an NR Repository Function (NRF), a Policy Control Function (PCF), a Network Exposure Function (NEF), a Unified Data Management (UDM), an Application Function (AF), and/or an Authentication Server Function (AUSF).

[0055] The NG-RAN 154 may connect the 5G-CN 152 to the UEs 156 through radio communications over the air interface. The NG-RAN 154 may include one or more gNBs, illustrated as gNB 160A and gNB 160B (collectively gNBs 160) and/or one or more ng-eNBs, illustrated as ng-eNB 162A and ng-eNB 162B (collectively ng-eNBs 162). The gNBs 160 and ng-eNBs 162 may be more generically referred to as base stations. The gNBs 160 and ng-eNBs 162 may include one or more sets of antennas for communicating with the UEs 156 over an air interface. For example, one or more of the gNBs 160 and/or one or more of the ng-eNBs 162 may include three sets of antennas to respectively control three cells (or sectors). Together, the cells of the gNBs 160 and the ng-eNBs 162 may provide radio coverage to the UEs 156 over a wide geographic area to support UE mobility.

[0056] As shown in FIG. 1B, the gNBs 160 and/or the ng-eNBs 162 may be connected to the 5G-CN 152 by means of an NG interface and to other base stations by an Xn interface. The NG and Xn interfaces may be established using direct physical connections and/or indirect connections over an underlying transport network, such as an internet protocol (IP) transport network. The gNBs 160 and/or the ng-eNBs 162 may be connected to the UEs 156 by means of a Uu interface. For example, as illustrated in FIG. 1B, gNB 160A may be connected to the UE 156A by means of a Uu interface. The NG, Xn, and Uu interfaces are associated with a protocol stack. The protocol stacks associated with the interfaces may be used by the network elements in FIG. 1B to exchange data and signaling messages and may include two planes: a

user plane and a control plane. The user plane may handle data of interest to a user. The control plane may handle signaling messages of interest to the network elements.

[0057] The gNBs 160 and/or the ng-eNBs 162 may be connected to one or more AMF/UPF functions of the 5G-CN 152, such as the AMF/UPF 158, by means of one or more NG interfaces. For example, the gNB 160A may be connected to the UPF 158B of the AMF/UPF 158 by means of an NG-User plane (NG-U) interface. The NG-U interface may provide delivery (e.g., non-guaranteed delivery) of user plane PDUs between the gNB 160A and the UPF 158B. The gNB 160A may be connected to the AMF 158A by means of an NG-Control plane (NG-C) interface. The NG-C interface may provide, for example, NG interface management, UE context management, UE mobility management, transport of NAS messages, paging, PDU session management, and configuration transfer and/or warning message transmission.

[0058] The gNBs 160 may provide NR user plane and control plane protocol terminations towards the UEs 156 over the Uu interface. For example, the gNB 160A may provide NR user plane and control plane protocol terminations toward the UE 156A over a Uu interface associated with a first protocol stack. The ng-eNBs 162 may provide Evolved UMTS Terrestrial Radio Access (E-UTRA) user plane and control plane protocol terminations towards the UEs 156 over a Uu interface, where E-UTRA refers to the 3GPP 4G radio-access technology. For example, the ng-eNB 162B may provide E-UTRA user plane and control plane protocol terminations towards the UE 156B over a Uu interface associated with a second protocol stack.

[0059] The 5G-CN 152 was described as being configured to handle NR and 4G radio accesses. It will be appreciated by one of ordinary skill in the art that it may be possible for NR to connect to a 4G core network in a mode known as “non-standalone operation.” In non-standalone operation, a 4G core network is used to provide (or at least support) control-plane functionality (e.g., initial access, mobility, and paging). Although only one AMF/UPF 158 is shown in FIG. 1B, one gNB or ng-eNB may be connected to multiple AMF/UPF nodes to provide redundancy and/or to load share across the multiple AMF/UPF nodes.

[0060] As discussed, an interface (e.g., Uu, Xn, and NG interfaces) between the network elements in FIG. 1B may be associated with a protocol stack that the network elements use to exchange data and signaling messages. A protocol stack may include two planes: a user plane and a control plane. The user plane may handle data of interest to a user, and the control plane may handle signaling messages of interest to the network elements.

[0061] FIG. 2A and FIG. 2B respectively illustrate examples of NR user plane and NR control plane protocol stacks for the Uu interface that lies between a UE 210 and a gNB 220.

The protocol stacks illustrated in FIG. 2A and FIG. 2B may be the same or similar to those used for the Uu interface between, for example, the UE 156A and the gNB 160A shown in FIG. 1B.

[0062] FIG. 2A illustrates a NR user plane protocol stack comprising five layers implemented in the UE 210 and the gNB 220. At the bottom of the protocol stack, physical layers (PHYs) 211 and 221 may provide transport services to the higher layers of the protocol stack and may correspond to layer 1 of the Open Systems Interconnection (OSI) model. The next four protocols above PHYs 211 and 221 comprise media access control layers (MACs) 212 and 222, radio link control layers (RLCs) 213 and 223, packet data convergence protocol layers (PDCPs) 214 and 224, and service data application protocol layers (SDAPs) 215 and 225. Together, these four protocols may make up layer 2, or the data link layer, of the OSI model.

[0063] FIG. 3 illustrates an example of services provided between protocol layers of the NR user plane protocol stack. Starting from the top of FIG. 2A and FIG. 3, the SDAPs 215 and 225 may perform QoS flow handling. The UE 210 may receive services through a PDU session, which may be a logical connection between the UE 210 and a DN. The PDU session may have one or more QoS flows. A UPF of a CN (e.g., the UPF 158B) may map IP packets to the one or more QoS flows of the PDU session based on QoS requirements (e.g., in terms of delay, data rate, and/or error rate). The SDAPs 215 and 225 may perform mapping/de-mapping between the one or more QoS flows and one or more data radio bearers. The mapping/de-mapping between the QoS flows and the data radio bearers may be determined by the SDAP 225 at the gNB 220. The SDAP 215 at the UE 210 may be informed of the mapping between the QoS flows and the data radio bearers through reflective mapping or control signaling received from the gNB 220. For reflective mapping, the SDAP 225 at the gNB 220 may mark the downlink packets with a QoS flow indicator (QFI), which may be observed by the SDAP 215 at the UE 210 to determine the mapping/de-mapping between the QoS flows and the data radio bearers.

[0064] The PDCPs 214 and 224 may perform header compression/decompression to reduce the amount of data that needs to be transmitted over the air interface, ciphering/deciphering to prevent unauthorized decoding of data transmitted over the air interface, and integrity protection (to ensure control messages originate from intended sources). The PDCPs 214 and 224 may perform retransmissions of undelivered packets, in-sequence delivery and reordering of packets, and removal of packets received in duplicate due to, for example, an intra-gNB handover. The PDCPs 214 and 224 may perform packet duplication to improve

the likelihood of the packet being received and, at the receiver, remove any duplicate packets. Packet duplication may be useful for services that require high reliability.

[0065] Although not shown in FIG. 3, PDCPs 214 and 224 may perform mapping/de-mapping between a split radio bearer and RLC channels in a dual connectivity scenario. Dual connectivity is a technique that allows a UE to connect to two cells or, more generally, two cell groups: a master cell group (MCG) and a secondary cell group (SCG). A split bearer is when a single radio bearer, such as one of the radio bearers provided by the PDCPs 214 and 224 as a service to the SDAPs 215 and 225, is handled by cell groups in dual connectivity. The PDCPs 214 and 224 may map/de-map the split radio bearer between RLC channels belonging to cell groups.

[0066] The RLCs 213 and 223 may perform segmentation, retransmission through Automatic Repeat Request (ARQ), and removal of duplicate data units received from MACs 212 and 222, respectively. The RLCs 213 and 223 may support three transmission modes: transparent mode (TM); unacknowledged mode (UM); and acknowledged mode (AM). Based on the transmission mode an RLC is operating, the RLC may perform one or more of the noted functions. The RLC configuration may be per logical channel with no dependency on numerologies and/or Transmission Time Interval (TTI) durations. As shown in FIG. 3, the RLCs 213 and 223 may provide RLC channels as a service to PDCPs 214 and 224, respectively.

[0067] The MACs 212 and 222 may perform multiplexing/demultiplexing of logical channels and/or mapping between logical channels and transport channels. The multiplexing/demultiplexing may include multiplexing/demultiplexing of data units, belonging to the one or more logical channels, into/from Transport Blocks (TBs) delivered to/from the PHYs 211 and 221. The MAC 222 may be configured to perform scheduling, scheduling information reporting, and priority handling between UEs by means of dynamic scheduling. Scheduling may be performed in the gNB 220 (at the MAC 222) for downlink and uplink. The MACs 212 and 222 may be configured to perform error correction through Hybrid Automatic Repeat Request (HARQ) (e.g., one HARQ entity per carrier in case of Carrier Aggregation (CA)), priority handling between logical channels of the UE 210 by means of logical channel prioritization, and/or padding. The MACs 212 and 222 may support one or more numerologies and/or transmission timings. In an example, mapping restrictions in a logical channel prioritization may control which numerology and/or transmission timing a logical channel may use. As shown in FIG. 3, the MACs 212 and 222 may provide logical channels as a service to the RLCs 213 and 223.

[0068] The PHYs 211 and 221 may perform mapping of transport channels to physical channels and digital and analog signal processing functions for sending and receiving information over the air interface. These digital and analog signal processing functions may include, for example, coding/decoding and modulation/demodulation. The PHYs 211 and 221 may perform multi-antenna mapping. As shown in FIG. 3, the PHYs 211 and 221 may provide one or more transport channels as a service to the MACs 212 and 222.

[0069] FIG. 4A illustrates an example downlink data flow through the NR user plane protocol stack. FIG. 4A illustrates a downlink data flow of three IP packets (n , $n+1$, and m) through the NR user plane protocol stack to generate two TBs at the gNB 220. An uplink data flow through the NR user plane protocol stack may be similar to the downlink data flow depicted in FIG. 4A.

[0070] The downlink data flow of FIG. 4A begins when SDAP 225 receives the three IP packets from one or more QoS flows and maps the three packets to radio bearers. In FIG. 4A, the SDAP 225 maps IP packets n and $n+1$ to a first radio bearer 402 and maps IP packet m to a second radio bearer 404. An SDAP header (labeled with an “H” in FIG. 4A) is added to an IP packet. The data unit from/to a higher protocol layer is referred to as a service data unit (SDU) of the lower protocol layer and the data unit to/from a lower protocol layer is referred to as a protocol data unit (PDU) of the higher protocol layer. As shown in FIG. 4A, the data unit from the SDAP 225 is an SDU of lower protocol layer PDCP 224 and is a PDU of the SDAP 225.

[0071] The remaining protocol layers in FIG. 4A may perform their associated functionality (e.g., with respect to FIG. 3), add corresponding headers, and forward their respective outputs to the next lower layer. For example, the PDCP 224 may perform IP-header compression and ciphering and forward its output to the RLC 223. The RLC 223 may optionally perform segmentation (e.g., as shown for IP packet m in FIG. 4A) and forward its output to the MAC 222. The MAC 222 may multiplex a number of RLC PDUs and may attach a MAC subheader to an RLC PDU to form a transport block. In NR, the MAC subheaders may be distributed across the MAC PDU, as illustrated in FIG. 4A. In LTE, the MAC subheaders may be entirely located at the beginning of the MAC PDU. The NR MAC PDU structure may reduce processing time and associated latency because the MAC PDU subheaders may be computed before the full MAC PDU is assembled.

[0072] FIG. 4B illustrates an example format of a MAC subheader in a MAC PDU. The MAC subheader includes: an SDU length field for indicating the length (e.g., in bytes) of the MAC SDU to which the MAC subheader corresponds; a logical channel identifier (LCID) field for identifying the logical channel from which the MAC SDU originated to aid in the

demultiplexing process; a flag (F) for indicating the size of the SDU length field; and a reserved bit (R) field for future use.

[0073] FIG. 4B further illustrates MAC control elements (CEs) inserted into the MAC PDU by a MAC, such as MAC 223 or MAC 222. For example, FIG. 4B illustrates two MAC CEs inserted into the MAC PDU. MAC CEs may be inserted at the beginning of a MAC PDU for downlink transmissions (as shown in FIG. 4B) and at the end of a MAC PDU for uplink transmissions. MAC CEs may be used for in-band control signaling. Example MAC CEs include: scheduling-related MAC CEs, such as buffer status reports and power headroom reports; activation/deactivation MAC CEs, such as those for activation/deactivation of PDCP duplication detection, channel state information (CSI) reporting, sounding reference signal (SRS) transmission, and prior configured components; discontinuous reception (DRX) related MAC CEs; timing advance MAC CEs; and random access related MAC CEs. A MAC CE may be preceded by a MAC subheader with a similar format as described for MAC SDUs and may be identified with a reserved value in the LCID field that indicates the type of control information included in the MAC CE.

[0074] Before describing the NR control plane protocol stack, logical channels, transport channels, and physical channels are first described as well as a mapping between the channel types. One or more of the channels may be used to carry out functions associated with the NR control plane protocol stack described later below.

[0075] FIG. 5A and FIG. 5B illustrate, for downlink and uplink respectively, a mapping between logical channels, transport channels, and physical channels. Information is passed through channels between the RLC, the MAC, and the PHY of the NR protocol stack. A logical channel may be used between the RLC and the MAC and may be classified as a control channel that carries control and configuration information in the NR control plane or as a traffic channel that carries data in the NR user plane. A logical channel may be classified as a dedicated logical channel that is dedicated to a specific UE or as a common logical channel that may be used by more than one UE. A logical channel may also be defined by the type of information it carries. The set of logical channels defined by NR include, for example:

- a paging control channel (PCCH) for carrying paging messages used to page a UE whose location is not known to the network on a cell level;
- a broadcast control channel (BCCH) for carrying system information messages in the form of a master information block (MIB) and several system information blocks (SIBs), wherein the system information messages may be used by the UEs

to obtain information about how a cell is configured and how to operate within the cell;

- a common control channel (CCCH) for carrying control messages together with random access;
- a dedicated control channel (DCCH) for carrying control messages to/from a specific the UE to configure the UE; and
- a dedicated traffic channel (DTCH) for carrying user data to/from a specific the UE.

[0076] Transport channels are used between the MAC and PHY layers and may be defined by how the information they carry is transmitted over the air interface. The set of transport channels defined by NR include, for example:

- a paging channel (PCH) for carrying paging messages that originated from the PCCH;
- a broadcast channel (BCH) for carrying the MIB from the BCCH;
- a downlink shared channel (DL-SCH) for carrying downlink data and signaling messages, including the SIBs from the BCCH;
- an uplink shared channel (UL-SCH) for carrying uplink data and signaling messages; and
- a random access channel (RACH) for allowing a UE to contact the network without any prior scheduling.

[0077] The PHY may use physical channels to pass information between processing levels of the PHY. A physical channel may have an associated set of time-frequency resources for carrying the information of one or more transport channels. The PHY may generate control information to support the low-level operation of the PHY and provide the control information to the lower levels of the PHY via physical control channels, known as L1/L2 control channels. The set of physical channels and physical control channels defined by NR include, for example:

- a physical broadcast channel (PBCH) for carrying the MIB from the BCH;
- a physical downlink shared channel (PDSCH) for carrying downlink data and signaling messages from the DL-SCH, as well as paging messages from the PCH;
- a physical downlink control channel (PDCCH) for carrying downlink control information (DCI), which may include downlink scheduling commands, uplink scheduling grants, and uplink power control commands;

- a physical uplink shared channel (PUSCH) for carrying uplink data and signaling messages from the UL-SCH and in some instances uplink control information (UCI) as described below;
- a physical uplink control channel (PUCCH) for carrying UCI, which may include HARQ acknowledgments, channel quality indicators (CQI), pre-coding matrix indicators (PMI), rank indicators (RI), and scheduling requests (SR); and
- a physical random access channel (PRACH) for random access.

[0078] Similar to the physical control channels, the physical layer generates physical signals to support the low-level operation of the physical layer. As shown in FIG. 5A and FIG. 5B, the physical layer signals defined by NR include: primary synchronization signals (PSS), secondary synchronization signals (SSS), channel state information reference signals (CSI-RS), demodulation reference signals (DMRS), sounding reference signals (SRS), and phase-tracking reference signals (PT-RS). These physical layer signals will be described in greater detail below.

[0079] FIG. 2B illustrates an example NR control plane protocol stack. As shown in FIG. 2B, the NR control plane protocol stack may use the same/similar first four protocol layers as the example NR user plane protocol stack. These four protocol layers include the PHYs 211 and 221, the MACs 212 and 222, the RLCs 213 and 223, and the PDCPs 214 and 224. Instead of having the SDAPs 215 and 225 at the top of the stack as in the NR user plane protocol stack, the NR control plane stack has radio resource controls (RRCs) 216 and 226 and NAS protocols 217 and 237 at the top of the NR control plane protocol stack.

[0080] The NAS protocols 217 and 237 may provide control plane functionality between the UE 210 and the AMF 230 (e.g., the AMF 158A) or, more generally, between the UE 210 and the CN. The NAS protocols 217 and 237 may provide control plane functionality between the UE 210 and the AMF 230 via signaling messages, referred to as NAS messages. There is no direct path between the UE 210 and the AMF 230 through which the NAS messages can be transported. The NAS messages may be transported using the AS of the Uu and NG interfaces. NAS protocols 217 and 237 may provide control plane functionality such as authentication, security, connection setup, mobility management, and session management.

[0081] The RRCs 216 and 226 may provide control plane functionality between the UE 210 and the gNB 220 or, more generally, between the UE 210 and the RAN. The RRCs 216 and 226 may provide control plane functionality between the UE 210 and the gNB 220 via signaling messages, referred to as RRC messages. RRC messages may be transmitted between the UE 210 and the RAN using signaling radio bearers and the same/similar PDCP, RLC, MAC, and PHY protocol layers. The MAC may multiplex control-plane and user-plane

data into the same transport block (TB). The RRCs 216 and 226 may provide control plane functionality such as: broadcast of system information related to AS and NAS; paging initiated by the CN or the RAN; establishment, maintenance and release of an RRC connection between the UE 210 and the RAN; security functions including key management; establishment, configuration, maintenance and release of signaling radio bearers and data radio bearers; mobility functions; QoS management functions; the UE measurement reporting and control of the reporting; detection of and recovery from radio link failure (RLF); and/or NAS message transfer. As part of establishing an RRC connection, RRCs 216 and 226 may establish an RRC context, which may involve configuring parameters for communication between the UE 210 and the RAN.

[0082] FIG. 6 is an example diagram showing RRC state transitions of a UE. The UE may be the same or similar to the wireless device 106 depicted in FIG. 1A, the UE 210 depicted in FIG. 2A and FIG. 2B, or any other wireless device described in the present disclosure. As illustrated in FIG. 6, a UE may be in at least one of three RRC states: RRC connected 602 (e.g., RRC_CONNECTED), RRC idle 604 (e.g., RRC_IDLE), and RRC inactive 606 (e.g., RRC_INACTIVE).

[0083] In RRC connected 602, the UE has an established RRC context and may have at least one RRC connection with a base station. The base station may be similar to one of the one or more base stations included in the RAN 104 depicted in FIG. 1A, one of the gNBs 160 or ng-eNBs 162 depicted in FIG. 1B, the gNB 220 depicted in FIG. 2A and FIG. 2B, or any other base station described in the present disclosure. The base station with which the UE is connected may have the RRC context for the UE. The RRC context, referred to as the UE context, may comprise parameters for communication between the UE and the base station. These parameters may include, for example: one or more AS contexts; one or more radio link configuration parameters; bearer configuration information (e.g., relating to a data radio bearer, signaling radio bearer, logical channel, QoS flow, and/or PDU session); security information; and/or PHY, MAC, RLC, PDCP, and/or SDAP layer configuration information. While in RRC connected 602, mobility of the UE may be managed by the RAN (e.g., the RAN 104 or the NG-RAN 154). The UE may measure the signal levels (e.g., reference signal levels) from a serving cell and neighboring cells and report these measurements to the base station currently serving the UE. The UE's serving base station may request a handover to a cell of one of the neighboring base stations based on the reported measurements. The RRC state may transition from RRC connected 602 to RRC idle 604 through a connection release procedure 608 or to RRC inactive 606 through a connection inactivation procedure 610.

[0084] In RRC idle 604, an RRC context may not be established for the UE. In RRC idle 604, the UE may not have an RRC connection with the base station. While in RRC idle 604, the UE may be in a sleep state for the majority of the time (e.g., to conserve battery power). The UE may wake up periodically (e.g., once in every discontinuous reception cycle) to monitor for paging messages from the RAN. Mobility of the UE may be managed by the UE through a procedure known as cell reselection. The RRC state may transition from RRC idle 604 to RRC connected 602 through a connection establishment procedure 612, which may involve a random access procedure as discussed in greater detail below.

[0085] In RRC inactive 606, the RRC context previously established is maintained in the UE and the base station. This allows for a fast transition to RRC connected 602 with reduced signaling overhead as compared to the transition from RRC idle 604 to RRC connected 602. While in RRC inactive 606, the UE may be in a sleep state and mobility of the UE may be managed by the UE through cell reselection. The RRC state may transition from RRC inactive 606 to RRC connected 602 through a connection resume procedure 614 or to RRC idle 604 through a connection release procedure 616 that may be the same as or similar to connection release procedure 608.

[0086] An RRC state may be associated with a mobility management mechanism. In RRC idle 604 and RRC inactive 606, mobility is managed by the UE through cell reselection. The purpose of mobility management in RRC idle 604 and RRC inactive 606 is to allow the network to be able to notify the UE of an event via a paging message without having to broadcast the paging message over the entire mobile communications network. The mobility management mechanism used in RRC idle 604 and RRC inactive 606 may allow the network to track the UE on a cell-group level so that the paging message may be broadcast over the cells of the cell group that the UE currently resides within instead of the entire mobile communication network. The mobility management mechanisms for RRC idle 604 and RRC inactive 606 track the UE on a cell-group level. They may do so using different granularities of grouping. For example, there may be three levels of cell-grouping granularity: individual cells; cells within a RAN area identified by a RAN area identifier (RAI); and cells within a group of RAN areas, referred to as a tracking area and identified by a tracking area identifier (TAI).

[0087] Tracking areas may be used to track the UE at the CN level. The CN (e.g., the CN 102 or the 5G-CN 152) may provide the UE with a list of TAIs associated with a UE registration area. If the UE moves, through cell reselection, to a cell associated with a TAI not included in the list of TAIs associated with the UE registration area, the UE may perform

a registration update with the CN to allow the CN to update the UE's location and provide the UE with a new the UE registration area.

[0088] RAN areas may be used to track the UE at the RAN level. For a UE in RRC inactive 606 state, the UE may be assigned a RAN notification area. A RAN notification area may comprise one or more cell identities, a list of RAIs, or a list of TAIs. In an example, a base station may belong to one or more RAN notification areas. In an example, a cell may belong to one or more RAN notification areas. If the UE moves, through cell reselection, to a cell not included in the RAN notification area assigned to the UE, the UE may perform a notification area update with the RAN to update the UE's RAN notification area.

[0089] A base station storing an RRC context for a UE or a last serving base station of the UE may be referred to as an anchor base station. An anchor base station may maintain an RRC context for the UE at least during a period of time that the UE stays in a RAN notification area of the anchor base station and/or during a period of time that the UE stays in RRC inactive 606.

[0090] A gNB, such as gNBs 160 in FIG. 1B, may be split in two parts: a central unit (gNB-CU), and one or more distributed units (gNB-DU). A gNB-CU may be coupled to one or more gNB-DUs using an F1 interface. The gNB-CU may comprise the RRC, the PDCP, and the SDAP. A gNB-DU may comprise the RLC, the MAC, and the PHY.

[0091] In NR, the physical signals and physical channels (discussed with respect to FIG. 5A and FIG. 5B) may be mapped onto orthogonal frequency divisional multiplexing (OFDM) symbols. OFDM is a multicarrier communication scheme that transmits data over F orthogonal subcarriers (or tones). Before transmission, the data may be mapped to a series of complex symbols (e.g., M-quadrature amplitude modulation (M-QAM) or M-phase shift keying (M-PSK) symbols), referred to as source symbols, and divided into F parallel symbol streams. The F parallel symbol streams may be treated as though they are in the frequency domain and used as inputs to an Inverse Fast Fourier Transform (IFFT) block that transforms them into the time domain. The IFFT block may take in F source symbols at a time, one from each of the F parallel symbol streams, and use each source symbol to modulate the amplitude and phase of one of F sinusoidal basis functions that correspond to the F orthogonal subcarriers. The output of the IFFT block may be F time-domain samples that represent the summation of the F orthogonal subcarriers. The F time-domain samples may form a single OFDM symbol. After some processing (e.g., addition of a cyclic prefix) and up-conversion, an OFDM symbol provided by the IFFT block may be transmitted over the air interface on a carrier frequency. The F parallel symbol streams may be mixed using an FFT block before being processed by the IFFT block. This operation produces Discrete Fourier Transform

(DFT)-precoded OFDM symbols and may be used by UEs in the uplink to reduce the peak to average power ratio (PAPR). Inverse processing may be performed on the OFDM symbol at a receiver using an FFT block to recover the data mapped to the source symbols.

[0092] FIG. 7 illustrates an example configuration of an NR frame into which OFDM symbols are grouped. An NR frame may be identified by a system frame number (SFN). The SFN may repeat with a period of 1024 frames. As illustrated, one NR frame may be 10 milliseconds (ms) in duration and may include 10 subframes that are 1 ms in duration. A subframe may be divided into slots that include, for example, 14 OFDM symbols per slot.

[0093] The duration of a slot may depend on the numerology used for the OFDM symbols of the slot. In NR, a flexible numerology is supported to accommodate different cell deployments (e.g., cells with carrier frequencies below 1 GHz up to cells with carrier frequencies in the mm-wave range). A numerology may be defined in terms of subcarrier spacing and cyclic prefix duration. For a numerology in NR, subcarrier spacings may be scaled up by powers of two from a baseline subcarrier spacing of 15 kHz, and cyclic prefix durations may be scaled down by powers of two from a baseline cyclic prefix duration of 4.7 μ s. For example, NR defines numerologies with the following subcarrier spacing/cyclic prefix duration combinations: 15 kHz/4.7 μ s; 30 kHz/2.3 μ s; 60 kHz/1.2 μ s; 120 kHz/0.59 μ s; and 240 kHz/0.29 μ s.

[0094] A slot may have a fixed number of OFDM symbols (e.g., 14 OFDM symbols). A numerology with a higher subcarrier spacing has a shorter slot duration and, correspondingly, more slots per subframe. FIG. 7 illustrates this numerology-dependent slot duration and slots-per-subframe transmission structure (the numerology with a subcarrier spacing of 240 kHz is not shown in FIG. 7 for ease of illustration). A subframe in NR may be used as a numerology-independent time reference, while a slot may be used as the unit upon which uplink and downlink transmissions are scheduled. To support low latency, scheduling in NR may be decoupled from the slot duration and start at any OFDM symbol and last for as many symbols as needed for a transmission. These partial slot transmissions may be referred to as mini-slot or subslot transmissions.

[0095] FIG. 8 illustrates an example configuration of a slot in the time and frequency domain for an NR carrier. The slot includes resource elements (REs) and resource blocks (RBs). An RE is the smallest physical resource in NR. An RE spans one OFDM symbol in the time domain by one subcarrier in the frequency domain as shown in FIG. 8. An RB spans twelve consecutive REs in the frequency domain as shown in FIG. 8. An NR carrier may be limited to a width of 275 RBs or $275 \times 12 = 3300$ subcarriers. Such a limitation, if used, may limit the NR carrier to 50, 100, 200, and 400 MHz for subcarrier spacings of 15, 30, 60, and 120 kHz,

respectively, where the 400 MHz bandwidth may be set based on a 400 MHz per carrier bandwidth limit.

[0096] FIG. 8 illustrates a single numerology being used across the entire bandwidth of the NR carrier. In other example configurations, multiple numerologies may be supported on the same carrier.

[0097] NR may support wide carrier bandwidths (e.g., up to 400 MHz for a subcarrier spacing of 120 kHz). Not all UEs may be able to receive the full carrier bandwidth (e.g., due to hardware limitations). Also, receiving the full carrier bandwidth may be prohibitive in terms of UE power consumption. In an example, to reduce power consumption and/or for other purposes, a UE may adapt the size of the UE's receive bandwidth based on the amount of traffic the UE is scheduled to receive. This is referred to as bandwidth adaptation.

[0098] NR defines bandwidth parts (BWPs) to support UEs not capable of receiving the full carrier bandwidth and to support bandwidth adaptation. In an example, a BWP may be defined by a subset of contiguous RBs on a carrier. A UE may be configured (e.g., via an RRC layer) with one or more downlink BWPs and one or more uplink BWPs per serving cell (e.g., up to four downlink BWPs and up to four uplink BWPs per serving cell). At a given time, one or more of the configured BWPs for a serving cell may be active. These one or more BWPs may be referred to as active BWPs of the serving cell. When a serving cell is configured with a secondary uplink carrier, the serving cell may have one or more first active BWPs in the uplink carrier and one or more second active BWPs in the secondary uplink carrier.

[0099] For unpaired spectra, a downlink BWP from a set of configured downlink BWPs may be linked with an uplink BWP from a set of configured uplink BWPs if a downlink BWP index of the downlink BWP and an uplink BWP index of the uplink BWP are the same. For unpaired spectra, a UE may expect that a center frequency for a downlink BWP is the same as a center frequency for an uplink BWP.

[0100] For a downlink BWP in a set of configured downlink BWPs on a primary cell (PCell), a base station may configure a UE with one or more control resource sets (CORESETs) for at least one search space. A search space is a set of locations in the time and frequency domains where the UE may find control information. The search space may be a UE-specific search space or a common search space (potentially usable by a plurality of UEs). For example, a base station may configure a UE with a common search space, on a PCell or on a primary secondary cell (PSCell), in an active downlink BWP.

[0101] For an uplink BWP in a set of configured uplink BWPs, a BS may configure a UE with one or more resource sets for one or more PUCCH transmissions. A UE may receive

downlink receptions (e.g., PDCCH or PDSCH) in a downlink BWP according to a configured numerology (e.g., subcarrier spacing and cyclic prefix duration) for the downlink BWP. The UE may transmit uplink transmissions (e.g., PUCCH or PUSCH) in an uplink BWP according to a configured numerology (e.g., subcarrier spacing and cyclic prefix length for the uplink BWP).

[0102] One or more BWP indicator fields may be provided in Downlink Control Information (DCI). A value of a BWP indicator field may indicate which BWP in a set of configured BWPs is an active downlink BWP for one or more downlink receptions. The value of the one or more BWP indicator fields may indicate an active uplink BWP for one or more uplink transmissions.

[0103] A base station may semi-statically configure a UE with a default downlink BWP within a set of configured downlink BWPs associated with a PCell. If the base station does not provide the default downlink BWP to the UE, the default downlink BWP may be an initial active downlink BWP. The UE may determine which BWP is the initial active downlink BWP based on a CORESET configuration obtained using the PBCH.

[0104] A base station may configure a UE with a BWP inactivity timer value for a PCell. The UE may start or restart a BWP inactivity timer at any appropriate time. For example, the UE may start or restart the BWP inactivity timer (*a*) when the UE detects a DCI indicating an active downlink BWP other than a default downlink BWP for a paired spectra operation; or (*b*) when a UE detects a DCI indicating an active downlink BWP or active uplink BWP other than a default downlink BWP or uplink BWP for an unpaired spectra operation. If the UE does not detect DCI during an interval of time (e.g., 1 ms or 0.5 ms), the UE may run the BWP inactivity timer toward expiration (for example, increment from zero to the BWP inactivity timer value, or decrement from the BWP inactivity timer value to zero). When the BWP inactivity timer expires, the UE may switch from the active downlink BWP to the default downlink BWP.

[0105] In an example, a base station may semi-statically configure a UE with one or more BWPs. A UE may switch an active BWP from a first BWP to a second BWP in response to receiving a DCI indicating the second BWP as an active BWP and/or in response to an expiry of the BWP inactivity timer (e.g., if the second BWP is the default BWP).

[0106] Downlink and uplink BWP switching (where BWP switching refers to switching from a currently active BWP to a not currently active BWP) may be performed independently in paired spectra. In unpaired spectra, downlink and uplink BWP switching may be performed simultaneously. Switching between configured BWPs may occur based on

RRC signaling, DCI, expiration of a BWP inactivity timer, and/or an initiation of random access.

[0107] FIG. 9 illustrates an example of bandwidth adaptation using three configured BWPs for an NR carrier. A UE configured with the three BWPs may switch from one BWP to another BWP at a switching point. In the example illustrated in FIG. 9, the BWPs include: a BWP 902 with a bandwidth of 40 MHz and a subcarrier spacing of 15 kHz; a BWP 904 with a bandwidth of 10 MHz and a subcarrier spacing of 15 kHz; and a BWP 906 with a bandwidth of 20 MHz and a subcarrier spacing of 60 kHz. The BWP 902 may be an initial active BWP, and the BWP 904 may be a default BWP. The UE may switch between BWPs at switching points. In the example of FIG. 9, the UE may switch from the BWP 902 to the BWP 904 at a switching point 908. The switching at the switching point 908 may occur for any suitable reason, for example, in response to an expiry of a BWP inactivity timer (indicating switching to the default BWP) and/or in response to receiving a DCI indicating BWP 904 as the active BWP. The UE may switch at a switching point 910 from active BWP 904 to BWP 906 in response receiving a DCI indicating BWP 906 as the active BWP. The UE may switch at a switching point 912 from active BWP 906 to BWP 904 in response to an expiry of a BWP inactivity timer and/or in response receiving a DCI indicating BWP 904 as the active BWP. The UE may switch at a switching point 914 from active BWP 904 to BWP 902 in response receiving a DCI indicating BWP 902 as the active BWP.

[0108] If a UE is configured for a secondary cell with a default downlink BWP in a set of configured downlink BWPs and a timer value, UE procedures for switching BWPs on a secondary cell may be the same/similar as those on a primary cell. For example, the UE may use the timer value and the default downlink BWP for the secondary cell in the same/similar manner as the UE would use these values for a primary cell.

[0109] To provide for greater data rates, two or more carriers can be aggregated and simultaneously transmitted to/from the same UE using carrier aggregation (CA). The aggregated carriers in CA may be referred to as component carriers (CCs). When CA is used, there are a number of serving cells for the UE, one for a CC. The CCs may have three configurations in the frequency domain.

[0110] FIG. 10A illustrates the three CA configurations with two CCs. In the intraband, contiguous configuration 1002, the two CCs are aggregated in the same frequency band (frequency band A) and are located directly adjacent to each other within the frequency band. In the intraband, non-contiguous configuration 1004, the two CCs are aggregated in the same frequency band (frequency band A) and are separated in the frequency band by a gap. In the

interband configuration 1006, the two CCs are located in frequency bands (frequency band A and frequency band B).

[0111] In an example, up to 32 CCs may be aggregated. The aggregated CCs may have the same or different bandwidths, subcarrier spacing, and/or duplexing schemes (TDD or FDD). A serving cell for a UE using CA may have a downlink CC. For FDD, one or more uplink CCs may be optionally configured for a serving cell. The ability to aggregate more downlink carriers than uplink carriers may be useful, for example, when the UE has more data traffic in the downlink than in the uplink.

[0112] When CA is used, one of the aggregated cells for a UE may be referred to as a primary cell (PCell). The PCell may be the serving cell that the UE initially connects to at RRC connection establishment, reestablishment, and/or handover. The PCell may provide the UE with NAS mobility information and the security input. UEs may have different PCells. In the downlink, the carrier corresponding to the PCell may be referred to as the downlink primary CC (DL PCC). In the uplink, the carrier corresponding to the PCell may be referred to as the uplink primary CC (UL PCC). The other aggregated cells for the UE may be referred to as secondary cells (SCells). In an example, the SCells may be configured after the PCell is configured for the UE. For example, an SCell may be configured through an RRC Connection Reconfiguration procedure. In the downlink, the carrier corresponding to an SCell may be referred to as a downlink secondary CC (DL SCC). In the uplink, the carrier corresponding to the SCell may be referred to as the uplink secondary CC (UL SCC).

[0113] Configured SCells for a UE may be activated and deactivated based on, for example, traffic and channel conditions. Deactivation of an SCell may mean that PDCCH and PDSCH reception on the SCell is stopped and PUSCH, SRS, and CQI transmissions on the SCell are stopped. Configured SCells may be activated and deactivated using a MAC CE with respect to FIG. 4B. For example, a MAC CE may use a bitmap (e.g., one bit per SCell) to indicate which SCells (e.g., in a subset of configured SCells) for the UE are activated or deactivated. Configured SCells may be deactivated in response to an expiration of an SCell deactivation timer (e.g., one SCell deactivation timer per SCell).

[0114] Downlink control information, such as scheduling assignments and scheduling grants, for a cell may be transmitted on the cell corresponding to the assignments and grants, which is known as self-scheduling. The DCI for the cell may be transmitted on another cell, which is known as cross-carrier scheduling. Uplink control information (e.g., HARQ acknowledgments and channel state feedback, such as CQI, PMI, and/or RI) for aggregated cells may be transmitted on the PUCCH of the PCell. For a larger number of aggregated

downlink CCs, the PUCCH of the PCell may become overloaded. Cells may be divided into multiple PUCCH groups.

[0115] FIG. 10B illustrates an example of how aggregated cells may be configured into one or more PUCCH groups. A PUCCH group 1010 and a PUCCH group 1050 may include one or more downlink CCs, respectively. In the example of FIG. 10B, the PUCCH group 1010 includes three downlink CCs: a PCell 1011, an SCell 1012, and an SCell 1013. The PUCCH group 1050 includes three downlink CCs in the present example: a PCell 1051, an SCell 1052, and an SCell 1053. One or more uplink CCs may be configured as a PCell 1021, an SCell 1022, and an SCell 1023. One or more other uplink CCs may be configured as a primary SCell (PSCell) 1061, an SCell 1062, and an SCell 1063. Uplink control information (UCI) related to the downlink CCs of the PUCCH group 1010, shown as UCI 1031, UCI 1032, and UCI 1033, may be transmitted in the uplink of the PCell 1021. Uplink control information (UCI) related to the downlink CCs of the PUCCH group 1050, shown as UCI 1071, UCI 1072, and UCI 1073, may be transmitted in the uplink of the PSCell 1061. In an example, if the aggregated cells depicted in FIG. 10B were not divided into the PUCCH group 1010 and the PUCCH group 1050, a single uplink PCell to transmit UCI relating to the downlink CCs, and the PCell may become overloaded. By dividing transmissions of UCI between the PCell 1021 and the PSCell 1061, overloading may be prevented.

[0116] A cell, comprising a downlink carrier and optionally an uplink carrier, may be assigned with a physical cell ID and a cell index. The physical cell ID or the cell index may identify a downlink carrier and/or an uplink carrier of the cell, for example, depending on the context in which the physical cell ID is used. A physical cell ID may be determined using a synchronization signal transmitted on a downlink component carrier. A cell index may be determined using RRC messages. In the disclosure, a physical cell ID may be referred to as a carrier ID, and a cell index may be referred to as a carrier index. For example, when the disclosure refers to a first physical cell ID for a first downlink carrier, the disclosure may mean the first physical cell ID is for a cell comprising the first downlink carrier. The same/similar concept may apply to, for example, a carrier activation. When the disclosure indicates that a first carrier is activated, the specification may mean that a cell comprising the first carrier is activated.

[0117] In CA, a multi-carrier nature of a PHY may be exposed to a MAC. In an example, a HARQ entity may operate on a serving cell. A transport block may be generated per assignment/grant per serving cell. A transport block and potential HARQ retransmissions of the transport block may be mapped to a serving cell.

[0118] In the downlink, a base station may transmit (e.g., unicast, multicast, and/or broadcast) one or more Reference Signals (RSs) to a UE (e.g., PSS, SSS, CSI-RS, DMRS, and/or PT-RS, as shown in FIG. 5A). In the uplink, the UE may transmit one or more RSs to the base station (e.g., DMRS, PT-RS, and/or SRS, as shown in FIG. 5B). The PSS and the SSS may be transmitted by the base station and used by the UE to synchronize the UE to the base station. The PSS and the SSS may be provided in a synchronization signal (SS) / physical broadcast channel (PBCH) block that includes the PSS, the SSS, and the PBCH. The base station may periodically transmit a burst of SS/PBCH blocks.

[0119] FIG. 11A illustrates an example of an SS/PBCH block's structure and location. A burst of SS/PBCH blocks may include one or more SS/PBCH blocks (e.g., 4 SS/PBCH blocks, as shown in FIG. 11A). Bursts may be transmitted periodically (e.g., every 2 frames or 20 ms). A burst may be restricted to a half-frame (e.g., a first half-frame having a duration of 5 ms). It will be understood that FIG. 11A is an example, and that these parameters (number of SS/PBCH blocks per burst, periodicity of bursts, position of burst within the frame) may be configured based on, for example: a carrier frequency of a cell in which the SS/PBCH block is transmitted; a numerology or subcarrier spacing of the cell; a configuration by the network (e.g., using RRC signaling); or any other suitable factor. In an example, the UE may assume a subcarrier spacing for the SS/PBCH block based on the carrier frequency being monitored, unless the radio network configured the UE to assume a different subcarrier spacing.

[0120] The SS/PBCH block may span one or more OFDM symbols in the time domain (e.g., 4 OFDM symbols, as shown in the example of FIG. 11A) and may span one or more subcarriers in the frequency domain (e.g., 240 contiguous subcarriers). The PSS, the SSS, and the PBCH may have a common center frequency. The PSS may be transmitted first and may span, for example, 1 OFDM symbol and 127 subcarriers. The SSS may be transmitted after the PSS (e.g., two symbols later) and may span 1 OFDM symbol and 127 subcarriers. The PBCH may be transmitted after the PSS (e.g., across the next 3 OFDM symbols) and may span 240 subcarriers.

[0121] The location of the SS/PBCH block in the time and frequency domains may not be known to the UE (e.g., if the UE is searching for the cell). To find and select the cell, the UE may monitor a carrier for the PSS. For example, the UE may monitor a frequency location within the carrier. If the PSS is not found after a certain duration (e.g., 20 ms), the UE may search for the PSS at a different frequency location within the carrier, as indicated by a synchronization raster. If the PSS is found at a location in the time and frequency domains, the UE may determine, based on a known structure of the SS/PBCH block, the locations of

the SSS and the PBCH, respectively. The SS/PBCH block may be a cell-defining SS block (CD-SSB). In an example, a primary cell may be associated with a CD-SSB. The CD-SSB may be located on a synchronization raster. In an example, a cell selection/search and/or reselection may be based on the CD-SSB.

[0122] The SS/PBCH block may be used by the UE to determine one or more parameters of the cell. For example, the UE may determine a physical cell identifier (PCI) of the cell based on the sequences of the PSS and the SSS, respectively. The UE may determine a location of a frame boundary of the cell based on the location of the SS/PBCH block. For example, the SS/PBCH block may indicate that it has been transmitted in accordance with a transmission pattern, wherein a SS/PBCH block in the transmission pattern is a known distance from the frame boundary.

[0123] The PBCH may use a QPSK modulation and may use forward error correction (FEC). The FEC may use polar coding. One or more symbols spanned by the PBCH may carry one or more DMRSs for demodulation of the PBCH. The PBCH may include an indication of a current system frame number (SFN) of the cell and/or a SS/PBCH block timing index. These parameters may facilitate time synchronization of the UE to the base station. The PBCH may include a master information block (MIB) used to provide the UE with one or more parameters. The MIB may be used by the UE to locate remaining minimum system information (RMSI) associated with the cell. The RMSI may include a System Information Block Type 1 (SIB1). The SIB1 may contain information needed by the UE to access the cell. The UE may use one or more parameters of the MIB to monitor PDCCH, which may be used to schedule PDSCH. The PDSCH may include the SIB1. The SIB1 may be decoded using parameters provided in the MIB. The PBCH may indicate an absence of SIB1. Based on the PBCH indicating the absence of SIB1, the UE may be pointed to a frequency. The UE may search for an SS/PBCH block at the frequency to which the UE is pointed.

[0124] The UE may assume that one or more SS/PBCH blocks transmitted with a same SS/PBCH block index are quasi co-located (QCLed) (e.g., having the same/similar Doppler spread, Doppler shift, average gain, average delay, and/or spatial Rx parameters). The UE may not assume QCL for SS/PBCH block transmissions having different SS/PBCH block indices.

[0125] SS/PBCH blocks (e.g., those within a half-frame) may be transmitted in spatial directions (e.g., using different beams that span a coverage area of the cell). In an example, a first SS/PBCH block may be transmitted in a first spatial direction using a first beam, and a second SS/PBCH block may be transmitted in a second spatial direction using a second beam.

- [0126]** In an example, within a frequency span of a carrier, a base station may transmit a plurality of SS/PBCH blocks. In an example, a first PCI of a first SS/PBCH block of the plurality of SS/PBCH blocks may be different from a second PCI of a second SS/PBCH block of the plurality of SS/PBCH blocks. The PCIs of SS/PBCH blocks transmitted in different frequency locations may be different or the same.
- [0127]** The CSI-RS may be transmitted by the base station and used by the UE to acquire channel state information (CSI). The base station may configure the UE with one or more CSI-RSs for channel estimation or any other suitable purpose. The base station may configure a UE with one or more of the same/similar CSI-RSs. The UE may measure the one or more CSI-RSs. The UE may estimate a downlink channel state and/or generate a CSI report based on the measuring of the one or more downlink CSI-RSs. The UE may provide the CSI report to the base station. The base station may use feedback provided by the UE (e.g., the estimated downlink channel state) to perform link adaptation.
- [0128]** The base station may semi-statically configure the UE with one or more CSI-RS resource sets. A CSI-RS resource may be associated with a location in the time and frequency domains and a periodicity. The base station may selectively activate and/or deactivate a CSI-RS resource. The base station may indicate to the UE that a CSI-RS resource in the CSI-RS resource set is activated and/or deactivated.
- [0129]** The base station may configure the UE to report CSI measurements. The base station may configure the UE to provide CSI reports periodically, aperiodically, or semi-persistently. For periodic CSI reporting, the UE may be configured with a timing and/or periodicity of a plurality of CSI reports. For aperiodic CSI reporting, the base station may request a CSI report. For example, the base station may command the UE to measure a configured CSI-RS resource and provide a CSI report relating to the measurements. For semi-persistent CSI reporting, the base station may configure the UE to transmit periodically, and selectively activate or deactivate the periodic reporting. The base station may configure the UE with a CSI-RS resource set and CSI reports using RRC signaling.
- [0130]** The CSI-RS configuration may comprise one or more parameters indicating, for example, up to 32 antenna ports. The UE may be configured to employ the same OFDM symbols for a downlink CSI-RS and a control resource set (CORESET) when the downlink CSI-RS and CORESET are spatially QCLed and resource elements associated with the downlink CSI-RS are outside of the physical resource blocks (PRBs) configured for the CORESET. The UE may be configured to employ the same OFDM symbols for downlink CSI-RS and SS/PBCH blocks when the downlink CSI-RS and SS/PBCH blocks are spatially

QCLeD and resource elements associated with the downlink CSI-RS are outside of PRBs configured for the SS/PBCH blocks.

[0131] Downlink DMRSs may be transmitted by a base station and used by a UE for channel estimation. For example, the downlink DMRS may be used for coherent demodulation of one or more downlink physical channels (e.g., PDSCH). An NR network may support one or more variable and/or configurable DMRS patterns for data demodulation. At least one downlink DMRS configuration may support a front-loaded DMRS pattern. A front-loaded DMRS may be mapped over one or more OFDM symbols (e.g., one or two adjacent OFDM symbols). A base station may semi-statically configure the UE with a number (e.g. a maximum number) of front-loaded DMRS symbols for PDSCH. A DMRS configuration may support one or more DMRS ports. For example, for single user-MIMO, a DMRS configuration may support up to eight orthogonal downlink DMRS ports per UE. For multiuser-MIMO, a DMRS configuration may support up to 4 orthogonal downlink DMRS ports per UE. A radio network may support (e.g., at least for CP-OFDM) a common DMRS structure for downlink and uplink, wherein a DMRS location, a DMRS pattern, and/or a scrambling sequence may be the same or different. The base station may transmit a downlink DMRS and a corresponding PDSCH using the same precoding matrix. The UE may use the one or more downlink DMRSs for coherent demodulation/channel estimation of the PDSCH.

[0132] In an example, a transmitter (e.g., a base station) may use a precoder matrices for a part of a transmission bandwidth. For example, the transmitter may use a first precoder matrix for a first bandwidth and a second precoder matrix for a second bandwidth. The first precoder matrix and the second precoder matrix may be different based on the first bandwidth being different from the second bandwidth. The UE may assume that a same precoding matrix is used across a set of PRBs. The set of PRBs may be denoted as a precoding resource block group (PRG).

[0133] A PDSCH may comprise one or more layers. The UE may assume that at least one symbol with DMRS is present on a layer of the one or more layers of the PDSCH. A higher layer may configure up to 3 DMRSs for the PDSCH.

[0134] Downlink PT-RS may be transmitted by a base station and used by a UE for phase-noise compensation. Whether a downlink PT-RS is present or not may depend on an RRC configuration. The presence and/or pattern of the downlink PT-RS may be configured on a UE-specific basis using a combination of RRC signaling and/or an association with one or more parameters employed for other purposes (e.g., modulation and coding scheme (MCS)), which may be indicated by DCI. When configured, a dynamic presence of a downlink PT-RS may be associated with one or more DCI parameters comprising at least MCS. An NR

network may support a plurality of PT-RS densities defined in the time and/or frequency domains. When present, a frequency domain density may be associated with at least one configuration of a scheduled bandwidth. The UE may assume a same precoding for a DMRS port and a PT-RS port. A number of PT-RS ports may be fewer than a number of DMRS ports in a scheduled resource. Downlink PT-RS may be confined in the scheduled time/frequency duration for the UE. Downlink PT-RS may be transmitted on symbols to facilitate phase tracking at the receiver.

[0135] The UE may transmit an uplink DMRS to a base station for channel estimation. For example, the base station may use the uplink DMRS for coherent demodulation of one or more uplink physical channels. For example, the UE may transmit an uplink DMRS with a PUSCH and/or a PUCCH. The uplink DM-RS may span a range of frequencies that is similar to a range of frequencies associated with the corresponding physical channel. The base station may configure the UE with one or more uplink DMRS configurations. At least one DMRS configuration may support a front-loaded DMRS pattern. The front-loaded DMRS may be mapped over one or more OFDM symbols (e.g., one or two adjacent OFDM symbols). One or more uplink DMRSs may be configured to transmit at one or more symbols of a PUSCH and/or a PUCCH. The base station may semi-statically configure the UE with a number (e.g. maximum number) of front-loaded DMRS symbols for the PUSCH and/or the PUCCH, which the UE may use to schedule a single-symbol DMRS and/or a double-symbol DMRS. An NR network may support (e.g., for cyclic prefix orthogonal frequency division multiplexing (CP-OFDM)) a common DMRS structure for downlink and uplink, wherein a DMRS location, a DMRS pattern, and/or a scrambling sequence for the DMRS may be the same or different.

[0136] A PUSCH may comprise one or more layers, and the UE may transmit at least one symbol with DMRS present on a layer of the one or more layers of the PUSCH. In an example, a higher layer may configure up to three DMRSs for the PUSCH.

[0137] Uplink PT-RS (which may be used by a base station for phase tracking and/or phase-noise compensation) may or may not be present depending on an RRC configuration of the UE. The presence and/or pattern of uplink PT-RS may be configured on a UE-specific basis by a combination of RRC signaling and/or one or more parameters employed for other purposes (e.g., Modulation and Coding Scheme (MCS)), which may be indicated by DCI. When configured, a dynamic presence of uplink PT-RS may be associated with one or more DCI parameters comprising at least MCS. A radio network may support a plurality of uplink PT-RS densities defined in time/frequency domain. When present, a frequency domain density may be associated with at least one configuration of a scheduled bandwidth. The UE

may assume a same precoding for a DMRS port and a PT-RS port. A number of PT-RS ports may be fewer than a number of DMRS ports in a scheduled resource. For example, uplink PT-RS may be confined in the scheduled time/frequency duration for the UE.

[0138] SRS may be transmitted by a UE to a base station for channel state estimation to support uplink channel dependent scheduling and/or link adaptation. SRS transmitted by the UE may allow a base station to estimate an uplink channel state at one or more frequencies. A scheduler at the base station may employ the estimated uplink channel state to assign one or more resource blocks for an uplink PUSCH transmission from the UE. The base station may semi-statically configure the UE with one or more SRS resource sets. For an SRS resource set, the base station may configure the UE with one or more SRS resources. An SRS resource set applicability may be configured by a higher layer (e.g., RRC) parameter. For example, when a higher layer parameter indicates beam management, an SRS resource in a SRS resource set of the one or more SRS resource sets (e.g., with the same/similar time domain behavior, periodic, aperiodic, and/or the like) may be transmitted at a time instant (e.g., simultaneously). The UE may transmit one or more SRS resources in SRS resource sets. An NR network may support aperiodic, periodic and/or semi-persistent SRS transmissions. The UE may transmit SRS resources based on one or more trigger types, wherein the one or more trigger types may comprise higher layer signaling (e.g., RRC) and/or one or more DCI formats. In an example, at least one DCI format may be employed for the UE to select at least one of one or more configured SRS resource sets. An SRS trigger type 0 may refer to an SRS triggered based on a higher layer signaling. An SRS trigger type 1 may refer to an SRS triggered based on one or more DCI formats. In an example, when PUSCH and SRS are transmitted in a same slot, the UE may be configured to transmit SRS after a transmission of a PUSCH and a corresponding uplink DMRS.

[0139] The base station may semi-statically configure the UE with one or more SRS configuration parameters indicating at least one of following: a SRS resource configuration identifier; a number of SRS ports; time domain behavior of an SRS resource configuration (e.g., an indication of periodic, semi-persistent, or aperiodic SRS); slot, mini-slot, and/or subframe level periodicity; offset for a periodic and/or an aperiodic SRS resource; a number of OFDM symbols in an SRS resource; a starting OFDM symbol of an SRS resource; an SRS bandwidth; a frequency hopping bandwidth; a cyclic shift; and/or an SRS sequence ID.

[0140] An antenna port is defined such that the channel over which a symbol on the antenna port is conveyed can be inferred from the channel over which another symbol on the same antenna port is conveyed. If a first symbol and a second symbol are transmitted on the same antenna port, the receiver may infer the channel (e.g., fading gain, multipath delay, and/or the

like) for conveying the second symbol on the antenna port, from the channel for conveying the first symbol on the antenna port. A first antenna port and a second antenna port may be referred to as quasi co-located (QCLed) if one or more large-scale properties of the channel over which a first symbol on the first antenna port is conveyed may be inferred from the channel over which a second symbol on a second antenna port is conveyed. The one or more large-scale properties may comprise at least one of: a delay spread; a Doppler spread; a Doppler shift; an average gain; an average delay; and/or spatial Receiving (Rx) parameters.

[0141] Channels that use beamforming require beam management. Beam management may comprise beam measurement, beam selection, and beam indication. A beam may be associated with one or more reference signals. For example, a beam may be identified by one or more beamformed reference signals. The UE may perform downlink beam measurement based on downlink reference signals (e.g., a channel state information reference signal (CSI-RS)) and generate a beam measurement report. The UE may perform the downlink beam measurement procedure after an RRC connection is set up with a base station.

[0142] FIG. 11B illustrates an example of channel state information reference signals (CSI-RSs) that are mapped in the time and frequency domains. A square shown in FIG. 11B may span a resource block (RB) within a bandwidth of a cell. A base station may transmit one or more RRC messages comprising CSI-RS resource configuration parameters indicating one or more CSI-RSs. One or more of the following parameters may be configured by higher layer signaling (e.g., RRC and/or MAC signaling) for a CSI-RS resource configuration: a CSI-RS resource configuration identity, a number of CSI-RS ports, a CSI-RS configuration (e.g., symbol and resource element (RE) locations in a subframe), a CSI-RS subframe configuration (e.g., subframe location, offset, and periodicity in a radio frame), a CSI-RS power parameter, a CSI-RS sequence parameter, a code division multiplexing (CDM) type parameter, a frequency density, a transmission comb, quasi co-location (QCL) parameters (e.g., QCL-scramblingidentity, crs-portscount, mbsfn-subframeconfiglist, csi-rs-configZPid, qcl-csi-rs-configNZPid), and/or other radio resource parameters.

[0143] The three beams illustrated in FIG. 11B may be configured for a UE in a UE-specific configuration. Three beams are illustrated in FIG. 11B (beam #1, beam #2, and beam #3), more or fewer beams may be configured. Beam #1 may be allocated with CSI-RS 1101 that may be transmitted in one or more subcarriers in an RB of a first symbol. Beam #2 may be allocated with CSI-RS 1102 that may be transmitted in one or more subcarriers in an RB of a second symbol. Beam #3 may be allocated with CSI-RS 1103 that may be transmitted in one or more subcarriers in an RB of a third symbol. By using frequency division multiplexing (FDM), a base station may use other subcarriers in a same RB (for example, those that are

not used to transmit CSI-RS 1101) to transmit another CSI-RS associated with a beam for another UE. By using time domain multiplexing (TDM), beams used for the UE may be configured such that beams for the UE use symbols from beams of other UEs.

[0144] CSI-RSs such as those illustrated in FIG. 11B (e.g., CSI-RS 1101, 1102, 1103) may be transmitted by the base station and used by the UE for one or more measurements. For example, the UE may measure a reference signal received power (RSRP) of configured CSI-RS resources. The base station may configure the UE with a reporting configuration and the UE may report the RSRP measurements to a network (for example, via one or more base stations) based on the reporting configuration. In an example, the base station may determine, based on the reported measurement results, one or more transmission configuration indication (TCI) states comprising a number of reference signals. In an example, the base station may indicate one or more TCI states to the UE (e.g., via an RRC signaling, a MAC CE, and/or a DCI). The UE may receive a downlink transmission with a receive (Rx) beam determined based on the one or more TCI states. In an example, the UE may or may not have a capability of beam correspondence. If the UE has the capability of beam correspondence, the UE may determine a spatial domain filter of a transmit (Tx) beam based on a spatial domain filter of the corresponding Rx beam. If the UE does not have the capability of beam correspondence, the UE may perform an uplink beam selection procedure to determine the spatial domain filter of the Tx beam. The UE may perform the uplink beam selection procedure based on one or more sounding reference signal (SRS) resources configured to the UE by the base station. The base station may select and indicate uplink beams for the UE based on measurements of the one or more SRS resources transmitted by the UE.

[0145] In a beam management procedure, a UE may assess (e.g., measure) a channel quality of one or more beam pair links, a beam pair link comprising a transmitting beam transmitted by a base station and a receiving beam received by the UE. Based on the assessment, the UE may transmit a beam measurement report indicating one or more beam pair quality parameters comprising, e.g., one or more beam identifications (e.g., a beam index, a reference signal index, or the like), RSRP, a precoding matrix indicator (PMI), a channel quality indicator (CQI), and/or a rank indicator (RI).

[0146] FIG. 12A illustrates examples of three downlink beam management procedures: P1, P2, and P3. Procedure P1 may enable a UE measurement on transmit (Tx) beams of a transmission reception point (TRP) (or multiple TRPs), e.g., to support a selection of one or more base station Tx beams and/or UE Rx beams (shown as ovals in the top row and bottom row, respectively, of P1). Beamforming at a TRP may comprise a Tx beam sweep for a set of

beams (shown, in the top rows of P1 and P2, as ovals rotated in a counter-clockwise direction indicated by the dashed arrow). Beamforming at a UE may comprise an Rx beam sweep for a set of beams (shown, in the bottom rows of P1 and P3, as ovals rotated in a clockwise direction indicated by the dashed arrow). Procedure P2 may be used to enable a UE measurement on Tx beams of a TRP (shown, in the top row of P2, as ovals rotated in a counter-clockwise direction indicated by the dashed arrow). The UE and/or the base station may perform procedure P2 using a smaller set of beams than is used in procedure P1, or using narrower beams than the beams used in procedure P1. This may be referred to as beam refinement. The UE may perform procedure P3 for Rx beam determination by using the same Tx beam at the base station and sweeping an Rx beam at the UE.

[0147] FIG. 12B illustrates examples of three uplink beam management procedures: U1, U2, and U3. Procedure U1 may be used to enable a base station to perform a measurement on Tx beams of a UE, e.g., to support a selection of one or more UE Tx beams and/or base station Rx beams (shown as ovals in the top row and bottom row, respectively, of U1). Beamforming at the UE may include, e.g., a Tx beam sweep from a set of beams (shown in the bottom rows of U1 and U3 as ovals rotated in a clockwise direction indicated by the dashed arrow). Beamforming at the base station may include, e.g., an Rx beam sweep from a set of beams (shown, in the top rows of U1 and U2, as ovals rotated in a counter-clockwise direction indicated by the dashed arrow). Procedure U2 may be used to enable the base station to adjust its Rx beam when the UE uses a fixed Tx beam. The UE and/or the base station may perform procedure U2 using a smaller set of beams than is used in procedure P1, or using narrower beams than the beams used in procedure P1. This may be referred to as beam refinement. The UE may perform procedure U3 to adjust its Tx beam when the base station uses a fixed Rx beam.

[0148] A UE may initiate a beam failure recovery (BFR) procedure based on detecting a beam failure. The UE may transmit a BFR request (e.g., a preamble, a UCI, an SR, a MAC CE, and/or the like) based on the initiating of the BFR procedure. The UE may detect the beam failure based on a determination that a quality of beam pair link(s) of an associated control channel is unsatisfactory (e.g., having an error rate higher than an error rate threshold, a received signal power lower than a received signal power threshold, an expiration of a timer, and/or the like).

[0149] The UE may measure a quality of a beam pair link using one or more reference signals (RSs) comprising one or more SS/PBCH blocks, one or more CSI-RS resources, and/or one or more demodulation reference signals (DMRSs). A quality of the beam pair link may be based on one or more of a block error rate (BLER), an RSRP value, a signal to

interference plus noise ratio (SINR) value, a reference signal received quality (RSRQ) value, and/or a CSI value measured on RS resources. The base station may indicate that an RS resource is quasi co-located (QCLed) with one or more DM-RSs of a channel (e.g., a control channel, a shared data channel, and/or the like). The RS resource and the one or more DM-RSs of the channel may be QCLed when the channel characteristics (e.g., Doppler shift, Doppler spread, average delay, delay spread, spatial Rx parameter, fading, and/or the like) from a transmission via the RS resource to the UE are similar or the same as the channel characteristics from a transmission via the channel to the UE.

[0150] A network (e.g., a gNB and/or an ng-eNB of a network) and/or the UE may initiate a random access procedure. A UE in an RRC_IDLE state and/or an RRC_INACTIVE state may initiate the random access procedure to request a connection setup to a network. The UE may initiate the random access procedure from an RRC_CONNECTED state. The UE may initiate the random access procedure to request uplink resources (e.g., for uplink transmission of an SR when there is no PUCCH resource available) and/or acquire uplink timing (e.g., when uplink synchronization status is non-synchronized). The UE may initiate the random access procedure to request one or more system information blocks (SIBs) (e.g., other system information such as SIB2, SIB3, and/or the like). The UE may initiate the random access procedure for a beam failure recovery request. A network may initiate a random access procedure for a handover and/or for establishing time alignment for an SCell addition.

[0151] FIG. 13A illustrates a four-step contention-based random access procedure. Prior to initiation of the procedure, a base station may transmit a configuration message 1310 to the UE. The procedure illustrated in FIG. 13A comprises transmission of four messages: a Msg 1 1311, a Msg 2 1312, a Msg 3 1313, and a Msg 4 1314. The Msg 1 1311 may include and/or be referred to as a preamble (or a random access preamble). The Msg 2 1312 may include and/or be referred to as a random access response (RAR).

[0152] The configuration message 1310 may be transmitted, for example, using one or more RRC messages. The one or more RRC messages may indicate one or more random access channel (RACH) parameters to the UE. The one or more RACH parameters may comprise at least one of following: general parameters for one or more random access procedures (e.g., RACH-configGeneral); cell-specific parameters (e.g., RACH-ConfigCommon); and/or dedicated parameters (e.g., RACH-configDedicated). The base station may broadcast or multicast the one or more RRC messages to one or more UEs. The one or more RRC messages may be UE-specific (e.g., dedicated RRC messages transmitted to a UE in an RRC_CONNECTED state and/or in an RRC_INACTIVE state). The UE may determine, based on the one or more RACH parameters, a time-frequency resource and/or an uplink

transmit power for transmission of the Msg 1 1311 and/or the Msg 3 1313. Based on the one or more RACH parameters, the UE may determine a reception timing and a downlink channel for receiving the Msg 2 1312 and the Msg 4 1314.

[0153] The one or more RACH parameters provided in the configuration message 1310 may indicate one or more Physical RACH (PRACH) occasions available for transmission of the Msg 1 1311. The one or more PRACH occasions may be predefined. The one or more RACH parameters may indicate one or more available sets of one or more PRACH occasions (e.g., prach-ConfigIndex). The one or more RACH parameters may indicate an association between (a) one or more PRACH occasions and (b) one or more reference signals. The one or more RACH parameters may indicate an association between (a) one or more preambles and (b) one or more reference signals. The one or more reference signals may be SS/PBCH blocks and/or CSI-RSs. For example, the one or more RACH parameters may indicate a number of SS/PBCH blocks mapped to a PRACH occasion and/or a number of preambles mapped to a SS/PBCH blocks.

[0154] The one or more RACH parameters provided in the configuration message 1310 may be used to determine an uplink transmit power of Msg 1 1311 and/or Msg 3 1313. For example, the one or more RACH parameters may indicate a reference power for a preamble transmission (e.g., a received target power and/or an initial power of the preamble transmission). There may be one or more power offsets indicated by the one or more RACH parameters. For example, the one or more RACH parameters may indicate: a power ramping step; a power offset between SSB and CSI-RS; a power offset between transmissions of the Msg 1 1311 and the Msg 3 1313; and/or a power offset value between preamble groups. The one or more RACH parameters may indicate one or more thresholds based on which the UE may determine at least one reference signal (e.g., an SSB and/or CSI-RS) and/or an uplink carrier (e.g., a normal uplink (NUL) carrier and/or a supplemental uplink (SUL) carrier).

[0155] The Msg 1 1311 may include one or more preamble transmissions (e.g., a preamble transmission and one or more preamble retransmissions). An RRC message may be used to configure one or more preamble groups (e.g., group A and/or group B). A preamble group may comprise one or more preambles. The UE may determine the preamble group based on a pathloss measurement and/or a size of the Msg 3 1313. The UE may measure an RSRP of one or more reference signals (e.g., SSBs and/or CSI-RSs) and determine at least one reference signal having an RSRP above an RSRP threshold (e.g., rsrp-ThresholdSSB and/or rsrp-ThresholdCSI-RS). The UE may select at least one preamble associated with the one or more reference signals and/or a selected preamble group, for example, if the association

between the one or more preambles and the at least one reference signal is configured by an RRC message.

[0156] The UE may determine the preamble based on the one or more RACH parameters provided in the configuration message 1310. For example, the UE may determine the preamble based on a pathloss measurement, an RSRP measurement, and/or a size of the Msg 3 1313. As another example, the one or more RACH parameters may indicate: a preamble format; a maximum number of preamble transmissions; and/or one or more thresholds for determining one or more preamble groups (e.g., group A and group B). A base station may use the one or more RACH parameters to configure the UE with an association between one or more preambles and one or more reference signals (e.g., SSBs and/or CSI-RSs). If the association is configured, the UE may determine the preamble to include in Msg 1 1311 based on the association. The Msg 1 1311 may be transmitted to the base station via one or more PRACH occasions. The UE may use one or more reference signals (e.g., SSBs and/or CSI-RSs) for selection of the preamble and for determining of the PRACH occasion. One or more RACH parameters (e.g., ra-ssb-OccasionMskIndex and/or ra-OccasionList) may indicate an association between the PRACH occasions and the one or more reference signals.

[0157] The UE may perform a preamble retransmission if no response is received following a preamble transmission. The UE may increase an uplink transmit power for the preamble retransmission. The UE may select an initial preamble transmit power based on a pathloss measurement and/or a target received preamble power configured by the network. The UE may determine to retransmit a preamble and may ramp up the uplink transmit power. The UE may receive one or more RACH parameters (e.g., PREAMBLE_POWER_RAMPING_STEP) indicating a ramping step for the preamble retransmission. The ramping step may be an amount of incremental increase in uplink transmit power for a retransmission. The UE may ramp up the uplink transmit power if the UE determines a reference signal (e.g., SSB and/or CSI-RS) that is the same as a previous preamble transmission. The UE may count a number of preamble transmissions and/or retransmissions (e.g., PREAMBLE_TRANSMISSION_COUNTER). The UE may determine that a random access procedure completed unsuccessfully, for example, if the number of preamble transmissions exceeds a threshold configured by the one or more RACH parameters (e.g., preambleTransMax).

[0158] The Msg 2 1312 received by the UE may include an RAR. In some scenarios, the Msg 2 1312 may include multiple RARs corresponding to multiple UEs. The Msg 2 1312 may be received after or in response to the transmitting of the Msg 1 1311. The Msg 2 1312 may be scheduled on the DL-SCH and indicated on a PDCCH using a random access RNTI

(RA-RNTI). The Msg 2 1312 may indicate that the Msg 1 1311 was received by the base station. The Msg 2 1312 may include a time-alignment command that may be used by the UE to adjust the UE's transmission timing, a scheduling grant for transmission of the Msg 3 1313, and/or a Temporary Cell RNTI (TC-RNTI). After transmitting a preamble, the UE may start a time window (e.g., ra-ResponseWindow) to monitor a PDCCH for the Msg 2 1312. The UE may determine when to start the time window based on a PRACH occasion that the UE uses to transmit the preamble. For example, the UE may start the time window one or more symbols after a last symbol of the preamble (e.g., at a first PDCCH occasion from an end of a preamble transmission). The one or more symbols may be determined based on a numerology. The PDCCH may be in a common search space (e.g., a Type1-PDCCH common search space) configured by an RRC message. The UE may identify the RAR based on a Radio Network Temporary Identifier (RNTI). RNTIs may be used depending on one or more events initiating the random access procedure. The UE may use random access RNTI (RA-RNTI). The RA-RNTI may be associated with PRACH occasions in which the UE transmits a preamble. For example, the UE may determine the RA-RNTI based on: an OFDM symbol index; a slot index; a frequency domain index; and/or a UL carrier indicator of the PRACH occasions. An example of RA-RNTI may be as follows:

$$\text{RA-RNTI} = 1 + s_id + 14 \times t_id + 14 \times 80 \times f_id + 14 \times 80 \times 8 \times ul_carrier_id$$

where s_id may be an index of a first OFDM symbol of the PRACH occasion (e.g., $0 \leq s_id < 14$), t_id may be an index of a first slot of the PRACH occasion in a system frame (e.g., $0 \leq t_id < 80$), f_id may be an index of the PRACH occasion in the frequency domain (e.g., $0 \leq f_id < 8$), and $ul_carrier_id$ may be a UL carrier used for a preamble transmission (e.g., 0 for an NUL carrier, and 1 for an SUL carrier).

The UE may transmit the Msg 3 1313 in response to a successful reception of the Msg 2 1312 (e.g., using resources identified in the Msg 2 1312). The Msg 3 1313 may be used for contention resolution in, for example, the contention-based random access procedure illustrated in FIG. 13A. In some scenarios, a plurality of UEs may transmit a same preamble to a base station and the base station may provide an RAR that corresponds to a UE. Collisions may occur if the plurality of UEs interpret the RAR as corresponding to themselves. Contention resolution (e.g., using the Msg 3 1313 and the Msg 4 1314) may be used to increase the likelihood that the UE does not incorrectly use an identity of another the UE. To perform contention resolution, the UE may include a device identifier in the Msg 3 1313 (e.g., a C-RNTI if assigned, a TC-RNTI included in the Msg 2 1312, and/or any other suitable identifier).

[0159] The Msg 4 1314 may be received after or in response to the transmitting of the Msg 3 1313. If a C-RNTI was included in the Msg 3 1313, the base station will address the UE on the PDCCH using the C-RNTI. If the UE's unique C-RNTI is detected on the PDCCH, the random access procedure is determined to be successfully completed. If a TC-RNTI is included in the Msg 3 1313 (e.g., if the UE is in an RRC_IDLE state or not otherwise connected to the base station), Msg 4 1314 will be received using a DL-SCH associated with the TC-RNTI. If a MAC PDU is successfully decoded and a MAC PDU comprises the UE contention resolution identity MAC CE that matches or otherwise corresponds with the CCCH SDU sent (e.g., transmitted) in Msg 3 1313, the UE may determine that the contention resolution is successful and/or the UE may determine that the random access procedure is successfully completed.

[0160] The UE may be configured with a supplementary uplink (SUL) carrier and a normal uplink (NUL) carrier. An initial access (e.g., random access procedure) may be supported in an uplink carrier. For example, a base station may configure the UE with two separate RACH configurations: one for an SUL carrier and the other for an NUL carrier. For random access in a cell configured with an SUL carrier, the network may indicate which carrier to use (NUL or SUL). The UE may determine the SUL carrier, for example, if a measured quality of one or more reference signals is lower than a broadcast threshold. Uplink transmissions of the random access procedure (e.g., the Msg 1 1311 and/or the Msg 3 1313) may remain on the selected carrier. The UE may switch an uplink carrier during the random access procedure (e.g., between the Msg 1 1311 and the Msg 3 1313) in one or more cases. For example, the UE may determine and/or switch an uplink carrier for the Msg 1 1311 and/or the Msg 3 1313 based on a channel clear assessment (e.g., a listen-before-talk).

[0161] FIG. 13B illustrates a two-step contention-free random access procedure. Similar to the four-step contention-based random access procedure illustrated in FIG. 13A, a base station may, prior to initiation of the procedure, transmit a configuration message 1320 to the UE. The configuration message 1320 may be analogous in some respects to the configuration message 1310. The procedure illustrated in FIG. 13B comprises transmission of two messages: a Msg 1 1321 and a Msg 2 1322. The Msg 1 1321 and the Msg 2 1322 may be analogous in some respects to the Msg 1 1311 and a Msg 2 1312 illustrated in FIG. 13A, respectively. As will be understood from FIGS. 13A and 13B, the contention-free random access procedure may not include messages analogous to the Msg 3 1313 and/or the Msg 4 1314.

[0162] The contention-free random access procedure illustrated in FIG. 13B may be initiated for a beam failure recovery, other SI request, SCell addition, and/or handover. For example, a

base station may indicate or assign to the UE the preamble to be used for the Msg 1 1321. The UE may receive, from the base station via PDCCH and/or RRC, an indication of a preamble (e.g., ra-PreambleIndex).

[0163] After transmitting a preamble, the UE may start a time window (e.g., ra-ResponseWindow) to monitor a PDCCH for the RAR. In the event of a beam failure recovery request, the base station may configure the UE with a separate time window and/or a separate PDCCH in a search space indicated by an RRC message (e.g., recoverySearchSpaceId). The UE may monitor for a PDCCH transmission addressed to a Cell RNTI (C-RNTI) on the search space. In the contention-free random access procedure illustrated in FIG. 13B, the UE may determine that a random access procedure successfully completes after or in response to transmission of Msg 1 1321 and reception of a corresponding Msg 2 1322. The UE may determine that a random access procedure successfully completes, for example, if a PDCCH transmission is addressed to a C-RNTI. The UE may determine that a random access procedure successfully completes, for example, if the UE receives an RAR comprising a preamble identifier corresponding to a preamble transmitted by the UE and/or the RAR comprises a MAC sub-PDU with the preamble identifier. The UE may determine the response as an indication of an acknowledgement for an SI request.

[0164] FIG. 13C illustrates another two-step random access procedure. Similar to the random access procedures illustrated in FIGS. 13A and 13B, a base station may, prior to initiation of the procedure, transmit a configuration message 1330 to the UE. The configuration message 1330 may be analogous in some respects to the configuration message 1310 and/or the configuration message 1320. The procedure illustrated in FIG. 13C comprises transmission of two messages: a Msg A 1331 and a Msg B 1332.

[0165] Msg A 1331 may be transmitted in an uplink transmission by the UE. Msg A 1331 may comprise one or more transmissions of a preamble 1341 and/or one or more transmissions of a transport block 1342. The transport block 1342 may comprise contents that are similar and/or equivalent to the contents of the Msg 3 1313 illustrated in FIG. 13A. The transport block 1342 may comprise UCI (e.g., an SR, a HARQ ACK/NACK, and/or the like). The UE may receive the Msg B 1332 after or in response to transmitting the Msg A 1331. The Msg B 1332 may comprise contents that are similar and/or equivalent to the contents of the Msg 2 1312 (e.g., an RAR) illustrated in FIGS. 13A and 13B and/or the Msg 4 1314 illustrated in FIG. 13A.

[0166] The UE may initiate the two-step random access procedure in FIG. 13C for licensed spectrum and/or unlicensed spectrum. The UE may determine, based on one or more factors,

whether to initiate the two-step random access procedure. The one or more factors may be: a radio access technology in use (e.g., LTE, NR, and/or the like); whether the UE has valid TA or not; a cell size; the UE's RRC state; a type of spectrum (e.g., licensed vs. unlicensed); and/or any other suitable factors.

[0167] The UE may determine, based on two-step RACH parameters included in the configuration message 1330, a radio resource and/or an uplink transmit power for the preamble 1341 and/or the transport block 1342 included in the Msg A 1331. The RACH parameters may indicate a modulation and coding schemes (MCS), a time-frequency resource, and/or a power control for the preamble 1341 and/or the transport block 1342. A time-frequency resource for transmission of the preamble 1341 (e.g., a PRACH) and a time-frequency resource for transmission of the transport block 1342 (e.g., a PUSCH) may be multiplexed using FDM, TDM, and/or CDM. The RACH parameters may enable the UE to determine a reception timing and a downlink channel for monitoring for and/or receiving Msg B 1332.

[0168] The transport block 1342 may comprise data (e.g., delay-sensitive data), an identifier of the UE, security information, and/or device information (e.g., an International Mobile Subscriber Identity (IMSI)). The base station may transmit the Msg B 1332 as a response to the Msg A 1331. The Msg B 1332 may comprise at least one of following: a preamble identifier; a timing advance command; a power control command; an uplink grant (e.g., a radio resource assignment and/or an MCS); a UE identifier for contention resolution; and/or an RNTI (e.g., a C-RNTI or a TC-RNTI). The UE may determine that the two-step random access procedure is successfully completed if: a preamble identifier in the Msg B 1332 is matched to a preamble transmitted by the UE; and/or the identifier of the UE in Msg B 1332 is matched to the identifier of the UE in the Msg A 1331 (e.g., the transport block 1342).

[0169] A UE and a base station may exchange control signaling. The control signaling may be referred to as L1/L2 control signaling and may originate from the PHY layer (e.g., layer 1) and/or the MAC layer (e.g., layer 2). The control signaling may comprise downlink control signaling transmitted from the base station to the UE and/or uplink control signaling transmitted from the UE to the base station.

[0170] The downlink control signaling may comprise: a downlink scheduling assignment; an uplink scheduling grant indicating uplink radio resources and/or a transport format; a slot format information; a preemption indication; a power control command; and/or any other suitable signaling. The UE may receive the downlink control signaling in a payload transmitted by the base station on a physical downlink control channel (PDCCH). The payload transmitted on the PDCCH may be referred to as downlink control information

(DCI). In some scenarios, the PDCCH may be a group common PDCCH (GC-PDCCH) that is common to a group of UEs.

[0171] A base station may attach one or more cyclic redundancy check (CRC) parity bits to a DCI in order to facilitate detection of transmission errors. When the DCI is intended for a UE (or a group of the UEs), the base station may scramble the CRC parity bits with an identifier of the UE (or an identifier of the group of the UEs). Scrambling the CRC parity bits with the identifier may comprise Modulo-2 addition (or an exclusive OR operation) of the identifier value and the CRC parity bits. The identifier may comprise a 16-bit value of a radio network temporary identifier (RNTI).

[0172] DCIs may be used for different purposes. A purpose may be indicated by the type of RNTI used to scramble the CRC parity bits. For example, a DCI having CRC parity bits scrambled with a paging RNTI (P-RNTI) may indicate paging information and/or a system information change notification. The P-RNTI may be predefined as “FFFE” in hexadecimal. A DCI having CRC parity bits scrambled with a system information RNTI (SI-RNTI) may indicate a broadcast transmission of the system information. The SI-RNTI may be predefined as “FFFF” in hexadecimal. A DCI having CRC parity bits scrambled with a random access RNTI (RA-RNTI) may indicate a random access response (RAR). A DCI having CRC parity bits scrambled with a cell RNTI (C-RNTI) may indicate a dynamically scheduled unicast transmission and/or a triggering of PDCCH-ordered random access. A DCI having CRC parity bits scrambled with a temporary cell RNTI (TC-RNTI) may indicate a contention resolution (e.g., a Msg 3 analogous to the Msg 3 1313 illustrated in FIG. 13A). Other RNTIs configured to the UE by a base station may comprise a Configured Scheduling RNTI (CS-RNTI), a Transmit Power Control-PUCCH RNTI (TPC-PUCCH-RNTI), a Transmit Power Control-PUSCH RNTI (TPC-PUSCH-RNTI), a Transmit Power Control-SRS RNTI (TPC-SRS-RNTI), an Interruption RNTI (INT-RNTI), a Slot Format Indication RNTI (SFI-RNTI), a Semi-Persistent CSI RNTI (SP-CSI-RNTI), a Modulation and Coding Scheme Cell RNTI (MCS-C-RNTI), and/or the like.

[0173] Depending on the purpose and/or content of a DCI, the base station may transmit the DCIs with one or more DCI formats. For example, DCI format 0_0 may be used for scheduling of PUSCH in a cell. DCI format 0_0 may be a fallback DCI format (e.g., with compact DCI payloads). DCI format 0_1 may be used for scheduling of PUSCH in a cell (e.g., with more DCI payloads than DCI format 0_0). DCI format 1_0 may be used for scheduling of PDSCH in a cell. DCI format 1_0 may be a fallback DCI format (e.g., with compact DCI payloads). DCI format 1_1 may be used for scheduling of PDSCH in a cell (e.g., with more DCI payloads than DCI format 1_0). DCI format 2_0 may be used for

providing a slot format indication to a group of UEs. DCI format 2_1 may be used for notifying a group of UEs of a physical resource block and/or OFDM symbol where the UE may assume no transmission is intended to the UE. DCI format 2_2 may be used for transmission of a transmit power control (TPC) command for PUCCH or PUSCH. DCI format 2_3 may be used for transmission of a group of TPC commands for SRS transmissions by one or more UEs. DCI format(s) for new functions may be defined in future releases. DCI formats may have different DCI sizes, or may share the same DCI size.

[0174] After scrambling a DCI with a RNTI, the base station may process the DCI with channel coding (e.g., polar coding), rate matching, scrambling and/or QPSK modulation. A base station may map the coded and modulated DCI on resource elements used and/or configured for a PDCCH. Based on a payload size of the DCI and/or a coverage of the base station, the base station may transmit the DCI via a PDCCH occupying a number of contiguous control channel elements (CCEs). The number of the contiguous CCEs (referred to as aggregation level) may be 1, 2, 4, 8, 16, and/or any other suitable number. A CCE may comprise a number (e.g., 6) of resource-element groups (REGs). A REG may comprise a resource block in an OFDM symbol. The mapping of the coded and modulated DCI on the resource elements may be based on mapping of CCEs and REGs (e.g., CCE-to-REG mapping).

[0175] FIG. 14A illustrates an example of CORESET configurations for a bandwidth part. The base station may transmit a DCI via a PDCCH on one or more control resource sets (CORESETs). A CORESET may comprise a time-frequency resource in which the UE tries to decode a DCI using one or more search spaces. The base station may configure a CORESET in the time-frequency domain. In the example of FIG. 14A, a first CORESET 1401 and a second CORESET 1402 occur at the first symbol in a slot. The first CORESET 1401 overlaps with the second CORESET 1402 in the frequency domain. A third CORESET 1403 occurs at a third symbol in the slot. A fourth CORESET 1404 occurs at the seventh symbol in the slot. CORESETs may have a different number of resource blocks in frequency domain.

[0176] FIG. 14B illustrates an example of a CCE-to-REG mapping for DCI transmission on a CORESET and PDCCH processing. The CCE-to-REG mapping may be an interleaved mapping (e.g., for the purpose of providing frequency diversity) or a non-interleaved mapping (e.g., for the purposes of facilitating interference coordination and/or frequency-selective transmission of control channels). The base station may perform different or same CCE-to-REG mapping on different CORESETs. A CORESET may be associated with a CCE-to-REG mapping by RRC configuration. A CORESET may be configured with an

antenna port quasi co-location (QCL) parameter. The antenna port QCL parameter may indicate QCL information of a demodulation reference signal (DMRS) for PDCCH reception in the CORESET.

[0177] The base station may transmit, to the UE, RRC messages comprising configuration parameters of one or more CORESETs and one or more search space sets. The configuration parameters may indicate an association between a search space set and a CORESET. A search space set may comprise a set of PDCCH candidates formed by CCEs at a given aggregation level. The configuration parameters may indicate: a number of PDCCH candidates to be monitored per aggregation level; a PDCCH monitoring periodicity and a PDCCH monitoring pattern; one or more DCI formats to be monitored by the UE; and/or whether a search space set is a common search space set or a UE-specific search space set. A set of CCEs in the common search space set may be predefined and known to the UE. A set of CCEs in the UE-specific search space set may be configured based on the UE's identity (e.g., C-RNTI).

[0178] As shown in FIG. 14B, the UE may determine a time-frequency resource for a CORESET based on RRC messages. The UE may determine a CCE-to-REG mapping (e.g., interleaved or non-interleaved, and/or mapping parameters) for the CORESET based on configuration parameters of the CORESET. The UE may determine a number (e.g., at most 10) of search space sets configured on the CORESET based on the RRC messages. The UE may monitor a set of PDCCH candidates according to configuration parameters of a search space set. The UE may monitor a set of PDCCH candidates in one or more CORESETs for detecting one or more DCIs. Monitoring may comprise decoding one or more PDCCH candidates of the set of the PDCCH candidates according to the monitored DCI formats. Monitoring may comprise decoding a DCI content of one or more PDCCH candidates with possible (or configured) PDCCH locations, possible (or configured) PDCCH formats (e.g., number of CCEs, number of PDCCH candidates in common search spaces, and/or number of PDCCH candidates in the UE-specific search spaces) and possible (or configured) DCI formats. The decoding may be referred to as blind decoding. The UE may determine a DCI as valid for the UE, in response to CRC checking (e.g., scrambled bits for CRC parity bits of the DCI matching a RNTI value). The UE may process information contained in the DCI (e.g., a scheduling assignment, an uplink grant, power control, a slot format indication, a downlink preemption, and/or the like).

[0179] The UE may transmit uplink control signaling (e.g., uplink control information (UCI)) to a base station. The uplink control signaling may comprise hybrid automatic repeat request (HARQ) acknowledgements for received DL-SCH transport blocks. The UE may

transmit the HARQ acknowledgements after receiving a DL-SCH transport block. Uplink control signaling may comprise channel state information (CSI) indicating channel quality of a physical downlink channel. The UE may transmit the CSI to the base station. The base station, based on the received CSI, may determine transmission format parameters (e.g., comprising multi-antenna and beamforming schemes) for a downlink transmission. Uplink control signaling may comprise scheduling requests (SR). The UE may transmit an SR indicating that uplink data is available for transmission to the base station. The UE may transmit a UCI (e.g., HARQ acknowledgements (HARQ-ACK), CSI report, SR, and the like) via a physical uplink control channel (PUCCH) or a physical uplink shared channel (PUSCH). The UE may transmit the uplink control signaling via a PUCCH using one of several PUCCH formats.

[0180] There may be five PUCCH formats and the UE may determine a PUCCH format based on a size of the UCI (e.g., a number of uplink symbols of UCI transmission and a number of UCI bits). PUCCH format 0 may have a length of one or two OFDM symbols and may include two or fewer bits. The UE may transmit UCI in a PUCCH resource using PUCCH format 0 if the transmission is over one or two symbols and the number of HARQ-ACK information bits with positive or negative SR (HARQ-ACK/SR bits) is one or two. PUCCH format 1 may occupy a number between four and fourteen OFDM symbols and may include two or fewer bits. The UE may use PUCCH format 1 if the transmission is four or more symbols and the number of HARQ-ACK/SR bits is one or two. PUCCH format 2 may occupy one or two OFDM symbols and may include more than two bits. The UE may use PUCCH format 2 if the transmission is over one or two symbols and the number of UCI bits is two or more. PUCCH format 3 may occupy a number between four and fourteen OFDM symbols and may include more than two bits. The UE may use PUCCH format 3 if the transmission is four or more symbols, the number of UCI bits is two or more and PUCCH resource does not include an orthogonal cover code. PUCCH format 4 may occupy a number between four and fourteen OFDM symbols and may include more than two bits. The UE may use PUCCH format 4 if the transmission is four or more symbols, the number of UCI bits is two or more and the PUCCH resource includes an orthogonal cover code.

[0181] The base station may transmit configuration parameters to the UE for a plurality of PUCCH resource sets using, for example, an RRC message. The plurality of PUCCH resource sets (e.g., up to four sets) may be configured on an uplink BWP of a cell. A PUCCH resource set may be configured with a PUCCH resource set index, a plurality of PUCCH resources with a PUCCH resource being identified by a PUCCH resource identifier (e.g., pucch-Resourceid), and/or a number (e.g. a maximum number) of UCI information bits the

UE may transmit using one of the plurality of PUCCH resources in the PUCCH resource set. When configured with a plurality of PUCCH resource sets, the UE may select one of the plurality of PUCCH resource sets based on a total bit length of the UCI information bits (e.g., HARQ-ACK, SR, and/or CSI). If the total bit length of UCI information bits is two or fewer, the UE may select a first PUCCH resource set having a PUCCH resource set index equal to “0”. If the total bit length of UCI information bits is greater than two and less than or equal to a first configured value, the UE may select a second PUCCH resource set having a PUCCH resource set index equal to “1”. If the total bit length of UCI information bits is greater than the first configured value and less than or equal to a second configured value, the UE may select a third PUCCH resource set having a PUCCH resource set index equal to “2”. If the total bit length of UCI information bits is greater than the second configured value and less than or equal to a third value (e.g., 1406), the UE may select a fourth PUCCH resource set having a PUCCH resource set index equal to “3”.

[0182] After determining a PUCCH resource set from a plurality of PUCCH resource sets, the UE may determine a PUCCH resource from the PUCCH resource set for UCI (HARQ-ACK, CSI, and/or SR) transmission. The UE may determine the PUCCH resource based on a PUCCH resource indicator in a DCI (e.g., with a DCI format 1_0 or DCI for 1_1) received on a PDCCH. A three-bit PUCCH resource indicator in the DCI may indicate one of eight PUCCH resources in the PUCCH resource set. Based on the PUCCH resource indicator, the UE may transmit the UCI (HARQ-ACK, CSI and/or SR) using a PUCCH resource indicated by the PUCCH resource indicator in the DCI.

[0183] FIG. 15 illustrates an example of a wireless device 1502 in communication with a base station 1504 in accordance with embodiments of the present disclosure. The wireless device 1502 and base station 1504 may be part of a mobile communication network, such as the mobile communication network 100 illustrated in FIG. 1A, the mobile communication network 150 illustrated in FIG. 1B, or any other communication network. Only one wireless device 1502 and one base station 1504 are illustrated in FIG. 15, but it will be understood that a mobile communication network may include more than one UE and/or more than one base station, with the same or similar configuration as those shown in FIG. 15.

[0184] The base station 1504 may connect the wireless device 1502 to a core network (not shown) through radio communications over the air interface (or radio interface) 1506. The communication direction from the base station 1504 to the wireless device 1502 over the air interface 1506 is known as the downlink, and the communication direction from the wireless device 1502 to the base station 1504 over the air interface is known as the uplink. Downlink

transmissions may be separated from uplink transmissions using FDD, TDD, and/or some combination of the two duplexing techniques.

[0185] In the downlink, data to be sent to the wireless device 1502 from the base station 1504 may be provided to the processing system 1508 of the base station 1504. The data may be provided to the processing system 1508 by, for example, a core network. In the uplink, data to be sent to the base station 1504 from the wireless device 1502 may be provided to the processing system 1518 of the wireless device 1502. The processing system 1508 and the processing system 1518 may implement layer 3 and layer 2 OSI functionality to process the data for transmission. Layer 2 may include an SDAP layer, a PDCP layer, an RLC layer, and a MAC layer, for example, with respect to FIG. 2A, FIG. 2B, FIG. 3, and FIG. 4A. Layer 3 may include an RRC layer as with respect to FIG. 2B.

[0186] After being processed by processing system 1508, the data to be sent to the wireless device 1502 may be provided to a transmission processing system 1510 of base station 1504. Similarly, after being processed by the processing system 1518, the data to be sent to base station 1504 may be provided to a transmission processing system 1520 of the wireless device 1502. The transmission processing system 1510 and the transmission processing system 1520 may implement layer 1 OSI functionality. Layer 1 may include a PHY layer with respect to FIG. 2A, FIG. 2B, FIG. 3, and FIG. 4A. For transmit processing, the PHY layer may perform, for example, forward error correction coding of transport channels, interleaving, rate matching, mapping of transport channels to physical channels, modulation of physical channel, multiple-input multiple-output (MIMO) or multi-antenna processing, and/or the like.

[0187] At the base station 1504, a reception processing system 1512 may receive the uplink transmission from the wireless device 1502. At the wireless device 1502, a reception processing system 1522 may receive the downlink transmission from base station 1504. The reception processing system 1512 and the reception processing system 1522 may implement layer 1 OSI functionality. Layer 1 may include a PHY layer with respect to FIG. 2A, FIG. 2B, FIG. 3, and FIG. 4A. For receive processing, the PHY layer may perform, for example, error detection, forward error correction decoding, deinterleaving, demapping of transport channels to physical channels, demodulation of physical channels, MIMO or multi-antenna processing, and/or the like.

[0188] As shown in FIG. 15, a wireless device 1502 and the base station 1504 may include multiple antennas. The multiple antennas may be used to perform one or more MIMO or multi-antenna techniques, such as spatial multiplexing (e.g., single-user MIMO or multi-user

MIMO), transmit/receive diversity, and/or beamforming. In other examples, the wireless device 1502 and/or the base station 1504 may have a single antenna.

[0189] The processing system 1508 and the processing system 1518 may be associated with a memory 1514 and a memory 1524, respectively. Memory 1514 and memory 1524 (e.g., one or more non-transitory computer readable mediums) may store computer program instructions or code that may be executed by the processing system 1508 and/or the processing system 1518 to carry out one or more of the functionalities discussed in the present application. Although not shown in FIG. 15, the transmission processing system 1510, the transmission processing system 1520, the reception processing system 1512, and/or the reception processing system 1522 may be coupled to a memory (e.g., one or more non-transitory computer readable mediums) storing computer program instructions or code that may be executed to carry out one or more of their respective functionalities.

[0190] The processing system 1508 and/or the processing system 1518 may comprise one or more controllers and/or one or more processors. The one or more controllers and/or one or more processors may comprise, for example, a general-purpose processor, a digital signal processor (DSP), a microcontroller, an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) and/or other programmable logic device, discrete gate and/or transistor logic, discrete hardware components, an on-board unit, or any combination thereof. The processing system 1508 and/or the processing system 1518 may perform at least one of signal coding/processing, data processing, power control, input/output processing, and/or any other functionality that may enable the wireless device 1502 and the base station 1504 to operate in a wireless environment.

[0191] The processing system 1508 and/or the processing system 1518 may be connected to one or more peripherals 1516 and one or more peripherals 1526, respectively. The one or more peripherals 1516 and the one or more peripherals 1526 may include software and/or hardware that provide features and/or functionalities, for example, a speaker, a microphone, a keypad, a display, a touchpad, a power source, a satellite transceiver, a universal serial bus (USB) port, a hands-free headset, a frequency modulated (FM) radio unit, a media player, an Internet browser, an electronic control unit (e.g., for a motor vehicle), and/or one or more sensors (e.g., an accelerometer, a gyroscope, a temperature sensor, a radar sensor, a lidar sensor, an ultrasonic sensor, a light sensor, a camera, and/or the like). The processing system 1508 and/or the processing system 1518 may receive user input data from and/or provide user output data to the one or more peripherals 1516 and/or the one or more peripherals 1526. The processing system 1518 in the wireless device 1502 may receive power from a power source and/or may be configured to distribute the power to the other components in the

wireless device 1502. The power source may comprise one or more sources of power, for example, a battery, a solar cell, a fuel cell, or any combination thereof. The processing system 1508 and/or the processing system 1518 may be connected to a GPS chipset 1517 and a GPS chipset 1527, respectively. The GPS chipset 1517 and the GPS chipset 1527 may be configured to provide geographic location information of the wireless device 1502 and the base station 1504, respectively.

[0192] FIG. 16A illustrates an example structure for uplink transmission. A baseband signal representing a physical uplink shared channel may perform one or more functions. The one or more functions may comprise at least one of: scrambling; modulation of scrambled bits to generate complex-valued symbols; mapping of the complex-valued modulation symbols onto one or several transmission layers; transform precoding to generate complex-valued symbols; precoding of the complex-valued symbols; mapping of precoded complex-valued symbols to resource elements; generation of complex-valued time-domain Single Carrier-Frequency Division Multiple Access (SC-FDMA) or CP-OFDM signal for an antenna port; and/or the like. In an example, when transform precoding is enabled, a SC-FDMA signal for uplink transmission may be generated. In an example, when transform precoding is not enabled, an CP-OFDM signal for uplink transmission may be generated by FIG. 16A. These functions are illustrated as examples and it is anticipated that other mechanisms may be implemented in various embodiments.

[0193] FIG. 16B illustrates an example structure for modulation and up-conversion of a baseband signal to a carrier frequency. The baseband signal may be a complex-valued SC-FDMA or CP-OFDM baseband signal for an antenna port and/or a complex-valued Physical Random Access Channel (PRACH) baseband signal. Filtering may be employed prior to transmission.

[0194] FIG. 16C illustrates an example structure for downlink transmissions. A baseband signal representing a physical downlink channel may perform one or more functions. The one or more functions may comprise: scrambling of coded bits in a codeword to be transmitted on a physical channel; modulation of scrambled bits to generate complex-valued modulation symbols; mapping of the complex-valued modulation symbols onto one or several transmission layers; precoding of the complex-valued modulation symbols on a layer for transmission on the antenna ports; mapping of complex-valued modulation symbols for an antenna port to resource elements; generation of complex-valued time-domain OFDM signal for an antenna port; and/or the like. These functions are illustrated as examples and it is anticipated that other mechanisms may be implemented in various embodiments.

[0195] FIG. 16D illustrates another example structure for modulation and up-conversion of a baseband signal to a carrier frequency. The baseband signal may be a complex-valued OFDM baseband signal for an antenna port. Filtering may be employed prior to transmission.

[0196] A wireless device may receive from a base station one or more messages (e.g. RRC messages) comprising configuration parameters of a plurality of cells (e.g. primary cell, secondary cell). The wireless device may communicate with at least one base station (e.g. two or more base stations in dual-connectivity) via the plurality of cells. The one or more messages (e.g. as a part of the configuration parameters) may comprise parameters of physical, MAC, RLC, PCDP, SDAP, RRC layers for configuring the wireless device. For example, the configuration parameters may comprise parameters for configuring physical and MAC layer channels, bearers, etc. For example, the configuration parameters may comprise parameters indicating values of timers for physical, MAC, RLC, PCDP, SDAP, RRC layers, and/or communication channels.

[0197] A timer may begin running once it is started and continue running until it is stopped or until it expires. A timer may be started if it is not running or restarted if it is running. A timer may be associated with a value (e.g. the timer may be started or restarted from a value or may be started from zero and expire once it reaches the value). The duration of a timer may not be updated until the timer is stopped or expires (e.g., due to BWP switching). A timer may be used to measure a time period/window for a process. When the specification refers to an implementation and procedure related to one or more timers, it will be understood that there are multiple ways to implement the one or more timers. For example, it will be understood that one or more of the multiple ways to implement a timer may be used to measure a time period/window for the procedure. For example, a random access response window timer may be used for measuring a window of time for receiving a random access response. In an example, instead of starting and expiry of a random access response window timer, the time difference between two time stamps may be used. When a timer is restarted, a process for measurement of time window may be restarted. Other example implementations may be provided to restart a measurement of a time window.

[0198] A UE may receive an RRC release message comprising suspend configuration parameters (or suspend indication) where the suspend configuration parameters comprises the resume identity and the NCC value. Based on the suspend configuration parameters, the UE may suspend an RRC connection. Based on the RRC release message, the UE may transition from an RRC connected state to either an RRC inactive or an RRC idle state. Based on the suspended RRC connection in the RRC idle state, the UE is in an RRC idle state with a suspended RRC connection.

[0199] RRC connection establishment may comprise the establishment of signaling radio bearer 1 (SRB1). A base station may complete the RRC connection establishment prior to completing the establishment of the S1 connection, (e.g., prior to receiving the UE context information from core network entity (e.g., AMF)). access stratum (AS) security is not activated during the initial phase of the RRC connection. During the initial phase of the RRC connection, the base station may configure the UE to perform measurement reporting. The UE may send the corresponding measurement reports after successful AS security activation. The UE may receive or accept a handover message (e.g., a handover command) when AS security has been activated.

[0200] After having initiated the initial (AS) security activation procedure, a base station may initiate establishment of SRB2 and DRBs. For example, the base station may initiate establishment of SRB2 and DRBs prior to receiving the confirmation of the initial security activation from the UE. The base station may apply ciphering and integrity protection for the RRC (connection) reconfiguration messages where the RRC reconfiguration message is used to establish SRB2 and DRBs. The base station may release the RRC connection based on the initial security activation and/ or the radio bearer establishment being failed. For example, security activation and DRB establishment may be triggered by a joint S1 procedure where the joint S1 procedure may not support partial success. For SRB2 and DRBs, (AS) security may be activated from the start. For example, the base station may not establish these bearers prior to activating security.

[0201] A UE-RRC layer may initiate an RRC connection establishment procedure, an RRC connection resume procedure, or an RRC connection re-establishment procedure. Based on initiating the RRC connection establishment procedure or the RRC connection resume procedure, the UE may perform one or more procedures where the one or more procedures comprise at least one of: performing a unified access control procedure (e.g., access barring check) for access attempt of the RRC establishment/resume procedure on a serving cell; applying default configurations parameters and configurations/parameters provided by SIB1, (e.g., based on the access attempt being allowed, applying default configurations and configurations/parameters provided by SIB1); performing sending a random access preamble to the serving cell, for example, based on the access attempt being allowed; sending an RRC request message to the serving cell (e.g., based on determining a reception of a random access response being successful, sending an RRC request message to the serving cell); starting a timer based on sending the RRC request message; receiving an RRC response message or an RRC reject message from the serving cell (e.g., in response to the RRC request message); or sending an RRC complete message (e.g., in response to receiving the

RRC response message, sending an RRC complete message). For the RRC connection re-establishment procedure, the UE may not perform the unified access procedure (e.g., access barring check) for access attempt of the RRC reestablishment procedure.

[0202] Based on initiating the RRC connection reestablishment procedure, the UE may stop one or more barring timer T309 for all access categories if the one or more barring timer T309 is running. Based on stopping the one or more barring timer T309, the UE may determine barring for the all access categories being alleviated. The UE may perform the RRC connection reestablishment procedure based on the barring for the all access categories being alleviated. For example, the UE may send an RRC reestablishment request without barring based on the barring for the all access categories being alleviated.

[0203] For initiating RRC connection establishment/resume/reestablishment procedure, the UE-RRC layer may use parameters in a received SIB1. The UE-RRC layer may use L1 parameter values and a time alignment timer in the SIB1. The UE-RRC layer may use UAC barring information in the SIB1 to perform the unified access control procedure. Based on the unified access control procedure, the UE-RRC layer may determine whether the access attempt of those RRC procedures is barred or allowed. Based on the determining the access attempt is allowed, the UE-RRC layer may determine send an RRC request message to a base station. The UE-NAS layer may or may not provide S-TMSI as an UE identity. The UE-RRC layer may set an UE identity in the RRC request message.

[0204] For the RRC setup request message, the UE in an RRC idle state may initiate an RRC connection establishment procedure. Based on initiating the RRC connection establishment procedure, the UE-RRC layer in an RRC idle state may set the UE identity to S-TMSI if the UE-NAS layer provides the S-TMSI. Otherwise, the UE-RRC layer in an RRC idle state may draw a 39-bit random value and set the UE identity to the random value.

[0205] For the RRC resume request message, the UE in an RRC inactive or an RRC idle state with a suspended RRC connection may initiate an RRC connection resume procedure. The UE may in an RRC inactive or idle state may initiate the RRC connection procedure to resume a (suspend) RRC connection; or perform/initiate UP small data transmission. Based on initiating the RRC connection resume procedure, the UE may select access category based on triggering condition of the RRC connection resume procedure and perform unified access control procedure based on the access category. Based on the unified access control procedure, the UE may consider access attempt for the RRC connection resume procedure as allowed. Based on considering the access attempt as allowed, the UE may apply the default L1 parameter values as specified in corresponding physical layer specifications, except for the parameters for which values are provided in SIB1, apply the default SRB1 configuration,

apply the CCCH configuration, apply the time alignment timer common included in SIB1, apply the default MAC cell group configuration, start a timer T319 and initiate transmission of an RRC resume request message.

[0206] Based on initiating the transmission of the RRC resume request message, the UE may restore the stored configuration parameters and the stored security keys from the (stored) UE inactive AS context except for the master cell group configuration parameters, MR-DC related configuration parameters (e.g., secondary cell group configuration parameters) and PDCP configuration parameters. The configuration parameter may comprise at least one of the C-RNTI used in the source PCell, the global cell identity and the physical cell identity of the source PCell, and all other parameters configured except for the ones within reconfiguration with sync and serving cell configuration common parameters in SIB. Based on current (restored) K_{gNB} or next hop (NH) parameters associated to the stored NCC value, the UE may derive a new key of a base station (K_{gNB}). Based on the new key of the base station, the UE may derive security keys for integrity protection and ciphering of RRC signalling (e.g., $K_{RRCCenc}$ and K_{RRCint} respectively) and security keys for integrity protection and ciphering of user plane data (e.g., K_{UPint} and the K_{UPenc} respectively). Based on configured algorithm and the K_{RRCint} and K_{UPint} , the UE may configure lower layers (e.g., PDCP layer) to apply integrity protection for all radio bearers except SRB0. Based on configured algorithm and the $K_{RRCCenc}$ and the K_{UPenc} , the UE may configure lower layers (e.g., PDCP layer) to apply ciphering for all radio bearers except SRB0.

[0207] Based on the security keys, the UE-RRC layer in an RRC inactive or idle state may set a resume MAC-I value to the 16 least significant bits of the MAC-I calculated based on variable resume MAC input, security key of integrity protection for RRC layer in a UE inactive AS context, the previous configured integrity protection algorithm, and other security parameters (e.g., count, bearer and direction). The variable resume MAC input may comprise at least one of: physical cell identity of a source cell; C-RNTI of the source cell; and cell identity of a target cell (e.g., a selected cell) where the cell identity is a cell identity in system information block (e.g., SIB1) of the target cell (e.g., the selected cell). The UE-RRC layer in an RRC inactive or idle state may re-establish PDCP entities for one or more bearers. The UE-RRC layer may resume one or more bearer. For example, based on resuming the RRC connection, the UE-RRC layer may resume SRB1. Based on performing the UP small data transmission, the UE-RRC layer may resume one or more SRB(s) and DRB(s). The UE may set the contents of the RRC resume request message. The RRC resume request message may comprise at least one of: resume identity; resume MAC-I; or resume cause. The resume cause may comprise at least one of emergency, high priority access, mt

access, mo signalling, mo data, mo voice call, mo sms, ran update, mps priority access, mcs priority access.

[0208] For the RRC reestablishment request message, the UE in an RRC connected state may initiate an RRC connection reestablishment procedure. Based on initiating the RRC connection reestablishment procedure, the UE-RRC layer in an RRC connected state may contain the physical cell identity of source PCell and a short MAC-I in the RRC reestablishment message. The UE-RRC layer in an RRC connected state may set the short MAC-I to the 16 east significant bits of the MAC-I calculated based on variable short MAC input, security key of integrity protection for RRC layer and the integrity protection algorithm, which was used in a source PCell or the PCell in which the trigger for the reestablishment occurred, and other security parameters (e.g., count, bearer and direction). The variable short MAC input may comprise at least one of: physical cell identity of the source PCell; C-RNTI of the source PCell; and cell identity of a target cell (e.g., a selected cell) where the cell identity is a cell identity in system information block (e.g., SIB1) of the target cell (e.g., the selected cell). The UE-RRC layer in an RRC connected state may re-establish PDCP entities and RLC entities for SRB1 and apply default SRB1 configuration parameters for SRB1. The UE-RRC layer in an RRC connected state may configure lower layers (e.g. PDCP layer) to suspend integrity protection and ciphering for SRB1 and resume SRB1.

[0209] The UE-RRC layer may send an RRC request message to lower layers (e.g., PDCP layer, RLC layer, MAC layer and/or PHY layer) for transmission where where the RRC request message may be an RRC setup request message, an RRC resume request message, or an RRC re-establishment message.

[0210] A UE-RRC layer may receive an RRC setup message in response to an RRC resume request message or an RRC reestablishment request message. Based on the RRC setup message, the UE-RRC layer may discard any sotred AS context, suspend configuration parameters and current AS security context. The UE-RRC layer may release radio resources for all established RBs except SRB0, including release of the RLC entities, of the associated PDCP entities and of SDAP. The UE-RRC layer may release the RRC configuration except for default L1 parameter values, default MAC cell group configuration and CCCH configuration. The UE-RRC layer may indicate to upper layers (e.g., NAS layer) fallback of the RRC connection. The UE-RRC layer may stop timer T380 if running where the timer T380 is periodic RNA update timer.

[0211] A UE-RRC layer may receive an RRC setup message in response to an RRC setup request message, an RRC resume request message or an RRC reestablishment request

message. The RRC setup message may comprise cell group configurations parameters and radio bearer configuration parameters. The radio bearer configuration parameters may comprise at least one of signaling bearer configuration parameters, data radio bearer configuration parameters and/or security configuration parameters. The security configuration parameters may comprise security algorithm configuration parameters and key to use indication indicating whether the radio bearer configuration parameters are using master key or secondary key. The signaling radio bearer configuration parameters may comprise one or more signaling radio bearer configuration parameters. Each signaling radio configuration parameters may comprise at least one of SRB identity, PDCP configuration parameters, reestablishPDCP indication and/or discard PDCP indication. The data radio bearer configuration parameters may comprise one or more data radio bearer configuration parameters. Each data radio configuration parameters may comprise at least one of drb identity, PDCP configuration parameters, SDAP configuration parameters, reestablishPDCP indication and/or recover PDCP indication. The radio bearer configuration in the RRC setup message may comprise signaling radio configuration parameters for SIB1. Based on the RRC setup message, the UE-RRC layer may establish SRB1. Based on the RRC setup message, the UE-RRC layer may perform a cell group configuration or radio bearer configuration. The UE-RRC layer may stop a barring timer and wait timer for the cell sending the RRC setup message. Based on receiving the RRC setup message, the UE-RRC layer may perform one or more of the following: transitioning to RRC connected state; stopping a cell re-selection procedure; considering the current cell, to which the UE sent the RRC setup message, to be the PCell; or/and sending an RRC setup complete message.

[0212] A UE-RRC layer may receive an RRC resume message in response to an RRC resume request message. Based on the RRC resume message, the UE-RRC layer may discard a UE inactive AS context and release a suspend configuration parameters except ran notification area information. Based on the configuration parameters in the RRC resume message, the UE-RRC layer may perform a cell group configuration, a radio bearer configuration, security key update procedure, measurement configuration procedure. Based on receiving the RRC resume message, the UE-RRC layer may perform one or more of the following: indicating upper layers (e.g., NAS layer) that the suspended RRC connection has been resumed; resuming SRB2, all DRBs and measurements; entering RRC connected state; stopping a cell (re)selection procedure; considering the current cell sending the RRC resume message to be the PCell; or/and sending an RRC resume complete message by setting the content of the RRC resume complete message.

[0213] A UE-RRC layer in an RRC inactive or idle state may receive an RRC reject message in response to an RRC setup request message or an RRC resume request message. The RRC reject message may contain wait timer. Based on the wait timer, the UE-RRC layer may start timer T302, with the timer value set to the wait timer. Based on the RRC reject message, the UE-RRC layer may inform upper layers (e.g., UE-NAS layer) about the failure to setup an RRC connection or resume an RRC connection. The UE-RRC layer may reset MAC and release the default MAC cell group configuration. Based on the RRC Reject received in response to a request from upper layers, the UE-RRC layer may inform the upper layer (e.g., NAS layer) that access barring is applicable for all access categories except categories '0' and '2'.

[0214] A UE-RRC layer in an RRC inactive or idle state may receive an RRC reject message in response to an RRC resume request message. Based on the RRC reject message, The UE-RRC layer may discard current security keys. The UE-RRC layer may set pending rna update value to true if resume is triggered due to an RNA update.

[0215] A UE-RRC layer in an RRC inactive or idle state may perform a cell (re)selection procedure while performing an RRC procedure to establish an RRC connection. Based on cell selection or cell reselection, the UE-RRC layer may change a cell on the UE camped and stop the RRC procedure. The UE-RRC layer may inform upper layers (e.g., NAS layer) about the failure of the RRC procedure.

[0216] A UE in RRC idle or RRC inactive state may perform one of two procedures such as initial cell selection and cell selection by leveraging stored information. The UE may perform the initial cell selection when the UE doesn't have stored cell information for the selected PLMN. Otherwise, the UE may perform the cell selection by leveraging stored information. For initial cell selection, a UE may scan all RF channels in the NR bands according to its capabilities to find a suitable cell. Based on results of the scan, the UE may search for the strongest cell on each frequency. The UE may select a cell which is a suitable cell. For the cell selection by leveraging stored information, the UE may requires stored information of frequencies and optionally also information on cell parameters from previously received measurement control information elements or from previously detected cells. Based on the stored information, the UE may search a suitable cell and select the suitable cell if the UE found the suitable cell. If the UE does not found the suitable cell, the UE may perform the initial cell selection.

[0217] A base station may configure cell selection criteria for cell selection. a UE may seek to identify a suitable cell for the cell selection. The suitable cell is a cell on which the UE may camp to obtain normal service. The suitable cell is one for which satisfies following

conditions: (1) the measured cell attributes satisfy the cell selection criteria; (2) the cell PLMN is the selected PLMN; registered or an equivalent PLMN; (3) the cell is not barred or reserved; and (4) the cell is not part of tracking area which is in the list of “forbidden tracking areas for roaming”. An RRC layer in a UE may inform a NAS layer in the UE of cell selection and reselection result based on changes in received system information relevant for NAS. For example, the cell selection and reselection result may be a cell identity, tracking area code and a PLMN identity.

[0218] A UE in an RRC connected state may detect a failure of a connection with a base station. The UE in the RRC connected state may activate AS security with the base station before the detecting the failure. The failure comprises at least one of: a radio link failure (RLF); a reconfiguration with sync failure; a mobility failure from new radio (NR); an integrity check failure indication from lower layers (e.g., PDCP layer) concerning signaling radio bearer 1 (SRB1) or signaling radio bearer 2 (SRB2); or an RRC connection reconfiguration failure.

[0219] The radio link failure may be a radio link failure of a primary cell of the base station. The base station may send a reconfiguration with sync in an RRC message to the UE in RRC connected state. The reconfiguration with sync may comprise a reconfiguration timer (e.g., T304). Based on receiving the reconfiguration sync, the UE may start the reconfiguration timer and perform the reconfiguration with sync (e.g., handover). Based on expiry of the reconfiguration timer, the UE determine the reconfiguration sync failure. A base station may send mobility from NR command message to the UE in RRC connected state. Based on receiving the mobility from NR command message, the UE may perform to handover from NR to a cell using other RAT (e.g., E-UTRA). The UE may determine the mobility failure from NR based on at least one of conditions being met: if the UE does not succeed in establishing the connection to the target radio access technology; or if the UE is unable to comply with any part of the configuration included in the mobility from NR command message; or if there is a protocol error in the inter RAT information included in the mobility from NR message.

[0220] Based on detecting the failure, the UE in the RRC connected state may initiate an RRC connection reestablishment procedure. Based on initiating the RRC connection reestablishment procedure, the UE may start a timer T311, suspend all radio bearers except for SRB0, reset MAC (layer). Based on initiating the RRC connection reestablishment procedure, the UE in the RRC connected state may release MCG SCells, release special cell (SpCell) configuration parameters and multi-radio dual connectivity (MR-DC) related

configuration parameters. For example, based on initiating the RRC connection reestablishment procedure, the UE may release master cell group configuration parameters.

[0221] Based on initiating the RRC connection reestablishment procedure, the UE in the RRC connected state may perform a cell selection procedure. Based on the cell selection procedure, the UE may select a cell. Based on selecting a suitable cell, the UE in the RRC connected state may stop the timer 311 and start a timer T301. Based on selecting the suitable cell, the UE in the RRC connected state may stop a barring timer T390 for all access categories. Based on stopping the barring timer T390, the UE in the RRC connected state may consider a barring for all access category to be alleviated for the cell. Based on selecting the cell, the UE in the RRC connected state may apply the default L1 parameter values except for the parameters provided in SIB1, apply the default MAC cell group configuration, apply the CCCH configuration, apply a timer alignment timer in SIB1 and initiate transmission of the RRC reestablishment request message. Based on initiating the transmission of the RRC reestablishment request message, the UE (RRC layer) in the RRC connected state may re-establish PDCP for SRB1, re-establish RLC for SRB1, apply default SRB configurations for SRB1, configure lower layers (PDCP layer) to suspend integrity protection and ciphering for SRB1, resume SRB1 and submit the RRC reestablishment request message to lower layers (PDCP layer) for transmission. The RRC reestablishment request message may comprise at least one of C-RNTI used in the source PCell, a physical cell identity (PCI) of the source PCell, short MAC-I or a reestablishment cause. The reestablishment cause may comprise at least one of reconfiguration failure, handover failure or other failure.

[0222] The UE in the RRC connected state may stop the timer T301 based on reception of an RRC response message in response of the RRC reestablishment request message. The RRC response message may comprise at least one of RRC reestablishment message or RRC setup message or RRC reestablishment reject message. The UE in the RRC connected state may stop the timer T301 when the selected cell becomes unsuitable.

[0223] Based on the cell selection procedure triggered by initiating the RRC connection reestablishment procedure, the UE in the RRC connected state may select an inter-RAT cell. Based on selecting an inter-RAT cell, the UE (UE-AS layer) in the RRC connected state may transition to RRC IDLE state and may provide a release cause 'RRC connection failure' to upper layers (UE-NAS layer) of the UE.

[0224] Based on expiry of the timer T311 or T301, the UE (UE-AS layer) may transition to an RRC idle state and may provide a release cause 'RRC connection failure' to upper layers (UE-NAS layer) of the UE.

- [0225]** Based on receiving the release cause 'RRC connection failure', the UE (UE-NAS layer) in the RRC idle state may perform a NAS signaling connection recovery procedure when the UE does not have signaling pending and user data pending. Based on performing the NAS signaling connection recovery procedure, the UE in the RRC idle state may initiate the registration procedure by sending a registration request message to the AMF.
- [0226]** Based on receiving the release cause 'RRC connection failure', the UE (UE-NAS layer) in the RRC idle state may perform a service request procedure by sending a service request message to the AMF when the UE has signaling pending or user data pending.
- [0227]** Based on receiving the RRC reestablishment request message, the target base station may check whether the UE context of the UE is locally available. Based on the UE context being not locally available, the target base station may perform a retrieve UE context procedure by sending a retrieve UE context request message to the source base station (the last serving base station) of the UE.
- [0228]** For RRC connection reestablishment procedure, the retrieve UE context request message may comprise at least one of: a UE context ID; integrity protection parameters; or a new cell identifier. The UE context ID may comprise at least one of: C-RNTI contained the RRC reestablishment request message; and a PCI of the source PCell (the last serving PCell). The integrity protection parameters for the RRC reestablishment procedure may be the short MAC-I. The new cell identifier may be an identifier of the target cell wherein the target cell is a cell where the RRC connection has been requested to be re-established. The new cell identifier is a cell identity in system information block (e.g., SIB1) of the target cell (e.g., the selected cell).
- [0229]** For the RRC connection reestablishment procedure, based on receiving the retrieve UE context request message, the source base station may check the retrieve UE context request message. If the source base station is able to identify the UE context by means of the UE context ID, and to successfully verify the UE by means of the integrity protection contained in the retrieve UE context request message, and decides to provide the UE context to the target base station, the source base station may respond to the target base station with a retrieve UE context response message. If the source base station is not able to identify the UE context by means of the UE context ID, or if the integrity protection contained in the retrieve UE context request message is not valid, the source base station may respond to the target base station with a retrieve UE context failure message.
- [0230]** For the RRC connection reestablishment procedure, the retrieve UE context response message may comprise at least one of Xn application protocol (XnAP) ID of the target base station, XnAP ID of the source base station, globally unique AMF identifier (GUAMI) or UE

context information (e.g., UE context information retrieve UE context response). The UE context information may comprise at least one of a NG-C UE associated signaling reference, UE security capabilities, AS security information, UE aggregate maximum bit rate, PDU session to be setup list, RRC context, mobility restriction list or index to RAT/frequency selection priority. The NG-C UE associated signaling reference may be a NG application protocol ID allocated at the AMF of the UE on the NG-C connection with the source base station. The AS security information may comprise a security key of a base station (K_{gNB}) and next hop chaining count (NCC) value. The PDU session to be setup list may comprise PDU session resource related information used at UE context in the source base station. The PDU session resource related information may comprise a PDU session ID, a PDU session resource aggregate maximum bitrate, a security indication, a PDU session type or QoS flows to be setup list. The security indication may comprise a user plane integrity protection indication and confidentiality protection indication which indicates the requirements on user plane (UP) integrity protection and ciphering for the corresponding PDU session, respectively. The security indication may also comprise at least one of an indication whether UP integrity protection is applied for the PDU session, an indication whether UP ciphering is applied for the PDU session and the maximum integrity protected data rate values (uplink and downlink) per UE for integrity protected DRBs. The PDU session type may indicate at least one of internet protocol version 4 (IPv4), IPv6, IPv4v6, ethernet or unstructured. The QoS flow to be setup list may comprise at least one of QoS flow identifier, QoS flow level QoS parameters (the QoS Parameters to be applied to a QoS flow) or bearer identity.

[0231] For the RRC connection reestablishment procedure, the retrieve UE context failure message may comprise at least XnAP ID of the target base station and a cause value.

[0232] For the RRC connection reestablishment procedure, based on receiving the retrieve UE context response message, the target base station may send an RRC reestablishment message to the UE. The RRC reestablishment message may comprise at least a network hop chaining count (NCC) value.

[0233] Based on receiving the RRC reestablishment message, the UE may derive a new security key of a base station (K_{gNB}) based on at least one of current K_{gNB} or next hop (NH) parameters associated to the NCC value. Based on the new security key of the base station and a previously configured integrity protection algorithm, the UE may derive a security key for integrity protection of an RRC signaling (K_{RRcInt}) and a security key for integrity protection of user plane (UP) data (K_{UPInt}). Based on the new security key of the base station and a previously configured ciphering algorithm, the UE may derive a security key for ciphering of an RRC signaling (K_{RRcEnc}) and a security key for ciphering of user plane (UP)

data (K_{UPenc}). Based on the K_{RRCint} , and the previously configured integrity protection algorithm, the UE may verify the integrity protection of the RRC reestablishment message. Based on the verifying being failed, the UE (UE-AS layer) may go to RRC IDLE state and may provide a release cause 'RRC connection failure' to upper layers (UE-NAS layer) of the UE. Based on the verifying being successful, the UE may configure to resume integrity protection for SRB1 based on the previously configured integrity protection algorithm and the K_{RRCint} and configure to resume ciphering for SRB1 based on the previously configured ciphering algorithm and K_{RRCenc} . The UE may send an RRC reestablishment complete message to the target base station.

[0234] Based on receiving the retrieve UE context failure message, the target base station may send an RRC release message to the UE. For example, based on the retrieve UE context failure message comprising the RRC release message, the target base station may send the RRC release message to the UE. Based on receiving the retrieve UE context failure message, the target base station may send an RRC setup message or an RRC reject message. Based on receiving the retrieve UE context failure message, the target base station may not send any response message to the UE.

[0235] FIG. 17 illustrates an example of an RRC connection reestablishment procedure. The UE in an RRC connected state may send and receive data to/from a first base station (for example, a source base station) via a cell 1 wherein the cell 1 is a primary cell (PCell) of the first base station. The UE may detect a failure of a connection with the first base station. Based on the failure, the UE may initiate the RRC reestablishment procedure. Based on initiating the RRC connection reestablishment procedure, the UE may start a timer T311, suspend all radio bearers except for SRB0, and/or reset a MAC (layer). Based on initiating the RRC connection reestablishment procedure, the UE may release MCG SCells, release the special cell (SpCell) configuration parameters and the multi-radio dual connectivity (MR-DC) related configuration parameters. Based on initiating the RRC connection reestablishment procedure, the UE may perform a cell selection procedure. Based on the cell selection procedure, the UE may select a cell 2 of a second base station (for example, a target base station) where the cell 2 is a suitable cell. Based on selecting a suitable cell, the UE may stop the timer T311 and start a timer T301. Based on selecting the suitable cell, the UE may stop one or more barring timer T309(s) for all access categories if the one or more barring timer T309(s) is running. Based on stopping the one or more barring timer T309(s), the UE may consider barring for all access category to be alleviated for the cell. Based on selecting the cell, the UE may apply the default L1 parameter values except for the parameters provided in SIB1, apply the default MAC cell group configuration, apply the CCCH

configuration, apply a timer alignment timer in SIB1 and initiate transmission of the RRC reestablishment request message. The RRC reestablishment message may comprise at least one of C-RNTI used in the source PCell (e.g., the cell 1), a physical cell identity (PCI) of the source PCell, short MAC-I or a reestablishment cause. Based on initiating the transmission of the RRC reestablishment request message, the UE (RRC layer) may re-establish PDCP for SRB1, re-establish RLC for SRB1, apply default SRB configurations for SRB1, configure lower layers (PDCP layer) to suspend integrity protection and ciphering for SRB1, resume SRB1 and submit the RRC reestablishment request message to lower layers (PDCP layer) for transmission. Based on initiating the transmission of the RRC reestablishment request message, the UE may send the RRC reestablishment request message to the second base station via the cell 2. Based on receiving the RRC reestablishment request message, the second base station may check whether the UE context of the UE is locally available. Based on the UE context being not locally available, the second base station may perform the retrieve UE context procedure by sending a retrieve UE context request message to the source base station of the UE. the retrieve UE context request message may comprise at least one of: a UE context ID; integrity protection parameters; or a new cell identifier. The UE context ID may comprise at least one of: C-RNTI contained the RRC reestablishment request message; and a PCI of the source PCell (the last serving PCell). The integrity protection parameters for the RRC reestablishment procedure may be the short MAC-I. The new cell identifier may be an identifier of the target cell wherein the target cell is a cell where the RRC connection has been requested to be re-established. The new cell identifier is a cell identity in system information block (e.g., SIB1) of the target cell (e.g., the selected cell). Based on receiving the retrieve UE context request message, the source base station may check the retrieve UE context request message. If the source base station is able to identify the UE context by means of the C-RNTI, and to successfully verify the UE by means of the short MAC-I, and decides to provide the UE context to the second base station, the source base station may respond to the second base station with a retrieve UE context response message. The retrieve UE context response message may comprise at least of GUAMI or the UE context information. Based on receiving the retrieve UE context response message, the second base station may send an RRC reestablishment message to the UE. The RRC reestablishment message may comprise a network hop chaining count (NCC) value. Based on receiving the RRC reestablishment message, the UE may derive a new security key of a base station (K_{gNB}) based on at least one of current K_{gNB} or next hop (NH) parameters associated to the NCC value. Based on the new security key of a base station (K_{gNB}) and the previously configured security algorithms, the UE may derive security keys for integrity

protection and ciphering of RRC signaling (e.g., K_{RRCint} and K_{RRCenc} respectively) and user plane (UP) data (e.g., K_{UPint} and K_{UPenc} respectively). Based on the security key for integrity protection of the RRC signaling (K_{RRCint}), the UE may verify the integrity protection of the RRC reestablishment message. Based on the verifying being successful, the UE may configure to resume integrity protection for one or more bearers (e.g., signalling radio bearer or an RRC message) based on the previously configured integrity protection algorithm and the K_{RRCint} and configure to resume ciphering for one or more bearers based on the previously configured ciphering algorithm and the K_{RRCenc} . The second base station may send a first RRC reconfiguration message. The RRC first reconfiguration message may comprise the SpCell configuration parameters. Based on receiving the SpCell configuration parameters, the UE may initiate transmission and reception of data to/from the second base station. The UE may send an RRC reestablishment complete message to the second base station. The RRC reestablishment complete message may comprise measurement report. Based on receiving the measurement report, the second base station may determine to configure SCells and/or secondary cell groups (e.g., SCG or PSCells). Based on the determining, the second base station may send a second RRC reconfiguration message comprising SCells configuration parameters and/or MR-DC related configuration parameters. Based receiving the second RRC reconfiguration message, the UE may transmit and receive data via the SCells and/or SCGs.

[0236] The RRC reconfiguration message may comprise at least one of cell group configuration parameters of MCG and/or SCG, radio bearer configuration parameters or AS security key parameters.

[0237] A target base station may receive the RRC resume request message. Based on receiving the RRC resume request message, the target base station may check whether the UE context of the UE is locally available. Based on the UE context being not locally available, the target base station may perform the retrieve UE context procedure by sending the retrieve UE context request message to the source base station (the last serving base station) of the UE. The retrieve UE context request message may comprise at least one of a UE context ID, integrity protection parameters, a new cell identifier or the resume cause wherein the resume cause is in the RRC resume request message.

[0238] For the RRC connection resume procedure, based on receiving the retrieve UE context request message, the source base station may check the retrieve UE context request message. If the source base station is able to identify the UE context by means of the UE context ID, and to successfully verify the UE by means of the integrity protection contained in the retrieve UE context request message, and decides to provide the UE context to the

target base station, the source base station may respond to the target base station with the retrieve UE context response message. If the source base station is not able to identify the UE context by means of the UE context ID, or if the integrity protection contained in the retrieve UE context request message is not valid, or, if the source base station decides not to provide the UE context to the target base station, the source base station may respond to the target base station with a retrieve UE context failure message.

[0239] For the RRC connection resume procedure, the retrieve UE context failure message may comprise at least XnAP ID of the target base station, an RRC release message or a cause value.

[0240] For the RRC connection resume procedure, based on receiving the retrieve UE context response message, the target base station may send an RRC resume message to the UE. The RRC resume message may comprise at least one of radio bearer configuration parameters, cell group configuration parameters for MCG and/or SCG, measurement configuration parameters or sk counter wherein the sk counter is used to derive a security key of secondary base station based on K_{gNB} .

[0241] Based on receiving the retrieve UE context failure message, the target base station may send an RRC release message to the UE. For example, based on the retrieve UE context failure message comprising the RRC release message, the target base station may send the RRC release message to the UE. Based on receiving the retrieve UE context failure message, the target base station may send an RRC setup message or an RRC reject message. Based on receiving the retrieve UE context failure message, the target base station may not send any response message to the UE.

[0242] FIG. 18 illustrates an example of an RRC connection resume procedure. A UE in RRC connected state may transmit and receive data to/from a first base station (a source base station) via a cell 1. The first base station may determine to transit a UE in RRC connected state to RRC inactive state. Based on the determining, the base station may send an RRC release message comprising the suspend configuration parameters. Based on receiving the RRC release message comprising suspend configuration parameters, the UE may store in the UE inactive AS Context the current security keys (e.g., K_{gNB} and $K_{RRChint}$ keys) and current configuration parameters. For example, the UE may store some of the current configuration parameters. The stored (current) configuration parameters may be at least one of: robust header compression (ROHC) state; QoS flow to DRB mapping rules; C-RNTI used in source PCell; global cell identity and physical cell identity of the source PCell; and all other parameters configured except for ones within reconfiguration with sync and serving cell configuration common parameters in SIB. The robust header compression (ROHC) state may

comprise ROHC states for all PDCP entity (or all bearers) where each PDCP entity per bearer (or each bearer) may have one ROHC state. The QoS flow to DRB mapping rules may be QoS flow to DRB mapping rules for all data radio bearer (DRB) where each DRB may have one QoS follow to DRB mapping rule. Based on receiving the RRC release message comprising suspend configuration parameters, the UE may suspend all SRB(s) and DRB(s) except for SRB0. Based on receiving the RRC release message comprising suspend configuration parameters, the UE may start a timer T380, enter RRC inactive state, perform cell selection procedure. Based on the cell selection procedure, the UE may select a cell 2 of a second base station (a target base station). The UE in RRC inactive state may initiate an RRC connection resume procedure. The UE may perform the unified access control procedure. Based on the unified access control procedure, the UE may consider access attempt for the RRC connection resume procedure as allowed. The UE may apply the default L1 parameter values as specified in corresponding physical layer specifications, except for the parameters for which values are provided in SIB1, apply the default SRB1 configuration, apply the CCCH configuration, apply the time alignment timer common included in SIB1, apply the default MAC cell group configuration, start a timer T319 and initiate transmission of an RRC resume request message. Based on initiating the transmission of the RRC resume request message, the UE may restore the stored configuration parameters and the stored security keys from the (stored) UE inactive AS context. For example, the UE may restore the stored configuration parameters and the stored security keys (e.g., K_{gNB} and K_{RRCint}) from the stored UE Inactive AS context except for the master cell group configuration parameters, MR-DC related configuration parameters (e.g., secondary cell group configuration parameters) and PDCP configuration parameters. Based on current (restored) K_{gNB} or next hop (NH) parameters associated to the stored NCC value, the UE may derive a new key of a base station (K_{gNB}). Based on the new key of the base station, the UE may derive security keys for integrity protection and ciphering of RRC signalling (e.g., K_{RRCenc} and K_{RRCint} respectively) and security keys for integrity protection and ciphering of user plane data (e.g., K_{UPint} and the K_{UPenc} respectively). Based on configured algorithm and the K_{RRCint} and K_{UPint} , the UE (RRC layer) may configure lower layers (e.g., PDCP layer) to apply integrity protection for all radio bearers except SRB0. Based on configured algorithm and the K_{RRCenc} and the K_{UPenc} , the UE may configure lower layers (e.g., PDCP layer) to apply ciphering for all radio bearers except SRB0. For communication between the UE and the base station, the integrity protection and/or the ciphering may be required. Based on the integrity protection and/or the ciphering, the UE may be able to transmit and receive data to/from the second base station. The UE may use the restored configuration parameters to transmit and receive

the data to/from the second base station. Based on initiating the transmission of the RRC resume request message, the UE may re-establish PDCP entities for one or more bearers, resume one or more bearers and submit the RRC resume request message to lower layers. Based on receiving the RRC resume request message, the second base station may check whether the UE context of the UE is locally available. Based on the UE context being not locally available, the second base station may perform the retrieve UE context procedure by sending the retrieve UE context request message to the first base station (the last serving base station) of the UE. The retrieve UE context request message may comprise at least one of: resume identity; resume MAC-I; or the resume cause. Based on receiving the retrieve UE context request message, the first base station may check the retrieve UE context request message. If the first base station is able to identify the UE context by means of the UE context ID, and to successfully verify the UE by means of the resume MAC-I and decides to provide the UE context to the second base station, the first base station may respond to the second base station with the retrieve UE context response message. Based on receiving the retrieve UE context response message, the second base station may send an RRC resume message to the UE. Based on receiving the RRC resume message, the UE may restore master cell group configuration parameters, secondary cell group configuration parameters and PDCP configuration parameters in the UE inactive AS context. Based on restoring the master cell group configuration parameter and/or the secondary cell group configuration parameters, the UE may configure SCells of MCG and/or SCG by configuring lower layers to consider the restored MCG and/or SCG SCells to be in deactivated state, discard the UE inactive AS context and release the suspend configuration parameters. The UE may transmit and receive data via the SCells and/or SCGs.

[0243] A UE in an RRC idle state may use early security reactivation when the UE is resuming a suspended RRC connection and at least one of conditions being met where the conditions may comprise the UE is initiating (UP) small data transmission based on the UP EDT conditions being met; the UE is initiating (UP) small data transmission (SDT) procedure using a configured grant (CG) (e.g., a preconfigured uplink resource/grant, PUR) based on the UP CG conditions being met; the UE is resuming a suspended RRC connection in 5G-CN; and the UE supports early security reactivation, system information block includes a support indication of early security reactivation, and the UE has a stored value of the NCC (next hop chaining count) provided in the RRC release message comprising suspend configuration parameters (or suspend indication) during the preceding suspend procedure. The resuming a suspended RRC connection may comprise at least one of: the

initiating an RRC connection resume procedure; and the transmitting an RRC resume request message.

- [0244]** A UE in an RRC idle state may initiate an RRC connection resume procedure to resume a suspended RRC connection. Based on using the early security reactivation, the UE may restore PDCP state and re-establish PDCP entities for all SRBs and all DRBs and resume all SRBs and all DRBs.
- [0245]** A UE in an RRC inactive or idle state may send an RRC request message. Based on the sending the RRC request message, the UE (UE-RRC layer) may start an RRC timer (e.g., T300 or T319). The UE in an RRC inactive or idle state may receive an RRC response message in response to the RRC request message. Based on receiving the RRC response message, the UE in an RRC inactive or idle state may stop the RRC timer.
- [0246]** The UE in an RRC inactive or idle state may detect a failure to resume an (suspended) RRC connection when the RRC timer is running. The failure may comprise at least one of: the RRC timer being expired; cell (re)selection; receiving an RRC reject message; and integrity check failure of SRB1 or SRB2.
- [0247]** A UE may in an RRC idle state initiate an RRC connection establishment procedure to establish an RRC connection. Based on the initiating, the UE may transmit an RRC setup request message to a base station. Based on the transmitting, the UE may start the RRC timer. Based on detecting the failure to resume the RRC connection when the RRC timer is running and the RRC request message not being an RRC resume request message (the RRC setup request being transmitted), the UE in an RRC idle state may perform to at least one of: reset MAC; release MAC configuration (parameters); and reestablish RLC for one or more bearers that are established.
- [0248]** A UE may in an RRC idle state initiate an RRC connection resume procedure to resume a suspended RRC connection. Based on the initiating, the UE may transmit an RRC resume request message to a base station. Based on the transmitting, the UE may start the RRC timer. Based on detecting the failure to resume the RRC connection when the RRC timer is running and the RRC request message being an RRC resume request message (the RRC resume request message being transmitted), the UE may reset MAC. Based on the failure being the RRC timer being expired or the cell (re)selection, the receiving an RRC reject message wherein the RRC reject message comprise an RRC suspend indication, the UE may perform as follow: if the UE is resuming the RRC connection after the early security reactivation, the UE may abort early security reactivation; or otherwise, the UE may reestablish RLC for one or more radio bearers that are established/suspended and suspend SRB1.

- [0249]** The aborting of the early security reactivation may comprise at least one of: deleting (or discard) security keys; reestablishing RLC entities for one or more SRB(s) and DRB(s); suspending the one or more SRB(s) and DRB(s) except signaling radio bearer 0 (SRB0); and configure to suspend integrity protection and ciphering.
- [0250]** Based on the RRC timer being expired, the UE in an RRC inactive state may perform to at least one of: reset MAC; discard UE inactive AS context; release suspend configuration parameters; delete (or discard) security keys; release all radio resources and transition to an RRC idle state wherein the releasing all radio resource may comprise release of MAC configuration (parameters), RLC entity and PDCP entity and SDAP for the established one or more bearers; and transition to an RRC idle state.
- [0251]** Based on the cell (re)selection when the RRC timer is running, the UE in an RRC inactive state may perform to at least one of: reset MAC; discard UE inactive AS context; release suspend configuration parameters; delete (or discard) security keys; release all radio resources and transition to an RRC idle state wherein the releasing all radio resource may comprise release of MAC configuration (parameters), RLC entity and PDCP entity and SDAP for the established one or more bearers; and transition to an RRC idle state.
- [0252]** When the RRC timer is running, the UE in an RRC inactive or idle state may receive an RRC reject message. Based on the receiving the RRC reject message, the UE in an RRC inactive or idle state may stop the RRC timer. Based on the RRC reject message not comprising the RRC suspend indication and the RRC request message being an RRC resume request message, the UE in an RRC idle state perform to at least one of: reset MAC; discard UE inactive AS context; and release all radio resources and transition to an RRC idle state wherein the releasing all radio resource may comprise release of MAC configuration (parameters), RLC entity and PDCP entity and SDAP for the established one or more bearers. Based on the RRC reject message and the RRC request message not being the RRC resume request message, the UE in an RRC idle state may perform to at least one of: reset MAC; and release default MAC configuration parameters. Based on the RRC reject message, the UE in an RRC inactive state may perform to at least one of: reset MAC; release default MAC configuration (parameters); delete (or discard) security keys; (re)suspend RRC connection; and stay in the RRC inactive state.
- [0253]** When the RRC timer is running and the UE is in an RRC inactive or idle state, integrity check failure occurs. For example, The UE in an RRC inactive or idle state may detect the integrity check failure on SRB1 or SRB2 when the RRC timer is running. Based on the integrity check failure and the RRC request message being an RRC resume request message, the UE in an RRC idle state perform at least one of: reset MAC; discard UE

inactive AS context; and release all radio resources and transition to an RRC idle state wherein the releasing all radio resource may comprise release of MAC configuration (parameters), RLC entity and PDCP entity and SDAP for the established one or more bearers. Based on the integrity check failure and the RRC request message being an RRC resume request message, the UE in an RRC inactive state may perform at least one of: reset MAC; discard UE inactive AS context; release suspend configuration parameters; delete (or discard) security keys; release all radio resources and transition to an RRC idle state wherein the releasing all radio resource may comprise release of MAC configuration (parameters), RLC entity and PDCP entity and SDAP for the established one or more bearers; and transition to an RRC idle state.

[0254] The UE in an RRC idle state may detect the failure to resume an RRC connection when the RRC timer is running. The UE in the RRC idle state may (re)suspend one or more radio bearers (or the RRC connection) based on the failure. Based on the suspending the one or more radio bearers, the UE in the RRC idle state may send an RRC resume request message to resume the RRC connection. For example, based on the suspending the one or more radio bearers, the UE in the RRC idle state may send an RRC resume request message to a base station when the UE have a data or signaling to transmit or receive a paging message from a base station. The UE in the RRC idle state may not suspend one or more radio bearers (or an RRC connection) based on the failure (e.g., release all radio resource). Based on not suspending the one or more radio bearers (or the RRC connection), the UE in an RRC idle state may release all radio resources and may send an RRC setup request message. For example, based on the not suspending the one or more radio bearers (or the RRC connection), the UE in the RRC idle state may send an RRC setup request message to a base station when the UE have a data or signaling to transmit or receive a paging message from a base station.

[0255] A base station may initiate an RRC connection release procedure to transit an RRC state of a UE from RRC connected state to RRC idle state, from an RRC connected state to RRC inactive state, from RRC inactive state back to RRC inactive state when the UE tries to resume, or from RRC inactive state to RRC idle state when the UE tries to resume. The RRC connection procedure may also be used to release an RRC connection of the UE and redirect a UE to another frequency. The base station may send the RRC release message comprising suspend configuration parameters when transitioning RRC state of the UE to an RRC inactive state. The suspend configuration parameters may comprise at least one of a resume identity, RNA configuration, RAN paging cycle, or network hop chaining count (NCC) value wherein the RNA configuration may comprise RNA notification area information, or

periodic RNA update timer value (e.g., T380 value). The base station may use the resume identity (e.g., inactive-RNTI (I-RNTI)) to identify the UE context when the UE is in RRC inactive state.

[0256] If the base station has a fresh and unused pair of {NCC, next hop (NH)}, the base station may include the NCC in the suspend configuration parameters. Otherwise, the base station may include the same NCC associated with the current K_{gNB} in the suspend configuration parameters. The NCC is used for AS security. The base station may delete the current AS keys (e.g., K_{RRCenc} , K_{UPenc}), and K_{UPint} after sending the RRC release message comprising the suspend configuration parameters to the UE but may keep the current AS key K_{RRCint} . If the sent NCC value is fresh and belongs to an unused pair of {NCC, NH}, the base station may save the pair of {NCC, NH} in the current UE AS security context and may delete the current AS key K_{gNB} . If the sent NCC value is equal to the NCC value associated with the current K_{gNB} , the base station may keep the current AS key K_{gNB} and NCC. The base station may store the sent resume identity together with the current UE context including the remainder of the AS security context.

[0257] Upon receiving the RRC release message comprising the suspend configuration parameters from the base station, the UE may verify that the integrity of the received RRC release message comprising the suspend configuration parameters is correct by checking PDCP MAC-I. If this verification is successful, then the UE may take the received NCC value and save it as stored NCC with the current UE context. The UE may delete the current AS keys K_{RRCenc} , K_{UPenc} , and K_{UPint} , but keep the current AS key K_{RRCint} key. If the stored NCC value is different from the NCC value associated with the current K_{gNB} , the UE may delete the current AS key K_{gNB} . If the stored NCC is equal to the NCC value associated with the current K_{gNB} , the UE shall keep the current AS key K_{gNB} . The UE may store the received resume identity together with the current UE context including the remainder of the AS security context, for the next state transition.

[0258] Based on receiving the RRC release message comprising the suspend configuration parameters, the UE may reset MAC, release the default MAC cell group configuration, re-establish RLC entities for one or more bearers. Based on receiving the RRC release message comprising suspend configuration parameters, the UE may store in the UE inactive AS context current configuration parameters and current security keys. For example, the UE may store some of the current configuration parameters. The stored current configuration parameters may comprise a robust header compression (ROHC) state, quality of service (QoS) flow to DRB mapping rules, the C-RNTI used in the source PCell, the global cell identity and the physical cell identity of the source PCell, and all other parameters configured

except for the ones within reconfiguration with sync and serving cell configuration common parameters in SIB. The stored security keys may comprise at least one of K_{gNB} and K_{RRCInt} . The serving cell configuration common parameters in SIB may be used to configure cell specific parameters of a UE's serving cell in SIB1. Based on receiving the RRC release message comprising the suspend configuration parameters, the UE may suspend all SRB(s) and DRB(s) except for SRB0. Based on receiving the RRC release message comprising suspend configuration parameters, the UE may start a timer T380, enter RRC inactive state, perform cell selection procedure.

[0259] A UE may receive an RRC release message from the base station of serving cell (or PCell). Based on the RRC release message, the UE may perform UE actions for the RRC release message from the base station. The UE may delay the UE actions for the RRC release message a period of time (e.g., 60 ms) from the moment the RRC release message was received or when the receipt of the RRC release message was successfully acknowledged. The UE may send HARQ acknowledgments to the base station for acknowledgments of the RRC release message. Based on a RLC protocol data unit (PDU) comprising the RRC release message and the RLC PDU comprising poll bit, the UE may send a RLC message (e.g. a status report) to the base station for acknowledgments of the RRC release message.

[0260] The UE actions for the RRC release message from the base station may comprise at least one of: suspending RRC connection; releasing RRC connection; cell (re)selection procedure; and/or idle/inactive measurements.

[0261] The RRC release message from the base station may comprise the suspend configuration parameters. Based on the suspend configuration parameters, the UE may perform the suspending RRC connection. The suspending RRC connection may comprise at least one of: medium access control (MAC) reset (or resetting MAC); releasing default MAC cell group configuration; re-establishing RLC entities for one or more radio bearers; storing current configuration parameters and current security keys; suspending one or more bearers where the bearers comprises signaling radio bearer and data radio bearer; and/or transitioning an RRC idle state or an RRC inactive state.

[0262] Based on the MAC reset, the UE may perform to at least one of: stop all timers running in the UE-MAC layer; consider all time alignment timers as expired; set new data indicators (NDIs) for all uplink HARQ processes to the value 0; stop, ongoing RACH procedure; discard explicitly signaled contention-free Random Access Resources, if any; flush Msg 3 buffer; cancel, triggered scheduling request procedure; cancel, triggered buffer status reporting procedure; cancel, triggered power headroom reporting procedure; flush the soft buffers for all DL HARQ processes; for each DL HARQ process, consider the next

received transmission for a TB as the very first transmission; and/or release, temporary C-RNTI.

[0263] Based on the considering the time alignment timers as expired, the UE may perform at least one of: flush all HARQ buffers for all serving cells; notify RRC to release PUCCH for all Serving cells, if configured; notify RRC to release SRS for all Serving Cells, if configured; clear any configured downlink assignments and configured uplink grants; clear any PUSCH resource for semi-persistent CSI reporting; and/or consider all running time alignment timers as expired.

[0264] The default MAC cell group configuration parameters may comprise buffer status report (BSR) configuration parameters (e.g., BSR timers) for a cell group of the base station and power headroom reporting (PHR) configuration parameters (e.g., PHR timers or PHR transmission power factor change parameter) for the cell group of the base station.

[0265] The re-establishing RLC entities may comprise at least one of: discarding all RLC SDUs, RLC SDU segments, and RLC PDUs, if any; stopping and resetting all timers of the RLC entities; and resetting all state variables of the RLC entities to their initial values.

[0266] The RRC release message from the base station may not comprise the suspend configuration parameters. Based on the RRC release message not comprising the suspend configuration parameters, the UE may perform the releasing RRC connection. For example, based on the RRC release message not comprising the suspend configuration parameters, the RRC release message may indicate a release of an RRC connection. The UE may perform the releasing RRC connection. The releasing RRC connection may comprise at least one of: MAC reset (or resetting MAC); discarding the stored configuration parameters and stored security keys (or discarding the stored UE inactive AS context); releasing the suspend configuration parameters; releasing all radio resources, including release of RLC entity, MAC configuration and associated PDCP entity and SDAP for all established radio bearers; and/or transitioning to an RRC idle state.

[0267] The RRC release message may be RRC early data complete message.

[0268] A UE may send or receive a small amount of data without transitioning from an RRC idle state or an RRC inactive state to an RRC connected state based on performing small data transmission. The performing small data transmission may comprise, while staying in the RRC idle state or the RRC inactive state (e.g., without transitioning to an RRC connected state), at least one of: initiating small data transmission; sending small data; and/or receiving a response message.

[0269] For example, based on the small data transmission, the UE in an RRC idle state or an RRC inactive state may perform initiating small data transmission. In response to the

initiating small data transmission, the UE in an RRC idle state or an RRC inactive state may perform sending small data. In response to the sending small data, the UE may receive a response message. For example, the response message may comprise a downlink data (or a downlink signaling). For example, based on the small data transmission, the UE in an RRC idle state or an RRC inactive state may perform sending small data. In response to the sending small data, the UE in an RRC idle state or an RRC inactive state may receive a response message. The sending small data may comprise at least one of sending at least one of an RRC request message, uplink data (or uplink signaling) or buffer status report (BSR). For example, the sending small data may comprise sending the RRC request message. For example, the sending small data may comprise sending the RRC request message and uplink data. For example, the sending small data may comprise sending the RRC request message, a first uplink data and the BSR requesting uplink resource for a second uplink data. The RRC request message may comprise at least one of: an RRC resume request message; or an RRC early data request message. The response message may comprise at least one of: an RRC response message in response to the RRC request message; downlink data; or acknowledgment for uplink data (e.g., the first uplink data); or uplink resource for uplink data (e.g., the second uplink data). The RRC response message for the RRC request message may comprise at least one of: an RRC release message; an RRC early data complete message; an RRC setup message; an RRC resume message; or an RRC reject message.

[0270] Based on receiving the RRC release message, the UE in an RRC idle state or an RRC inactive state may transition to the RRC idle state or the RRC inactive state or stay in the RRC idle state or the RRC inactive state. Based on receiving the RRC early data complete message, the UE in an RRC idle state or an RRC inactive state may transition to the RRC idle state (or stay in the RRC idle state). Based on receiving the RRC release message or the RRC early data complete message, the UE may consider sending small data being successful. Based on receiving the RRC setup message or the RRC resume message, the UE in an RRC idle state or an RRC inactive state may transition to an RRC connected state. Based on receiving the RRC setup message or the RRC resume message, the UE may consider sending small data being successful. Based on receiving the RRC reject message, the UE in an RRC idle state or an RRC inactive state may transition to an RRC idle state. Based on receiving the RRC reject message, the UE may consider sending small data being not successful.

[0271] Based on receiving a first RRC release message, a UE may transition to an RRC inactive or idle state. The UE in an RRC inactive or idle state may perform small data transmission. The UE in an RRC inactive or idle state may initiate/trigger to perform the small data transmission based on having small data to transmit or based on receiving paging

message. The paging message may indicate the small data transmission. Based on the performing the small data transmission, the UE in an RRC idle state or an RRC inactive state may send uplink data via the Msg 3. The Msg 3 may be a message transmitted on UL-SCH containing C-RNTI MAC CE or CCCH SDU optionally multiplexed with DTCH. For example, the CCCH SDU may be associated with the UE contention resolution identity, as part of a random access procedure. For example, the UE in an RRC idle state or an RRC inactive state may send the CCCH SDU using preconfigured uplink resource (PUR). The CCCH SDU may comprise at least one of the RRC request message and the uplink data (e.g., the first uplink data). The DTCH may comprise the uplink data (e.g., the first uplink data). Based on the performing the small data transmission, the UE in an RRC idle state or an RRC inactive state may receive downlink data in response to the sending small data without transitioning to an RRC connected state. For example, based on the performing the small data transmission, the UE in an RRC idle state or an RRC inactive state may send the RRC request message and receive at least one of the RRC response message and/or downlink data in response to the RRC request message. The RRC release message may comprise a second RRC release message wherein the RRC release message may comprise the downlink data. Based on the second RRC release message, the UE may transition to an RRC inactive or idle state.

[0272] The small data transmission may comprise user plane (UP) small data transmission and control plane (CP) small data transmission. Based on the UP small data transmission, the UE in an RRC idle state or an RRC inactive may send uplink data via user plane (e.g., DTCH). Based on the CP small data transmission, the UE in an RRC idle state or an RRC inactive may send uplink data via control plane (e.g., CCCH). Based on the UP small data transmission, the base station of the UE may receive downlink data via user plane from UPF of the UE. Based on the CP small data transmission, the base station of the UE may receive downlink data via control plane from AMF of the UE. In response to the CCCH SDU and/or the DTCH SDU, the base station may send a response message to the UE in an RRC idle state or an RRC inactive.

[0273] The small data transmission may comprise at least one of initiating small data transmission, sending small data and receiving a response message. UP small data transmission may comprise at least one of initiating UP small data transmission, sending UP small data and receiving a response message. CP small data transmission may comprise at least one of sending CP small data via control plane and receiving a response message.

[0274] The initiating small data transmission may comprise initiating UP small data transmission. The sending small data may comprise at least one of sending UP small data

and/or sending CP small data via control plane. The response message may be a response message in response to at least one of the RRC request message and/or the (first) uplink data.

[0275] For the UP small data transmission, the DTCH SDU may comprise the uplink data. For example, for the UP small data transmission, the UE may send the DTCH SDU multiplexed with CCCH SDU. For example, for the UP small data transmission, the CCCH SDU may comprise at least one of the uplink data and an RRC request message. For example, for the UP small data transmission, the RRC request message may be an RRC resume request message. For the CP small data transmission, the UE may send CCCH SDU comprising the uplink data. For example, for the CP small data transmission, the RRC request message may comprise the uplink data. For example, for the CP small data transmission, the RRC request message may be an RRC early data request message.

[0276] In an example, a small data transmission (SDT) procedure may comprise exchange of user data between a wireless device and a base station while the wireless device is in a non-connected state (e.g., a radio resource control (RRC) non-connected state) (e.g., an idle state, inactive state, etc.). The amount of data exchanged in an SDT transmission of the SDT procedure may be smaller than a threshold amount of data. The SDT procedure may comprise one SDT transmission of a small amount of data and/or a sequence of SDT transmissions. For example, using an SDT procedure, the wireless device and/or base station may transmit and/or receive data via the user plane (UP) or the control plane (CP) while the wireless device remains in the non-connected state (e.g., idle, inactive, etc.). For example, using an SDT procedure, the wireless device may transmit and/or receive data without completing a connection setup or resume procedure (and without control plane signaling associated with setup and/or resumption). The data may comprise user data and a signal.

[0277] In an example, a wireless device may require a grant to transmit data (e.g., uplink data) associated with an SDT procedure. The wireless device may receive the grant from/via a base station. The grant may be an uplink grant for one or more uplink resources, and the wireless device may use the one or more uplink resources to transmit data (e.g., uplink data). The grant may be a dynamic uplink grant or a configured uplink grant of the one or more uplink resources. The dynamic uplink grant may indicate one or more specific uplink resources to be used for uplink transmission at a specific time. The configured uplink grant may indicate resources which are repeating, intermittent, and/or periodic. For example, a configured uplink grant configuration may indicate a periodicity of the configured uplink grant and one or more uplink resources of the configured uplink grant configuration may be used and re-used at periodic intervals. For example, a configured uplink grant may be configured/activated, and resources associated with a configured uplink grant configuration

of the configured uplink grant may be used until the configured uplink grant is released/deactivated. As an illustration, a dynamic uplink grant may indicate resources at time k , whereas a configured uplink grant may grant resources at times $k+nT$, where T is a period of the configured uplink grant and n is an integer $[0, 1, 2, \dots]$.

[0278] In an example, the wireless device may obtain the uplink grant via a physical or MAC signal (e.g., DCI or an random access (RA) response) indicating the uplink grant. For example, in a random access (RA)-based procedure (e.g., an early data transmission (EDT) procedure), the wireless device may send an RA preamble requesting one or more uplink resources. Based on the RA preamble, the wireless device may receive an uplink grant indicating one or more uplink resources for transmitting the small data.

[0279] In an example, the wireless device may obtain the uplink grant based on a configured uplink grant. The configured uplink grant may be associated with a configured uplink grant configuration (e.g., preconfigured uplink resource (PUR) configuration). The wireless device may receive the configured uplink grant configuration via an RRC message (e.g., an RRC release message). The configured uplink grant configuration may indicate a grant of one or more uplink resources, and the wireless device may use and/or re-use the one or more uplink resources (e.g., pre-configured uplink resources) for transmitting the small data.

[0280] For the configured uplink grant transmission (e.g., uplink transmission using preconfigured uplink resource (PUR)), a UE may send configured uplink grant configuration request message to a base station where the configured uplink grant configuration request message may comprise at least one of: requested number of configured uplink grant occasions where the number may be one or infinite; requested periodicity of configured uplink grant; requested transport block size (TBS) for configured uplink grant; and/or requested time offset for a first configured uplink grant occasion.

[0281] The base station may send configured uplink grant configuration (parameters) comprising the preconfigured uplink resource to the UE. For example, in response to the configured uplink grant configuration request message, the base station may send configured uplink grant configuration parameters comprising the preconfigured uplink resource to the UE. For example, the base station may send an RRC release message comprising the configured uplink grant configuration parameters.

[0282] The configured uplink grant configuration parameters may comprise at least one of: an indication to setup or release configured uplink grant configuration parameters; number of configured uplink grant occasions; configured uplink grant resource identifier (configured uplink grant RNTI); configured uplink grant configuration identity (configured uplink grant configID); value of the time offset for a first configured uplink grant occasion (configured

uplink grant start time); periodicity of configured uplink grant resource (configured uplink grant periodicity); duration of configured uplink grant response window (configured uplink grant response window time); threshold(s) of change in serving cell RSRP in dB for TA validation (configured uplink grant change threshold(s)) where the thresholds comprise RSRP increase threshold and RSRP decrease threshold; value of time alignment timer for configured uplink grant; and/or physical configuration parameters for configured uplink grant. The physical configuration parameters for configured uplink grant may comprises at least one of: PUSCH configuration parameters for configured uplink grant; PDCCH configuration parameters for configured uplink grant; PUCCH configuration parameters for configured uplink grant; downlink carrier configuration parameters used for configured uplink grant; and/or uplink carrier frequency of the uplink carrier used for configured uplink grant. The configured uplink grant RNTI may be assigned to more than one UE. The configured uplink grant configID may be unique in one base station.

[0283] A UE may determine to perform initiating SDT using configured uplink grant (CG based SDT) based on configured uplink grant conditions being met. The configured uplink grant conditions may comprise at least one of: the UE has a valid configured uplink grant configuration parameters; the UE has a valid timing alignment (TA) value; system information of a serving cell indicates configured uplink grant support; establishment or resumption request is for mobile originating calls and the establishment cause is mo data or mo exception data or delay tolerant access; the UE supports configured uplink grant; the size of the resulting MAC PDU including the total uplink data is expected to be smaller than or equal to the TBS configured for configured uplink grant; and the UE has a stored NCC value provided in the RRC release message comprising suspend configuration parameters during the preceding suspend procedure.

[0284] The UE may determine the timing alignment value for small data transmission for configured uplink grant to being valid based on TA validation conditions for configured uplink grant being met. The TA validation conditions for configured uplink grant may comprise at least one of: the time alignment timer for configured uplink grant is running; or serving cell RSRP has not increased by more than the RSRP increase threshold and has not decreased by more than the RSRP decrease threshold.

[0285] In response to receiving the configured uplink grant configuration parameters, the UE may store or replace configured uplink grant configuration parameters provided by the configured uplink grant configuration parameters based on the indication requesting to setup configured uplink grant configuration parameters. In response to receiving the configured uplink grant configuration parameters, the UE may start a time alignment timer for

configured uplink grant with the value of time alignment timer for configured uplink grant and configure the configured uplink grant configuration parameters. For example, based on the indication requesting to setup configured uplink grant configuration parameters, the UE may start a time alignment timer for configured uplink grant with the value of time alignment timer for configured uplink grant and configure the configured uplink grant configuration parameters. In response to receiving the configured uplink grant configuration parameters, the UE may discard configured uplink grant configuration parameters based on the indication requesting to release configured uplink grant configuration parameters. In response to the configuring the configured uplink grant configuration parameters, the UE may generate the configured uplink grant based on the configured uplink grant configuration parameters. For example, based on the configured uplink grant configuration parameters, the UE may determine when generating the configured uplink grant. For example, based on the configured uplink grant start time and the configured uplink grant periodicity, the UE may determine when generating the configured uplink grant. For example, based on the PUSCH configuration parameters, the UE may determine (transport blocks for) the configured uplink grant. For example, based on the PUSCH configuration parameters, the UE may determine (transport blocks for) the configured uplink grant.

[0286] FIG. 19 illustrates an example of data transmission based on a configured uplink grant (e.g., preconfigured uplink resource (PUR)). Based on receiving a first RRC release message, the UE may transition to an RRC non-connected state (e.g., an RRC idle state or an RRC inactive state). As illustrated in FIG. 19, the UE may send a configuration request for a configuration of a configured uplink grant (“CUG” in the illustration). The UE may receive parameters of a configured uplink grant configuration via an RRC release message. The previous RRC release message may be the first RRC release message. In response to receiving the configured uplink grant configuration parameters, the UE in an RRC idle state or an RRC inactive state may start a time alignment timer for configured uplink grant with the value of time alignment timer for configured uplink grant and configure the configured uplink grant configuration parameters. In response to the configuring the configured uplink grant configuration parameters, the UE in an RRC idle state or an RRC inactive state may generate the configured uplink grant based on the configured uplink grant configuration parameters. Based on the first RRC release message, the UE may perform a cell (re)selection procedure. Based on the cell (re)selection procedure, the UE in an RRC idle state or an RRC inactive state may select a cell 2 of a second base station (a target base station). The UE in an RRC idle state or an RRC inactive state may have a first uplink data in uplink buffer or receive a paging message. The UE in an RRC idle state or an RRC inactive state may determine to

perform the small data transmission based on the UP configured uplink grant conditions or CP configured uplink grant conditions being met. For example, in response to the having the first uplink data or receiving paging message, the UE in an RRC idle state or an RRC inactive state may determine to perform the small data transmission based on the UP configured uplink grant conditions or CP configured uplink grant conditions being met. Based on the determining, the UE may perform the small data transmission. Based on the uplink resource/grant for configured uplink grant, the UE may perform the sending small data. For example, the UE in an RRC idle state or an RRC inactive may send at least one of an RRC request message and/or the first uplink data, using the uplink resource for configured uplink grant. For example, based on the sending small, the UE in an RRC idle state or an RRC inactive may send Msg 3 comprising at least one of CCCH SDU and/or DTCH SDU where the CCCH SDU comprises an RRC request message and the DTCH SDU comprises the first uplink data. In response to the sending small data using configured uplink grant, the UE (UE-MAC entity) may start configured uplink grant response window timer with the configured uplink grant response window time. Based on the starting, the UE may monitor PDCCH identified by configured uplink grant RNTI until the configured uplink grant response window timer is expired. The UE (UE-MAC entity) may receive a downlink message (e.g., DCI) identified by the configured uplink grant RNTI on the PDCCH. Based on receiving the downlink message indicating an uplink grant for retransmission, the UE may restart the configured uplink grant response window timer at last subframe of a PUSCH transmission indicating the uplink grant, pulse time gap (e.g., 4 subframes). Based on the restarting, the UE in an RRC idle state or an RRC inactive state may monitor PDCCH identified by configured uplink grant RNTI until the configured uplink grant response window timer is expired. Based on receiving the downlink message indicating L1 (layer 1) ack for configured uplink grant, the UE in an RRC idle state or an RRC inactive state may stop the configured uplink grant response window timer and consider the small data transmission using configured uplink grant successful. Based on receiving the downlink message indicating fallback for configured uplink grant, the UE in an RRC idle state or an RRC inactive state may stop the configured uplink grant response window timer and consider the small data transmission using configured uplink grant being failed. Based on receiving the downlink message indicating PDCCH transmission (downlink grant or downlink assignment) addressed to the configured uplink grant RNTI and/or MAC PDU comprising the uplink data being successfully decoded, the UE in an RRC idle state or an RRC inactive state may stop the configured uplink grant response window timer and consider the small data transmission using configured uplink grant successful. Based on the PDCCH

transmission, the UE in an RRC idle state or an RRC inactive state may receive at least one of an RRC response message and downlink data wherein the RRC response message at least one of an RRC release message or an RRC early data complete message. Based on not receiving any downlink message until the configured uplink grant response window timer being expired, the UE in an RRC idle state or an RRC inactive state may consider the small data transmission using configured uplink grant being failed. Based on considering the small data transmission using configured uplink grant being failed, the UE may perform random access procedure. For example, the random access procedure may comprise EDT RACH procedure.

[0287] FIG. 20 illustrates an example of UP configured uplink grant and CP configured uplink grant. A UE in an RRC connected state may communicate with a first base station based on first configuration parameters and first security keys. The first base station may send an RRC release message to the UE. Based on receiving the RRC release message comprising the first suspend configuration parameters, the UE may perform the suspending RRC connection based on the first suspend configuration parameters. The UE may transition to an RRC idle state or an RRC inactive state. The UE may receive configured uplink grant configuration parameters via previous RRC release message. The previous RRC release message may be the RRC release message. In response to receiving the configured uplink grant configuration parameters, the UE in an RRC idle state or an RRC inactive state may start a time alignment timer for configured uplink grant with the value of time alignment timer for configured uplink grant and configure the configured uplink grant configuration parameters. In response to the configuring the configured uplink grant configuration parameters, the UE in an RRC idle state or an RRC inactive state may generate the configured uplink grant based on the configured uplink grant configuration parameters. Based on the RRC release message, the UE in an RRC idle state or an RRC inactive state may perform a cell (re)selection procedure. Based on the cell (re)selection procedure, the UE in an RRC idle state or an RRC inactive state may select a cell 2 of a second base station (a target base station). The UE in an RRC idle state or an RRC inactive state may determine to perform the initiating UP small data transmission based on the UP configured uplink grant conditions being met. Based on the determining to perform the initiating UP small data transmission, the UE in an RRC idle state or an RRC inactive may perform the initiating UP small data transmission using the first suspend configuration parameters. Based on the (preconfigured) uplink resource for configured uplink grant, the UE in an RRC idle state or an RRC inactive may perform the sending UP small data using the first suspend configuration parameters. For

example, the UE in an RRC idle state or an RRC inactive may send uplink data using the uplink resource for configured uplink grant.

[0288] In the example of FIG. 20, a UE in an RRC connected state may communicate with a first base station based on first configuration parameters and first security keys. The first base station may send an RRC release message to the UE. Based on receiving the RRC release message not comprising the first suspend configuration parameters, the UE may perform the releasing RRC connection based on the RRC release message. The UE may transition to an RRC idle state. The UE may receive configured uplink grant configuration parameters via previous RRC release message. The previous RRC release message may be the RRC release message. In response to receiving the configured uplink grant configuration parameters, the UE in an RRC idle state may start a time alignment timer for configured uplink grant with the value of time alignment timer for configured uplink grant and configure the configured uplink grant configuration parameters. In response to the configuring the configured uplink grant configuration parameters, the UE in an RRC idle state may generate configured uplink grant for configured uplink grant based on the configured uplink grant configuration parameters. Based on the RRC release message, the UE in an RRC idle state may perform a cell (re)selection procedure. Based on the cell (re)selection procedure, the UE in an RRC idle state may select a cell 2 of a second base station (a target base station). The UE in an RRC idle state may determine to perform the sending CP small data via control plane based on the CP configured uplink grant conditions being met. Based on the determining, the UE in an RRC idle state may perform the sending CP small data via control plane. For example, based on the (preconfigured) uplink resource for configured uplink grant, the UE in an RRC idle state may perform the sending CP small data via control plane. For example, the UE in an RRC idle state may send at least one of an RRC request message and/or uplink data using the uplink resource for configured uplink grant. For example, the RRC request message may be an RRC early data request message and/or comprise the uplink data.

[0289] A first base station (source base station) sends an RRC release message to a wireless device where the RRC release message comprises suspend configuration and the configuration of the at least one configured uplink grant of a first cell. The suspend configuration may comprise a resume identity. Based on the RRC release message, the first base station may store mapping of a resume identity and configuration of at least one configured uplink grant of a first cell. Based on the suspend configuration, the wireless device may suspend an RRC connection. The wireless device may determine to resume the RRC connection. Based on the determining, the wireless device suspending an RRC connection may send an RRC resume request message comprising resume identity. The

resume identity may be delivered to the first base station based on the retrieve UE context procedure. Based on the resume identity, the first base station may release the configuration.

[0290] The UE may receive configured uplink grant configuration (parameters) of a first cell. The configured uplink grant configuration may comprise at least one of: a configured uplink grant configuration identity; and configured uplink grant of a first cell. In the figures, for brevity, the configured uplink grant configuration identifier may be abbreviated as “CULG-configID”. The UE may send to send an RRC setup request message via the first cell and not using the configured uplink grant of the first cell. Based on the sending the RRC setup message not using the configured uplink grant and having the configured uplink grant configuration, the UE may send an RRC setup complete message comprising the configured uplink grant configuration identifier. The UE may send the RRC setup complete message in response to receiving an RRC setup message. The UE may receive the RRC setup message in response to the RRC setup request message. Based on receiving the configured uplink grant configuration identifier, a base station of the first cell may identify the configured uplink grant configuration associated to the configured uplink grant configuration identifier. Based on the identifying the configured uplink grant configuration, the base station may manage the configured uplink grant configuration. For example, the managing may comprise releasing. The configured uplink grant configuration identifier is unique identity per a base station.

[0291] In existing technologies, a wireless device may receive a first configured uplink grant configuration of a first cell from a first base station. Based on receiving the first configured uplink grant configuration of the first cell, the wireless device may store the first configured uplink grant configuration of the first cell. The wireless device in the RRC idle state may select a second cell. For example, the second cell may be selected for a connection based on the signal strength of the second cell. The wireless device may initiate a random access procedure on the second cell, where the random access procedure comprises the RRC connection establishment procedure. Based on initiating the random access procedure, the wireless device may disconnect from the first cell and/or release the first configured uplink grant configuration of the first cell. The first base station may not recognize that the first configured uplink grant is not be used any longer. The first base station may maintain the first configured uplink grant configuration parameters. Based on maintaining the first configured uplink grant configuration parameters, the first cell may keep allocating resources associated with the first configured uplink grant, which may waste the allocated resources by preventing other network entities from using them.

[0292] FIG. 21 illustrates an example of wireless device release of configured uplink grant configuration parameters. A wireless device in an RRC connected state may sends a

configured uplink grant configuration request message to a first base station via a first cell. The first base station may send an RRC release message comprising the configured uplink grant configuration (parameters) to the wireless device. The first base station may store the configured uplink grant configuration. Based on the RRC release message, the wireless device may transition to an RRC idle state. The wireless device may select a second cell based on cell (re)selection. The wireless device may initiate a random access procedure via the second cell where the random access procedure comprises the RRC connection establishment procedure. Based on the random access procedure, the wireless device may release the configured uplink grant configuration. The first base station may not recognize the configured uplink grant configuration being released by the wireless device. The first base station may maintain the configured uplink grant configuration and the first cell may keep allocating the configured uplink grant of the wireless device.

[0293] In embodiments of the disclosure, a wireless device in an RRC idle state may send one or more RRC messages indicating releasing at least one configured uplink grant of a first cell to a second base station. The second base station may send the one or more RRC message to a first base station based on the first cell being a cell of the first base station. Based on the one or more RRC messages, the first base station may release the configured uplink grant configuration of the first cell. Based on the embodiments, the first base station can avoid waste of radio resource due to unnecessarily allocating configured uplink grant.

[0294] In an example, a UE may select a second cell. The UE may determine to establish an RRC connection via the second cell. Based on the determining, the UE may send one or more RRC messages indicating releasing at least one configured uplink grant of one or more configurations (configured uplink grant configurations) of a first cell. Based on the determining, the UE may send one or more RRC messages indicating releasing the one or more configurations (configured uplink grant configurations) of a first cell.

[0295] In an example, the one or more RRC message may comprise at least one of: one or more cell identities of the first cell; or one or more configured uplink grant configuration identifiers; a resume identity.

[0296] In an example, a UE may select a second cell. The UE may determine to establish an RRC connection via the second cell. Based on the determining, the UE may initiate an RRC procedure to establish an RRC connection. For example, based on the initiating via the second cell, the UE may decide to release at least one of: the at least one configured uplink grant of a first cell of the one or more configurations; or the one or more configurations of the at least one configured uplink grant of the first cell. Based on the deciding, the UE may send one or more RRC messages indicating releasing at least one of: at least one configured

uplink grant of one or more configurations of a first cell; or the one or more configurations of the at least one configured uplink grant of the first cell. The RRC procedure comprise an RRC connection establishment procedure.

[0297] In an example, from the first cell, the UE may receive at least one first radio resource control (RRC) message comprising one or more configurations of the at least one configured uplink grant of a first cell. The one or more RRC message may comprise at least one of: one or more cell identities of cells of one or more configurations; one or more configured uplink grant configuration identifiers of the one or more configurations. The one or more configurations may not comprise configurations of the second cell and a cell identity of the second cell.

[0298] In an example, based on receiving the one or more configurations, the UE may store the one or more configuration. For example, the at least one first RRC message may comprise an RRC release message. Based on the RRC release message, the UE may transition from an RRC connected state to an RRC idle state. The RRC release message may comprise the one or more configurations. The configuration may be an indication to keep configured uplink grant configuration which the UE stored.

[0299] In an example, based on at least one of: the second cell being different from the first cell; and the determining to establish an RRC connection via the second cell, the UE may determine to release at least one of: at least one configured uplink grant of the first cell of the one or more configurations; or the one or more configurations of the at least one configured uplink grant of the first cell.

[0300] In an example, the one or more RRC messages may comprise one or more cell identity of the first cell where the first cell comprise one or more cells associated to the one or more configurations. For example, the UE may select a second cell. The UE may initiate the RRC procedure to establish an RRC connection via the second cell. Based on the initiating, the UE may determine to release at least one of: at least one configured uplink grant of the first cell of the one or more configurations; or the one or more configurations of the at least one configured uplink grant of the first cell. Based on the determining, the UE may send the one or more RRC message comprising the one or more cell identities of the first cell. For example, the UE may send the one or more cell identities of the first cell for the indicating releasing the at least one configured uplink grant of the first cell or the one or more configurations of the first cell.

[0301] In an example, the UE may send the one or more RRC messages comprising one or more configured uplink grant configuration identities (configured uplink grant configuration identifiers) of the wireless device. For example, the UE may send the one or more RRC

messages comprising the one or more configured uplink grant configuration identifiers based on at least one of: the one or more RRC messages being not in response to transmission using at least one configured uplink grant of the one or more configured uplink grant configuration identifiers; and the determining to release the at least one configured uplink grant or the one or more configured uplink grant configurations of the one or more configured uplink grant configuration identifiers. For example, the UE may send the one or more RRC messages comprising the one or more configured uplink grant configuration identifiers associated to the first cell based on at least one of: the determining to establish an RRC connection via the second cell; and sending the one or more RRC messages not using at least one configured uplink grant of configuration of the second cell. For example, the UE may send the one or more RRC messages comprising the one or more configured uplink grant configuration identifiers of the one or more configurations of the first cell based on sending the one or more RRC messages (e.g., an RRC setup request message) being not in response to transmission using at least one configured uplink grant of the one or more configurations. The configuration may comprise the configured uplink grant configuration identifier.

[0302] In an example, the UE may send one or more RRC messages comprising at least one of: one or more cell identities of the first cell and one or more configured uplink grant configuration identifiers of the one or more configuration.

[0303] In an example, the one or more RRC messages may comprise at least one of: one or more cell identities of the first cell; and one or more configured uplink grant configuration identifiers of the one or more configuration of the first cell. For example, the UE may select a second cell. The UE may initiate the RRC procedure to establish an RRC connection via the second cell. Based on the initiating, the UE may determine to release at least one of: at least one configured uplink grant of the first cell of the one or more configurations; or the one or more configurations of the at least one configured uplink grant of the first cell. Based on the determining, the UE may send the one or more RRC message.

[0304] In an example, the at least one first RRC message may comprise one or more configurations of at least one configured uplink grant. Each configured uplink grant configuration of the one or more configurations may comprise one configured uplink grant configuration identifier. The each configured uplink grant configuration may be associated to at least one cell identity. The UE may send one or more RRC messages indicating the releasing at least one of: at least one configured uplink grant of the first cell of the one or more configurations; or the one or more configurations of the at least one configured uplink grant of the first cell. The one or more RRC message may comprise a list of a configured uplink grant configuration identifier and at least one cell identity associated to single

configuration. For example, the UE may send the one or more RRC messages comprising the list associated to the first cell. The first cell may comprising one or more cells different from the second cell.

[0305] In an example, the UE may receive three configurations where a first configuration comprises configuration of at least one configured uplink grant of a first cell, a second configuration comprises configuration of at least one configured uplink grant of a second cell, and a third configuration comprise configuration of at least one configured uplink grant of a third cell. The UE may select the second cell. The UE may determine to establish an RRC connection via the second cell. Based on the determining, the UE may send one or more RRC messages indicating releasing at least one of: the at least one configured uplink grant of the first configuration and the third configuration; or the first configuration and the third configuration. The one or more RRC messages may comprise a list comprise at least one of: a configured uplink grant configuration identifier of the first configuration and a cell identity of the first cell; and a configured uplink grant configuration identifier of the third configuration and a cell identity of the third cell. The UE may determine to establish an RRC connection not using configured uplink grant of the second configuration. For example, the UE may send the one or more RRC messages (e.g., an RRC setup request message) being not in response to transmission using at least one configured uplink grant of the second configurations. Based on the determining, the one or more RRC message may comprise at least one of: a configured uplink grant configuration identifier of the second configuration; and a cell identity of the second cell. Based on the determining, the UE may decide to release at least one of: the at least one configured uplink grant of the second configuration; or the second configuration. Based on the deciding, the one or more RRC message may comprise at least one of: the configured uplink grant configuration identifier of the second configuration; and the cell identity of the second cell. For example, the UE may send the one or more RRC messages without using the at least one configured uplink grant of the first configuration or the third configuration. For example, the UE may send the one or more RRC messages (e.g., an RRC setup request message) being not in response to transmission using at least one configured uplink grant of the first configuration or the third configuration. Based on the sending, the UE may determine to release the first configuration and the third configuration. The UE may determine to use configured uplink grant of the second configuration to send the one or more RRC messages. Based on the determining, the one or more RRC message may comprise a list comprise at least one of: the configured uplink grant configuration identifier of the first configuration and the cell identity of the first configuration; the configured uplink

grant configuration identifier of the third configuration and the cell identity of the third configuration.

[0306] In an example, the UE may receive a confirmation indication of the one or more configuration being released in response to the one or more RRC messages. The UE may release the one or more configuration of the at least one configured uplink grant based on at least one of: the receiving the confirmation indication; or receiving an RRC response message in response to the one or more RRC messages. For example, the UE may receive the RRC response message in response to the one or more RRC messages. The RRC response message may comprise the confirmation indication. Based on the RRC response message, the UE may release the one or more configuration.

[0307] In an example, the confirmation indication may comprise one or more indications. The indication may indicate one of the one or more configurations being released. The UE may receive the confirmation indication comprising the one or more indications. Based on the one or more indications, the UE may release one or more configurations associated to the one or more indications. For example, the UE may keep one or more configurations based one at least one of: not receiving the confirmation indication (e.g., the one or more indications) associated to the one or more configurations; or receiving an indication to keep the one or more configurations. The RRC response message may comprise the indication. For example, the UE may suspend one or more configurations based one at least one of: not receiving the confirmation indication (e.g., the one or more indications) associated to the one or more configurations; or receiving an indication to suspend the one or more configurations. The UE may receive an indication to resume the one or more configuration (e.g., the suspended one or more configurations). Based on receiving the indication to resume the one or more configurations, the UE may resume the one or more configuration associated to the resume indication. The indication to keep or suspend or resume indication may comprise configured uplink grant config ID. The RRC response message may comprise the indication or the confirmation indication.

[0308] In an example, a UE may select a second cell. The UE may determine to establish an RRC connection via the second cell. Based on the determining, the UE may initiate an RRC procedure to establish an RRC connection. For example, based on the initiating via the second cell, the UE may decide to release at least one of: the a least one of configured uplink grant of the one or configurations of the first cell; or the one or more configurations of a first cell. Based on the deciding, the UE may send one or more RRC messages indicating releasing at least one of: the a least one of configured uplink grant of the one or

configurations of the first cell; or the one or more configurations of a first cell. The RRC procedure comprise an RRC connection establishment procedure.

[0309] In an example, the UE may send the one or more RRC messages comprising at least one of: one or more cell identities of one or more configurations; and one or more configured uplink grant configuration identifiers of the one or more configurations. The one or more configurations may not comprise configurations of the second cell. The UE may receive the RRC response message in response to the one or more RRC messages. Based on the RRC response message, the UE may release the one or more configuration. For example, based on the determining to establish an RRC connection via the second cell, the UE may release at least one of: at least one configured uplink grant of the first cell of the one or more configurations; or the one or more configurations of the at least one configured uplink grant of the first cell. The UE may send the one or more RRC messages indicating the releasing at least one of: the at least one configured uplink grant of the first cell of the one or more configurations; or the one or more configurations of the at least one configured uplink grant of the first cell. Based on the RRC response message, the UE may release the one or more configurations. For example, the UE may store at least one of: configured uplink grant configuration identifiers of the one or more configurations; one or more cell identities associated to the one or more configurations. For example, based on the determining to establish an RRC connection via the second cell, the UE may store at least one of: configured uplink grant configuration identifiers of the one or more configurations; one or more cell identities associated to the one or more configurations. In response to the storing, the UE may release the one or more configurations. In response to the releasing, the UE may send the one or more RRC messages comprising at least one of: the one or more cell identities of one or more configurations; the one or more configured uplink grant configuration identifiers of the one or more configurations.

[0310] In an example, the one or more RRC messages may comprise at least one of: the RRC setup request message; the RRC setup complete message; the configured uplink grant configuration request message; an configured uplink grant configuration release request message; and a UE information request message.

[0311] In an example, the UE may receive the RRC setup message in response to the RRC setup request message. The UE may send the RRC setup complete message in response to RRC setup message.

[0312] In an example, the RRC setup request message may comprise at least one of: a serving temporary mobile subscribe identity (S-TMSI); or a random value for contention resolution.

[0313] In an example, the RRC setup complete message may comprise at least one of: one or more cell identities of cells associated to the one or more configurations; and one or more configured uplink grant configuration identifiers of the one or more configurations. For example, the RRC setup complete message may comprise the list of a configured uplink grant configuration identifier and a cell identity associated to the configured uplink grant configuration identifier where the configured uplink grant configuration identifier is a configured uplink grant configuration identifier of the one or more configurations.

[0314] In an example, the configured uplink grant configuration release request message may comprise at least one of: cell identities of the one or more configurations; and configured uplink grant configuration identifiers of the one or more configurations. For example, the configured uplink grant configuration release request message may comprise the list of a configured uplink grant configuration identifier and a cell identity associated to the configured uplink grant configuration identifier where the configured uplink grant configuration identifier is a configured uplink grant configuration identifier of the one or more configurations. The UE may send the configured uplink grant configuration release request message in response to transition to an RRC connected state. For example, The UE may send the configured uplink grant configuration release request message via SRB2.

[0315] In an example, based on the receiving the RRC setup message, the UE may release at least one of: the at least one configured uplink grant of the first cell of the one or more configurations; or the one or more configurations of the at least one configured uplink grant of the first cell.

[0316] In an example, the UE may select the second cell. For example, the UE in an RRC idle state may select the second cell based on cell (re)selection.

[0317] In an example, the second cell may be different from the first cell. A second base station of the second cell may be different from a first base station of the first cell.

[0318] In an example, the cell identities may comprise at least one of: a physical cell identity; or a global cell identity. For example, the cell identity of the first cell may comprise at least one of: a physical cell identity; or a global cell identity.

[0319] In an example, the UE may determine to establish the RRC connection at least one of : having uplink data to transmit; or receiving a paging message. For example, the UE may initiate the RRC procedure to establish the RRC connection at least one of : having uplink data to transmit; or receiving a paging message.

[0320] In an example, the RRC response message may comprise at least one of: the RRC setup message; an RRC reconfiguration message; and a UE information response message. The UE may receive the UE information response message in response to the UE

information request message. The UE may receive the RRC reconfiguration message in response to the RRC setup complete message.

[0321] In an example, from the UE, a second base station may receive the one or more RRC messages indicating releasing at least one of: the at least one configured uplink grants of the one or more configurations; or the one or more configurations. The one or more RRC messages comprise at least one of: one or more cell identities of the one or more configurations; one or more configured uplink grant configuration identifiers of the one or more configurations. The second base station may comprise the second cell.

[0322] In an example, the second base station may determine one or more first base stations of the first cell based on the one or more cell identities of the first cell. The first cell comprise one or more cells associated to the one or more configurations. The second base station may classify the one or more RRC messages according to a base station where the base station comprises the one or more first base stations. The second base station may send the one or more RRC messages to the base station. For example, the second base station may classify the one or more cell identities according to the base station. The second base station may classify the one or more cell identities of the base station into cell identities of the base station. Based on the classifying, the second base station send an Xn message to the base station where the Xn message comprises the cell identities and configured uplink grant configuration identifier associated to the cell identities. The second base station may send one or more Xn message to the one or more first base stations.

[0323] In an example, the second base station may receive one or more Xn response message from the one or more first base stations in response to the one or more Xn messages. Each Xn response message of the one or more Xn response message may comprise the confirmation indication.

[0324] In an example, the second base station may send one or more confirmation indications to the UE. The second base station may send the one or more Xn response messages to the UE. The RRC response message may comprise the one or more confirmation indications or the one or more Xn response messages.

[0325] In an example, a first base station may send the at least one first RRC message to the UE via the first cell where the at least one first RRC message may comprise the configuration of at least one preconfigured uplink resource (configured uplink grant) of a first cell. From the second base station, the first base station may receive the one or more RRC messages (or the Xn message) indicating releasing at least one of: the at least one configured uplink grant of the first cell of the one or more configurations; or the one or more

configuration of the at least one configured uplink grant of the first cell. Based on the one or more RRC messages, the first base station may release or suspend the configuration.

[0326] In an example, in response to the one or more RRC messages, the first base station may determine to release or suspend or update one or more configurations of at least one configured uplink grant of the first cell. Based on the determining the one or more configurations, the first base station may send a message indicating the determining (e.g., the releasing or the suspending or the updating) to the UE via the second base station. For example, based on determining to release the one or more configurations, the first base station may send the confirmation indication of the one or more configurations being released to the UE via the second base station. For example, the first base station may determine to keep or suspend or resume the one or more configurations. Based on the determining, the first base station may send an indication to keep or suspend or resume the one or more configurations.

[0327] FIG. 22 illustrates an example of an enhanced configured uplink grant release procedure. The UE in an RRC connected state may send a configured uplink grant request message to the first base station via the first cell. Based on the configured uplink grant request message, the first base station may send an RRC release message comprising configuration of at least one configured uplink grant of the first cell. The configuration may comprise configured uplink grant configuration identifier. The first base station may store mapping of a configured uplink grant configuration identifier and the configuration. Based on the RRC release message, the UE may transition from the RRC connected state to an RRC idle state and release an RRC connection. The UE in the RRC idle state may select a second cell. The second cell may be a cell of a second base station. The UE in the RRC idle state may determine to establish an RRC connection via the second cell. Based on the determining, the UE may release the at least configured uplink grant of the configuration. Based on the releasing, the UE may send one or more RRC messages comprising a cell identity of the first cell and the configured uplink grant configuration identifier of the configuration. Based on the cell identity of the first cell, the second base station may determine that the first cell is a cell of the first base station. Based on the determining, the second base station may send the one or more RRC messages to the first base station. Based on the configured uplink grant configuration identifier of the one or more RRC messages, the first base station may identify the configuration of the configured uplink grant configuration identifier. Based on the one or more RRC messages, the first base station may release or suspend or keep the configuration of the UE. Based on the releasing or the suspending or the

keeping, the first base station may send an message indicating the releasing or the suspending or the keeping to the UE via the second base station.

[0328] In existing technologies, a first base station (source base station) may store mapping of a resume identity and configuration of at least one configured uplink grant of a first cell when suspending an RRC connection of a wireless device. A wireless device suspending an RRC connection may send a resume identity. The resume identity may comprise an identity of the first cell and a UE identity. The resume identity may be delivered to the first base station based on the retrieve UE context request message. Based on the resume identity, the first base station may identify the configuration. The wireless device suspending the RRC connection may release the RRC connection when detecting a failure to resume the RRC connection. Based on the releasing the RRC connection, the wireless device may not send the resume identity. Based on not sending the resume identity, the first base station may not identify the configuration and not release the configuration. The first base station may maintain the configured uplink grant configuration parameters. Based on maintaining the configured uplink grant configuration parameters, the first cell may keep allocating the configured uplink grant, which may cause waste of the configured uplink grant.

[0329] In embodiments of the disclosure, a wireless device suspending an RRC connection may release the RRC connection. The wireless device may determine to establish the RRC connection. Based on the determining, the wireless device may send one or more RRC messages indicating releasing at least one of: at least one configured uplink grant of a first cell of the one or more configurations; or the one or more configurations of the at least one configured uplink grant of the first cell. Based on receiving the one or more RRC messages, the second base station may send the one or more RRC message to a first base station based on the first cell where the first cell is a cell of the first base station. Based on the one or more RRC messages, the first base station may release the configured uplink grant configuration of the first cell. Based on the embodiments, the first base station can avoid waste of radio resource due to unnecessarily allocating configured uplink grant.

[0330] In an example, the UE suspending an RRC connection may release the RRC connection based on a failure to resume the RRC connection. The UE may select a second cell. The UE may determine to establish the RRC connection via the second cell. Based on the determining, the UE may send one or more RRC messages indicating releasing at least one of: the at least one configured uplink grant of a first cell of the one or more configurations; or the one or more configurations of the at least one configured uplink grant of the first cell.

[0331] In an example, the one or more RRC message may comprise one or more cell identities of the first cell or a resume identity. The one or more RRC messages comprising the one or more cell identities of the first cell, the one or more RRC message may comprise the one or more configured uplink grant configuration identifiers. For example, based on the indicating, the one or more RRC message may comprise the one or more cell identities of the first cell and the one or more configured uplink grant configuration identifiers. Based on the indicating, the one or more RRC message may comprise the resume identity.

[0332] In an example, a first base station may send at least one RRC message to a UE where the at least one RRC message comprises suspend configuration to suspend an RRC connection and configuration of at least one configured uplink grant of a first cell. The suspend configuration may comprise a resume identity. The configuration may comprise configured uplink grant configuration identifier. The first base station may store mapping of the resume identity and the configuration or mapping of the configured uplink grant configuration identifier and the configuration. Based on receiving the configuration, the UE may store the configuration. Based on receiving the suspend configuration, the UE may suspend the RRC connection.

[0333] In an example, based on the suspend configuration, the UE may suspend an RRC connection. An RRC release message may comprise the suspend configuration. Based on the RRC release message, the UE may transition an RRC inactive state or an RRC idle state. The UE may determine to resume the suspended RRC connection. Based on determining, the UE may initiate an RRC connection resume procedure. Based on the initiating, the UE may send an RRC resume request message via a third cell where the RRC resume request message comprises the resume identity. Based on the sending, the UE may start the RRC timer for the RRC resume request message. The UE may detect a failure to resume the RRC connection if the RRC timer is running. Based on detecting the failure, the UE may release the suspended RRC connection.

[0334] In an example, based on the releasing the suspended RRC connection, the UE may perform releasing an RRC connection. The UE may determine to establish the RRC connection. Based on the determining, the UE may send one or more RRC messages for the RRC connection. The one or more RRC messages may comprise the RRC setup request message.

[0335] In an example, the failure to resume the RRC connection may comprise at least one of: the RRC timer being expired; selecting a cell being different from the third cell if the RRC timer is running; receiving a fallback indication; receiving a (RRC) reject message; or inability to comply with an RRC response message. The UE may receive the RRC response

message in response to the RRC resume request message if the RRC timer is running. The RRC response message may comprise at least one of: an RRC resume message; an RRC setup message; and an RRC release message.

[0336] FIG. 23 illustrates an example of an enhanced configured uplink grant release procedure for a failure to resume an RRC connection. The UE in an RRC connected state may send a configured uplink grant request message to a first base station via the first cell. Based on the configured uplink grant request message, the first base station may send an RRC release message comprising suspend configuration and configuration of at least one configured uplink grant of the first cell. The configuration may comprise configured uplink grant configuration identifier. The suspend configuration may comprise a resume identity of the UE. The first base station may store mapping of the configured uplink grant configuration identifier and the configuration or mapping of the resume identity and the configuration. Based on the RRC release message, the UE may transition from the RRC connected state to an RRC inactive state or an RRC idle state. Based on the suspend configuration, the UE may suspend an RRC connection. The UE may detect a failure to resume the RRC connection. Based on the failure, the UE may release the suspended RRC connection. Based on the releasing the suspended RRC connection, the UE may transition to an RRC idle state if the UE is in an RRC inactive state. The UE in the RRC idle state may select a second cell. The UE in the RRC idle state may determine to establish an RRC connection via the second cell. Based on the determining, the UE may release the at least configured uplink grant of the configuration. Based on the releasing, the UE may send one or more RRC messages indicating the releasing the at least configured uplink grant. Based on the indicating, the one or more RRC messages may comprise either the configured uplink grant configuration identifier and a cell identity of the first cell, or the resume identity. Based on the cell identity of the first cell or the resume identity, the second base station may determine that the first cell is a cell of the first base station. Based on the determining, the second base station may send the one or more RRC messages to the first base station. Based on the configured uplink grant configuration identifier or the resume identity, the first base station may identify the configuration. Based on the identifying, the first base station may release or suspend or keep the configuration of the UE. Based on the releasing or the suspending or the keeping, the first base station may send an message indicating the releasing or the suspending or the keeping to the UE via the second base station.

[0337] In the example of FIG 23, an option 1 illustrates an example of mapping of configured uplink grant configuration identifier and configured uplink grant configuration. The first base station may store mapping of the configured uplink grant configuration

identifier and the configuration. The UE may send the one or more RRC message comprising the configured uplink grant configuration identifier and the cell identity of the first cell. An option 2 illustrate an example of mapping of the resume identity and the configuration. The first base station may store mapping of the resume identity and the configuration. The UE may send the one or more RRC message comprising the resume identity.

[0338] In existing technologies, a base station may comprise at least one gNB Central Unit (gNB-CU) and at least one a gNB Distributed Unit (gNB-DU) where the base station may be the first base station or the second base station. Based on sending the at least one RRC message comprising the configured uplink grant configuration, the gNB-CU may store the (configured uplink grant) configuration and the gNB-DU may allocate the at least one configured uplink grant of the first cell of the one or more configurations. The wireless device may send the one or more RRC messages comprising the one or more cell identity of the first cell of the one or more configurations and the one or more configured uplink grant configuration identifiers to the base station. The one or more RRC messages may be delivered to the gNB-CU via the gNB-DU. The gNB-DU may not know the releasing of the at least configured uplink grant of the first cell (or the releasing of the one or more configurations). The first cell of the gNB-DU may keep allocating the at least configured uplink grant, which may cause waste of the configured uplink grant.

[0339] In embodiments of the disclosure, from a wireless device, a gNB-CU may receive one or more RRC messages indicating releasing of at least configured uplink grant of a first cell of one or more configurations (or releasing of one or more configurations) where the one or more RRC messages comprise a cell identity of the first cell and a configured uplink grant configuration identifier. Based on receiving the one or more RRC messages, the gNB-CU may send a message indicating the releasing of the at least configured uplink grant of the first cell of the one or more configurations (or releasing of one or more configurations) to a gNB-DU where the message comprise at least one of: the cell identity of the first cell and an identity indicating the configuration of the first cell where the identity comprise at least one of: a configured uplink grant configuration identifier; configured uplink grant RNTI; or a resume identity. Based on the embodiments, the gNB-DU can avoid waste of radio resource due to unnecessarily allocating configured uplink grant.

[0340] In an example, from a wireless device, the gNB-CU may receive one or more RRC messages indicating releasing of at least configured uplink grant of the first cell of the one or more configurations (or releasing of the one or more configurations) of a first cell where the one or more RRC messages comprise at least one of: one or more cell identities of the first cell; one or more configured uplink grant configuration identifiers; or a resume identity.

[0341] In an example, based on the cell identity, the gNB-CU may identify that the first cell is a cell of the gNB-DU. Based on the one or more RRC messages, the gNB-CU may determine to send a F1AP (F1 application protocol) message indicating the releasing of the at least configured uplink grant (or the releasing of the configured uplink grant configuration) of the first cell. The F1AP message may comprise the one or more RRC messages. The F1AP message may comprise at least one of: the one or more cell identity of the first cell and one or more identities indicating the one or more configurations of the at least one configured uplink grant of the first cell where the identity comprise at least one of: a configured uplink grant configuration identifier; configured uplink grant RNTI; or a resume identity. Based on the identifying, the gNB-CU may send the F1AP message to the gNB-DU.

[0342] In an example, the F1AP message may comprise the configured uplink grant configuration identifier. For example, the F1AP message may comprise the resume identity. the F1AP message may comprise the configured uplink grant RNTI and the cell identity of the first cell.

[0343] In an example, the F1AP message may comprise an indication to release or suspend or resume or update at least one configured uplink grant of a first cell of a configuration (or a configuration of at least one configured uplink grant of a first cell). The indication may be associated to the at least one configured uplink grant (or the configuration) based on at least one of: the identity and/or the cell identity of the first cell. Based on at least one of: the identity and/or the cell identity of the first cell, the gNB-DU may identify the at least one configured uplink grant (or the configuration). Based on the identifying, the gNB-DU may release or suspend or resume or update the at least one configured uplink grant or the configuration based on the indication. Based on the releasing or suspending or resuming or updating, the gNB-DU may send a F1AP response message indicating the releasing or suspending or resuming or updating. Based on the indication to update, the F1AP message may comprise configured uplink grant configuration parameters where the configured uplink grant configuration parameters is associated to the indication. Based on receiving the indication to update, the gNB-DU may replace the at least one configured uplink grant of a first cell of a configuration (or the configuration of at least one configured uplink grant of a first cell) with the configured uplink grant configuration parameters. Based on receiving the indication to release, the gNB-DU may release the at least one configured uplink grant (or the configuration) associated to the identity and/or the cell identity of the first cell in the F1AP message. Based on receiving the indication to suspend, the gNB-DU may suspend the at least one configured uplink grant (or the configuration) associated to the identity and/or the cell identity of the first cell in the F1AP message. Based on receiving the indication to resume,

the gNB-DU may resume the suspended at least one configured uplink grant (or the suspended configuration) associated to the identity and/or the cell identity of the first cell in the F1AP message.

[0344] In an example, the gNB-DU may store the at least one configured uplink grant of the first cell of the configuration or the configuration of the at least one configured uplink grant of the first cell. Based on at least one of: the identify and a cell identity of the first cell, the gNB-DU may identify the at least one configured uplink grant of the first cell of the configuration or the configuration of the at least one configured uplink grant of the first cell. The identity comprise at least one of: a configured uplink grant configuration identifier; configured uplink grant RNTI; or a resume identity. For example, the gNB-DU may store mapping of the identity and at least one of: the at least one configured uplink grant of the first cell of the configuration; or the configuration of the at least one configured uplink grant of the first cell.

[0345] In an example, the gNB-DU may store mapping of a configured uplink grant configuration identifier and at least one configured uplink grant of a first cell of a configuration (or a configuration of at least one configured uplink grant of a first cell). The gNB-DU may store mapping of a resume identity and at least one configured uplink grant of a first cell of a configuration. The gNB-DU may store mapping of a parameter and at least one configured uplink grant of a first cell of a configuration where a parameter comprise a configured uplink grant RNTI of at least one configured uplink grant of a first cell and a cell identity of a first cell. Based on the mapping, the gNB-DU may identify the at least one configured uplink grant of the first cell.

[0346] FIG. 24 illustrates an example of configured uplink grant release in CU DU architecture. A UE may release at least one configured uplink grant of a first cell of a configuration (or the configuration of the at least one configured uplink grant of the first cell). Based on the releasing, the UE may send the one or more RRC messages to gNB-CU where the one or more RRC messages comprise at least one of: configured uplink grant configuration identifier of the configuration; and a cell identity of the first cell. A first base station may comprise at least one gNB-CU and at least one gNB-DU. For example, the UE may send the one or more RRC messages to the first base station via a second base station. Based on receiving the one or more RRC messages, the gNB-CU may send the F1AP message comprising at least one of: the identity and the cell identity of the first cell. Based on receiving the F1AP message, the gNB-DU may release the at least one configured uplink grant of the first cell of the configuration (or the configuration of the at least one configured

uplink grant of the first cell). In response to the F1AP message, the gNB-DU may send a F1AP response message to the gNB-CU.

[0347] In existing technologies, a wireless device may send a configured uplink grant configuration request message to a base station via a serving cell. In response to the configured uplink grant configuration request message, the base station may send configured uplink grant configuration parameters of the serving cell via an RRC release message. The wireless device may need configured uplink grant configuration parameters of another cell different from the serving cell. The wireless device may not send the configured uplink grant configuration request message to the base station until the another cell becomes a serving cell. The wireless device may lose a chance to request or use the configured uplink grant (configuration), which may cause an increase of power consumption and latency of uplink transmission of the wireless device.

[0348] In embodiments of the disclosure, a wireless device may send a configured uplink grant configuration request message indicating one or more cells to a base station where the one or more cells comprise cells which the wireless device requests configured uplink grant configuration parameters or configured uplink grant. Based on the configured uplink grant configuration request message, the base station may send the configured uplink grant configuration parameters of the one or more cells. The configured uplink grant configuration parameters may comprise the at least one configured uplink grant of the one or more cells.

[0349] In an example, the UE may send a configured uplink grant configuration request message comprising one or more cell identities. The configured uplink grant configuration request message may comprise requested configured uplink grant parameters where the request configured uplink grant configuration parameters may comprise at least one of: requested number of configured uplink grant occasions where the number may be one or infinite; requested periodicity of configured uplink grant; requested transport block size (TBS) for configured uplink grant; and/or requested time offset for a first configured uplink grant occasion. For example, the configured uplink grant configuration request message may comprise at least one of: the one or more cell identities and the one or more request configured uplink grant parameters. For example, the configured uplink grant configuration request message may comprise a list of a cell identity and request configured uplink grant parameters associated to the cell identity.

[0350] In an example, based on the configured uplink grant configuration request message, the base station may send one or more (configured uplink grant) configurations comprising at least one of: one or more cell identities and one or more configured uplink grant configuration identifiers. For example, each configured uplink grant configuration of the one

or more configurations may comprise at least one of: one or more cell identities and a configured uplink grant configuration identifier.

[0351] In an example, the base station may determine one or more first base stations based on the one or more cell identities. For example, based on the one or more cell identities, the base station may determine the one or more first base stations may comprise one or more first cells of the one or more cell identities. The base station may send one or more Xn messages to the one or more first base stations. The base station may generate each Xn message associated to a first base station where the first base station is one of the one or more first base stations. Each Xn message for the first base station may comprise at least one of: requested configured uplink grant parameters associated to the first base station; configured uplink grant configuration identifier; and UE identity. The request configured uplink grant parameters associated to the first base station may comprise request configured uplink grant parameters of one or more cells of the first base station. The base station may determine the configured uplink grant configuration identifier of the requested configured uplink grant parameters associated to the first base station. The UE identity may comprise at least one of: C-RNTI of the base station; a resume identity; and S-TMSI. Based on receiving the one or more Xn messages, the one or more first base stations may send configured uplink grant configuration parameters of the one or more first cells to the base station. The base station may send the configured uplink grant configuration parameters to the UE.

[0352] In an example, based on the one or more configurations, the UE may send uplink packet via a first cell using at least configured uplink grant of the first cell of the one or more configurations where the one or more cell identities comprise a cell identity of the first cell. For example, the UE may select on a first cell. The UE may initiate an RRC procedure to establish or resume an RRC connection. The UE may find a cell identity of the first cell in the one or more cell identities. The UE may identify a configuration of at least one configured uplink grant of a first cell based on the cell identity of the first cell. Based on the identifying, the UE may send uplink packet using the at least one configured uplink grant of the configuration.

[0353] FIG. 25 illustrates an example of configured uplink grant configuration request comprising a cell identity. The UE in an RRC connected state may send a configured uplink grant configuration request message to a base station where the configured uplink grant configuration request message comprises a cell identity of a first cell. The UE may send the configured uplink grant configuration request message via a second cell to the base station. Based on the configured uplink grant configuration request message, the base station may send configured uplink grant configuration parameters of the first cell.

- [0354]** From a first cell, a wireless device may receive at least one first radio resource control (RRC) message comprising: an indication of a release of an RRC connection; and configuration of at least one preconfigured uplink resource (configured uplink grant) of the first cell. The wireless device may select a second cell. The wireless device may determine to establish an RRC connection via the second cell. The wireless device may send, based on the determining, one or more RRC messages for the RRC connection, wherein the one or more RRC messages comprise a cell identity of the first cell that indicates releasing the at least one configured uplink grant.
- [0355]** The second cell may be different from the first cell.
- [0356]** The wireless device may send a configured uplink grant configuration identity (configured uplink grant configuration identifier) of the wireless device.
- [0357]** The sending the configured uplink grant configuration identifier may comprise sending the configured uplink grant configuration identifier based on at least one of: the one or more RRC messages being not in response to transmission using the at least one configured uplink grant; and the releasing the at least one configured uplink grant.
- [0358]** The one or more RRC messages may comprise the configured uplink grant configuration identifier.
- [0359]** The configuration of the at least configured uplink grant may comprise the cell identity of the first cell.
- [0360]** The wireless device may receive, in response to the one or more RRC messages, a confirmation indication of the configuration being released.
- [0361]** The wireless device may release the configuration of the at least one configured uplink grant comprises releasing the configuration of the at least one configured uplink grant based on at least one of: the receiving the confirmation indication; or receiving an RRC response message in response to the one or more RRC messages.
- [0362]** The one or more RRC messages comprise at least one of: an RRC setup request message;
- [0363]** an RRC setup complete message; a configured uplink grant configuration release request message; and a configured uplink grant configuration request message.
- [0364]** The wireless device may send, based on the determining to establish the RRC connection, the RRC setup request message wherein the RRC setup request message comprises at least one of: a serving temporary mobile subscribe identity (S-TMSI); or a random value for contention resolution.
- [0365]** The wireless device may receive, in response to the RRC setup request message, an RRC setup message.

- [0366] The wireless device may send, in response to the RRC setup message, the RRC setup complete message.
- [0367] The RRC setup complete message may comprise at least one of: the cell identity of the first cell; and the configured uplink grant configuration identifier.
- [0368] The configured uplink grant release request message comprises at least one of: the cell identity of the first cell; and the configured uplink grant configuration identifier.
- [0369] The releasing the at least one configured uplink grant may comprise releasing at least configured uplink grant in response to the receiving the RRC setup message.
- [0370] The releasing the at least one configured uplink grant may comprise releasing the configuration.
- [0371] The wireless device may select the second cell based on a signal quality of the cell exceeding a threshold.
- [0372] The cell identity of the first cell may comprise at least one of: a physical cell identity; or a global cell identity.
- [0373] The determining to establish the RRC connection may comprise determining to establish an RRC connection based on at least one of : having uplink data to transmit; or receiving a paging message.
- [0374] The configuration of the at least one configured uplink grant may comprise the configured uplink grant configuration identifier.
- [0375] The at least one first RRC message may comprise an RRC release message.
- [0376] The RRC response message may comprise at least one of: the RRC setup message; an RRC reconfiguration message; and a UE information response message.
- [0377] A second base station may receive, from the wireless device, one or more a radio resource control (RRC) messages indicating that the wireless device releases at least one preconfigured uplink resource (configured uplink grant) of a first cell wherein the one or more RRC messages comprise at least one of: a cell identity of the first cell; and a configured uplink grant configuration identity (configured uplink grant configuration identifier). The second base station may determine, based the cell identity, a first base station of the first cell. The second base station may send the one or more RRC messages to the first base station.
- [0378] The second base station may receive, from the first base station, a confirmation indication of the configuration being released in response to the one or more RRC messages.
- [0379] The second base station may send, to the wireless device, the confirmation indication.
- [0380] A first base station may send at least one first radio resource control (RRC) message to a wireless device where the at least one first RRC message comprise: an indication of a release of an RRC connection; and configuration of at least one preconfigured uplink

resource (configured uplink grant) of a first cell. The first base station may receive, from a second base station, one or more RRC messages indicating that the wireless device releases the at least one configured uplink grant, wherein the one or more RRC messages comprise at least one of: a cell identity of the first cell; and a configured uplink grant configuration identity (configured uplink grant configuration identifier). The first base station may release, based on the one or more RRC messages, the configuration.

- [0381] In response to the one or more RRC messages, the first base station may send, to the wireless device via the second base station, a confirmation indication of the configuration being released being released.
- [0382] From a first cell, a wireless device may receive at least one first radio resource control (RRC) message comprising: suspend configuration to suspend an RRC connection; and configuration of at least one preconfigured uplink resource (configured uplink grant) of the first cell. The wireless device may detect a failure to resume the RRC connection. The wireless device may release, based on the failure, the RRC connection. The wireless device may selecting a second cell. The wireless device may determine to establish an RRC connection via the second cell. The wireless device may send, based on the determining, one or more RRC messages indicating releasing the at least one configured uplink grant.
- [0383] The one or more RRC messages may comprise a cell identity of the first cell or a resume identity.
- [0384] The one or more RRC message may comprise a configured uplink grant configuration identity (configured uplink grant configuration identifier) of the wireless device based on the one or more RRC messages comprising the cell identity of the first cell
- [0385] The failure may comprise at least one of: an RRC timer being expired; selecting a cell being different from a third cell if the RRC timer is running; receiving a fallback indication; receiving a (RRC) reject message; or inability to comply with an RRC response message.
- [0386] The wireless device may send an RRC resume request message requesting to resume the RRC connection via the third cell.
- [0387] The wireless device may start, based on the sending the RRC resume request message, the RRC timer.
- [0388] The RRC response message may comprises at least one of: an RRC resume message; an RRC setup message; and an RRC release message.
- [0389] The RRC reject message may not comprise a suspend indication.
- [0390] The suspend configuration may comprise the resume identity.
- [0391] A wireless device may receive, from a first cell, at least one first radio resource control (RRC) release message comprising configuration of at least one preconfigured uplink

resource (configured uplink grant) of the first cell. The wireless device may select a second cell. The wireless device may determine to establish an RRC connection via the second cell. The wireless device may send, based on the determining, one or more RRC messages indicating releasing the configuration.

[0392] The one or more RRC messages may comprise the cell identity and the configured uplink grant configuration identifier based on at least one of: releasing an RRC connection; and/or a first base station storing mapping of the configured uplink grant configuration identifier and the configuration wherein the first base station comprises the first cell.

[0393] The releasing the RRC connection may comprise releasing the RRC connection based on at least one of: the at least one RRC message indicating a release of an RRC connection; and detecting a failure to resume an suspended/suspending RRC connection.

[0394] The one or more RRC message may comprise a resume identity based on at least one of: suspending the RRC connection; releasing the suspended/suspending RRC connection; or the first base station storing mapping of the resume identity and the configuration.

[0395] The suspending the RRC connection may comprise suspending the RRC connection based on suspend configuration wherein the at least one configured uplink grant comprises the suspend configuration.

[0396] The wireless device may send an RRC resume request message requesting to resume the suspended/suspending RRC connection.

[0397] The detecting the failure may comprise detecting the failure in response to the sending the RRC resume request message.

[0398] The suspend configuration may comprise the resume identity.

[0399] A wireless device may select a second cell. The wireless device may initiate an RRC procedure to establish or resume an RRC connection via the second cell. Based on the initiating, the wireless device may determine to release one or more configurations of at least one preconfigured uplink resource (configured uplink grant) of a first cell. Based on the determining, the wireless device may send one or more RRC messages indicating releasing the one or more configurations.

[0400] The second cell may be different from the first cell.

[0401] The wireless device may receive at least one first radio resource control (RRC) message comprising the one or more configurations.

[0402] The RRC procedure may comprise an RRC connection establishment procedure.

[0403] From a wireless device, a base station central unit may receive one or more a radio resource control (RRC) messages indicating releasing of at least one preconfigured uplink resource (configured uplink grant) of a first cell. The base station central unit may send a

message to a base station distributed unit where the message may indicate the releasing of the at least one configured uplink grant of the first cell where the message comprise at least one of: configured uplink grant RNTI; and a cell identity of the first cell.

[0404] The message comprises at least one of: a configured uplink grant configuration identity; or a resume identity.

[0405] The one or more RRC messages comprise at least one of: a cell identity of the first cell; a configured uplink grant configuration identity (configured uplink grant configuration identifier); and/or the resume identity.

[0406] A wireless device may send a first message requesting preconfigured uplink resource (configured uplink grant) configuration of a first cell to a base station via a second cell. From the base station, the wireless device may receive at least one first RRC message comprising configuration of at least one configured uplink grant of the first cell.

[0407] The wireless device may send one or more uplink packets based on the at least one configured uplink grant.

[0408] The second cell may be different from the first cell.

CLAIMS

1. A method comprising:

transmitting, by a wireless device to a first base station, a configured uplink grant configuration request;

receiving, by the wireless device via a first cell of the first base station, a first radio resource control, RRC, release message comprising a plurality of configured uplink grant configurations for data transmission while the wireless device is in an RRC inactive state or an RRC idle state, wherein the plurality of configured uplink grant configurations correspond to a plurality of configured uplink grant configuration identifiers;

transitioning, by the wireless device and based on the first RRC release message, to the RRC inactive state or an RRC idle state;

communicating, by the wireless device, while in the RRC inactive state or the RRC idle state, with the first base station via the first cell, based on a first configured uplink grant configuration of the plurality of configured uplink grant configurations;

selecting, by the wireless device while in the RRC inactive state or the RRC idle state, a second cell of a second base station;

transmitting, by the wireless device to the second base station and based on the selecting the second cell, a second RRC message indicating:

a first cell identifier of the first cell;

a first configured uplink grant configuration identifier of the first configured uplink grant configuration; and

a release indication for the first configured uplink grant configuration;

releasing, by the wireless device, the first configured uplink grant configuration.

2. The method of claim 1, wherein the first configured uplink grant configuration identifier comprises at least one of:

an identity of the configured uplink grant configuration of the first configured uplink grant;

a radio network temporary identifier, RNTI, of the first configured uplink grant;

a resume identity of the wireless device; and

a serving temporary mobile subscribe identity, S-TMSI, of the wireless device.

3. The method of any of claims 1 to 2, wherein the first configured uplink grant configuration further comprises:

radio resource information of the first configured uplink grant;

- a start time of the first configured uplink grant; and
periodicity of the first configured uplink grant.
4. The method of any of claims 1 to 3, wherein the first cell identifier of the first cell comprises at least one of:
a physical cell identity of the first cell; and
a global cell identity of the first cell.
5. A method comprising:
receiving, by a wireless device via a first cell of a first base station, a first radio resource control, RRC, release message comprising one or more configured uplink grant configurations for data transmission in an RRC inactive state or an RRC idle state, wherein the one or more configured uplink grant configurations correspond to one or more configured uplink grant configuration identifiers; and
communicating, by the wireless device, while in the RRC inactive state or the RRC idle state, with the first base station, based on a first configured uplink grant configuration of the one or more configured grant configurations;
selecting, by the wireless device while in the RRC inactive state or the RRC idle state, a second cell;
transmitting, by the wireless device via the second cell, a second RRC message indicating:
a first cell identifier of the first cell;
a first configured uplink grant configuration identifier of the first configured uplink grant configuration; and
a release indication for the first configured uplink grant configuration.
6. The method of claim 5, further comprising transmitting, by the wireless device to the first base station, a configured uplink grant configuration request.
7. The method of any of claims 5 to 6, further comprising transitioning, by the wireless device and based on the first RRC release message, to the RRC inactive state or an RRC idle state.
8. The method of any of claims 5 to 7, wherein the first configured uplink grant configuration identifier comprises at least one of:
an identity of the configured uplink grant configuration of the first configured uplink grant;
a radio network temporary identifier, RNTI, of the first configured uplink grant;

a resume identity of the wireless device; and
a serving temporary mobile subscribe identity, S-TMSI, of the wireless device.

9. The method of any of claims 5 to 8, wherein the first configured uplink grant configuration further comprises:

radio resource information of the first configured uplink grant;
a start time of the first configured uplink grant; and
periodicity of the first configured uplink grant.

10. The method of any of claims 5 to 9, wherein the first cell identifier of the first cell comprises at least one of:

a physical cell identity of the first cell; and
a global cell identity of the first cell.

11. A method comprising:

receiving, by a wireless device from a first base station, a first radio resource control, RRC, release message comprising a first configured uplink grant configuration of a first cell for an RRC non-connected state of the wireless device; and
transmitting, by the wireless device via a second cell, a second RRC message comprising a release indication for the first configured uplink grant configuration.

12. The method of claim 11, wherein the RRC non-connected state is an RRC inactive state or an RRC idle state.

13. The method of any of claims 11 to 12, further comprising transmitting, by the wireless device, a configured uplink grant configuration request.

14. The method of any of claims 11 to 13, wherein the first RRC release message is received from the first base station.

15. The method of any of claims 11 to 14, wherein the second cell is of a second base station.

16. The method of any of claims 11 to 15, wherein the first configured uplink grant configuration corresponds to a first configured uplink grant configuration identifier.

17. The method of claim 16, wherein the first configured uplink grant configuration identifier comprises at least one of:

an identity of the configuration of the first configured uplink grant;

a radio network temporary identifier, RNTI, of the first configured uplink grant;
a resume identity of the wireless device; and
a serving temporary mobile subscribe identity, S-TMSI, of the wireless device.

18. The method of any of claims 11 to 17, wherein the configuration of the first configured uplink grant comprises at least one of:

a physical cell identity of the first cell; and
a global cell identity of the first cell.

19. The method of any of claims 11 to 18, wherein the first RRC release message comprises a plurality of configured uplink grant configurations corresponding to a plurality of configured uplink grant configuration identifiers.

20. The method of any of claims 11 to 19, wherein the first configured uplink grant configuration is one of the plurality of configured uplink grant configurations.

21. The method of any of claims 11 to 20, wherein the first configured uplink grant configuration is for data transmission, by the wireless device in the RRC non-connected state, via the first cell.

22. The method of any of claims 11 to 21, wherein the first configured uplink grant configuration further comprises:

radio resource information of the first configured uplink grant;
a start time of the first configured uplink grant; and
periodicity of the first configured uplink grant.

23. The method of any of claims 11 to 22, wherein the first configured uplink grant configuration configures a configured grant comprising one or more periodic uplink resources for transmission of uplink data by the wireless device.

24. The method of any of claims 11 to 23, further comprising transitioning, by the wireless device and based on the first RRC release message, to the RRC non-connected state.

25. The method of claim 24, wherein the transitioning is based on a suspend configuration received in the first RRC release message.

26. The method of any of claims 11 to 25, further comprising communicating, by the wireless device via the first cell while in the RRC non-connected state, based on the first configured uplink grant configuration.
27. The method of any of claim 26, wherein the communicating in the RRC non-connected state is associated with a small data transmission, SDT, procedure of the wireless device.
28. The method of any of claims 11 to 27, wherein the second cell is different from the first cell.
29. The method of any of claims 11 to 28, wherein the first configured uplink grant configuration for the RRC non-connected state is associated with the small data transmission, SDT, procedure.
30. The method of any of claims 11 to 29, further comprising selecting the second cell, by the wireless device while in the RRC non-connected state, based on a signal quality of the second cell exceeding a threshold.
31. The method of any of claims 11 to 30, wherein the second RRC message indicates a first cell identifier of the first cell.
32. The method of claim 31, wherein the first cell identifier of the first cell comprises at least one of:
- a physical cell identity of the first cell; and
 - a global cell identity of the first cell.
33. The method of any of claims 11 to 32, wherein the second RRC messages comprises at least one of:
- an RRC setup request message;
 - an RRC setup complete message;
 - a configured uplink grant configuration release request message; and
 - a configured uplink grant configuration request message.
34. The method of any of claims 11 to 33, wherein the transmitting the second RRC message is:
- while an RRC connection of the wireless device is suspended; or
 - while the RRC connection of the wireless device is released.

35. The method of claim 34, further comprising releasing the suspended RRC connection based on detecting a failure to resume the suspended RRC connection.
36. The method of any of claims 11 to 35, wherein the one or more second RRC message indicate a first configured uplink grant configuration identifier of the first configured uplink grant configuration.
37. The method of any of claims 11 to 36, further comprising releasing, by the wireless device, the first configured uplink grant configuration.
38. The method of claim 37, wherein the releasing is based on at least one of:
determining to establish or resume an RRC connection via the second cell;
receiving a confirmation indication of the configured uplink grant being released; or
receiving an RRC response message in response to the second RRC message.
39. A wireless device comprising one or more processors and memory storing instructions that, when executed by the one or more processors, cause the wireless device to perform the method of any of claims 1 to 38.
40. A non-transitory computer-readable medium comprising instructions that, when executed by one or more processors, cause the one or more processors to perform the method of any of claims 1 to 38.
41. A method comprising:
transmitting, by a first base station to a wireless device, a first radio resource control, RRC, release message comprising a first configured uplink grant configured uplink grant configuration of a first cell for an RRC non-connected state of the wireless device; and
receiving, by the first base station from a second base station, one or more messages comprising a release indication for the first configured uplink grant configuration of the first cell; and
releasing, based on the one or more messages, the first configured uplink grant configuration.
42. The method of claim 41, further comprising receiving, from the wireless device a configured uplink grant configuration request, wherein the transmitting the first configured uplink grant configuration is based on the receiving.

43. The method of any of claims 41 to 42, wherein the first configured uplink grant configuration corresponds to a first configured uplink grant configuration identifier.
44. The method of claim 43, wherein the first configured uplink grant configuration identifier comprises at least one of:
- an identity of the configuration of the first configured uplink grant;
 - a radio network temporary identifier, RNTI, of the first configured uplink grant;
 - a resume identity of the wireless device; and
 - a serving temporary mobile subscribe identity, S-TMSI, of the wireless device.
45. The method of any of claims 41 to 44, further comprising transitioning, by the first base station and based on the transmitting the first RRC release message, an RRC state of the wireless device to the RRC non-connected state.
46. The method of any of claims 41 to 45, further comprising communicating, by the first base station with the wireless device via the first cell, while the wireless device is in the RRC non-connected state, based on the first configured uplink grant configuration.
47. The method of claim 46, wherein the communicating in the RRC non-connected state is associated with a small data transmission, SDT, procedure of the wireless device.
48. The method of any of claims 41 to 47, wherein the one or more messages comprise a first cell identifier of the first cell.
49. The method of any of claims 41 to 48, wherein the one or more messages comprise a first configured uplink grant configuration identifier of the first configured uplink grant configuration.
50. The method of any of claims 41 to 49, wherein the RRC non-connected state is an RRC inactive state or an RRC idle state.
51. A method comprising:
- receiving, by a second base station from a wireless device via a second cell, a second RRC message comprising a release indication for a first configured uplink grant configuration of a first cell;
 - sending, by the second base station to a first base station associated with the first cell, one or more messages comprising the release indication for the first configured uplink grant configuration of the first cell.

52. The method of claim 51, wherein the second RRC messages comprises at least one of:
- an RRC setup request message;
 - an RRC setup complete message;
 - a configured uplink grant configuration release request message; and
 - a configured uplink grant configuration request message.
53. The method of any of claims 51 to 52, wherein the second RRC message indicates a first configured uplink grant configuration identifier of the first configured uplink grant configuration.
54. The method of any of claims 51 to 53, wherein the second RRC message indicates a first cell identifier of the first cell.
55. The method of claim 54, further comprising determining, based on the first cell identifier, that the first base station is associated with the first cell.
56. The method of claim 55, wherein the sending the one or more messages to the first base station is based on the determining that the first base station is associated with the first cell.
57. The method of any of claims 51 to 56, wherein the sending the one or more messages to the first base station is based on the second RRC message comprising the release indication.
58. A base station comprising one or more processors and memory storing instructions that, when executed by the one or more processors, cause the base station to perform the method of any of claims 41 to 57.
59. A non-transitory computer-readable medium comprising instructions that, when executed by one or more processors, cause the one or more processors to perform the method of any of claims 41 to 57.
60. A system, comprising:
- a wireless device comprising: one or more processors and memory storing instructions that, when executed by the one or more processors, cause the wireless device to:
 - receive, from a first base station, a first radio resource control, RRC, release message comprising a first configured uplink grant configuration of a first cell for an RRC non-connected state of the wireless device;

transmit, via a second cell to a second base station, a second RRC message comprising a release indication for the first configured uplink grant configuration; the first base station, wherein the first base station comprises: one or more processors and memory storing instructions that, when executed by the one or more processors, cause the first base station to:

transmit the first RRC release message;

receive, from a second base station, one or more messages comprising a release indication for the first configured uplink grant configuration; and

release, based on the one or more RRC messages, the first configured uplink grant configuration; and

the second base station, wherein the second base station comprises: one or more processors and memory storing instructions that, when executed by the one or more processors, cause the second base station to:

receive, from the wireless device via the second cell, the second RRC message comprising the release indication for the first configured uplink grant configuration of the first cell; and

send, to the first base station, the one or more messages comprising the release indication for the first configured uplink grant configuration.

61. A method comprising:

receiving, by a base station central unit, BS-CU, from a base station distributed unit, BS-DU, associated with a first cell, a first configured uplink grant configuration of a first cell for an RRC non-connected state of a wireless device;

transmitting, by the BS-CU to the wireless device, a first radio resource control, RRC, release message comprising the first configured uplink grant configuration of the first cell;

receiving, by the BS-CU from the wireless device via a second cell, a second RRC message comprising a release indication for the first configured uplink grant configuration of the first cell; and

sending, to the BS-DU, a message indicating release of the first configured uplink grant configuration.

62. The method of claim 61, wherein:

the second cell is associated with the BS-DU; or

the BS-DU is a first BS-DU and the second cell is associated with a second BS-DU different from the first BS-DU.

63. The method of any of claims 61 to 62, wherein the second RRC message comprises a first configured uplink grant configuration identifier of the first configured uplink grant configuration.
64. The method of any of claims 61 to 63, wherein the second RRC message indicates a first cell identifier of the first cell.
65. The method of claim 64, further comprising determining, based on the first cell identifier, that the BS-DU is associated with the first cell.
66. The method of claim 65, wherein the sending the message to the BS-DU is based on the determining that the BS-DU is associated with the first cell.
67. The method of any of claims 61 to 66, wherein the message comprises at least one of:
a first configured uplink grant configuration identifier of the first configured uplink grant configuration; and
a first cell identifier of the first cell.
68. The method of any of claims 61 to 67, wherein the sending the message to the BS-DU is based on the second RRC message comprising the release indication.
69. The method of any of claims 61 to 68, wherein the first configured uplink grant configuration for the RRC non-connected state is associated with a small data transmission, SDT, procedure.
70. The method of any of claims 61 to 69, wherein the RRC non-connected state is an RRC inactive state or an RRC idle state.
71. A method comprising:
transmitting, by a base station central unit, BS-CU, to a wireless device, a first radio resource control, RRC, release message comprising a first configured uplink grant configuration of a first cell for an RRC non-connected state of the wireless device;
receiving, by the BS-CU from the wireless device via a second cell, a second RRC message comprising a release indication for the first configured uplink grant configuration of the first cell; and
sending, to a base station distributed unit, BS-DU, associated with the first cell, a message indicating release of the first configured uplink grant configuration.

72. The method of claim 71, further comprising receiving, by the BS-CU from the BS-DU, the first configured uplink grant configuration of the first cell.
73. The method of claim 72, wherein the receiving the first configured uplink grant configuration of the first cell is before the transmitting the first RRC release message to the wireless device.
74. The method of any of claims 71 to 73, wherein the message comprises a first configured uplink grant configuration identifier of the first configured uplink grant configuration .
75. The method of any of claims 71 to 74, wherein the message comprises a first cell identifier of the first cell.
76. The method of any of claims 71 to 75, wherein the second cell is associated with the BS-DU.
77. The method of any of claims 71 to 75, wherein the BS-DU is a first BS-DU and the second cell is associated with a second BS-DU different from the first BS-DU.
78. The method of any of claims 71 to 77, wherein the second RRC message comprises at least one of:
- an RRC setup request message;
 - an RRC setup complete message;
 - a configured uplink grant configuration release request message; and
 - a configured uplink grant configuration request message.
79. The method of any of claims 71 to 78, wherein the second RRC message comprises a first configured uplink grant configuration identifier of the first configured uplink grant configuration.
80. The method of claim 79, wherein the first configured uplink grant configuration identifier comprises at least one of:
- an identity of the configuration of the first configured uplink grant;
 - a radio network temporary identifier, RNTI, of the first configured uplink grant;
 - a resume identity of the wireless device; and
 - a serving temporary mobile subscribe identity, S-TMSI, of the wireless device.

81. The method of any of claims 71 to 80, wherein the second RRC message indicates a first cell identifier of the first cell.
82. The method of claim 81, wherein the first cell identifier of the first cell comprises at least one of:
- a physical cell identity of the first cell; and
 - a global cell identity of the first cell.
83. The method of claim 82, further comprising determining, based on the first cell identifier, that the BS-DU is associated with the first cell.
84. The method of claim 83, wherein the sending the message to the BS-DU is based on the determining that the BS-DU is associated with the first cell.
85. The method of any of claims 71 to 84, wherein the sending the message to the BS-DU is based on the second RRC message comprising the release indication.
86. The method of any of claims 71 to 85, wherein the second cell is different from the first cell.
87. The method of any of claims 71 to 86, wherein the first configured uplink grant configuration for the RRC non-connected state is associated with a small data transmission, SDT, procedure.
88. The method of any of claims 71 to 87, wherein the RRC non-connected state is an RRC inactive state or an RRC idle state.
89. A base station central unit comprising one or more processors and memory storing instructions that, when executed by the one or more processors, cause the base station central unit to perform the method of any of claims 61 to 88.
90. A non-transitory computer-readable medium comprising instructions that, when executed by one or more processors, cause the one or more processors to perform the method of any of claims 61 to 88.
91. A method comprising:
- transmitting, by a base station distributed unit, BS-DU, to a base station central unit, BS-CU, a first configured uplink grant configuration of a first cell for an RRC non-connected state of a wireless device;

receiving, from the BS-CU, a message indicating release of the first configured uplink grant configuration; and

releasing, by the BS-DU and based on the message, the first configured uplink grant configuration of the first cell.

92. The method of claim 91, further comprising receiving, by the BS-DU from the wireless device, a configured uplink grant configuration request, wherein the transmitting the first configured uplink grant configuration to the BS-CU is based on the receiving.

93. The method of claim 92, further comprising determining, by the BS-DU based on the configured uplink grant configuration request, the first configured uplink grant configuration of the first cell, wherein the transmitting the first configured uplink grant configuration is based on the determining.

94. The method of any of claims 91 to 93, further comprising transmitting, by the BS-DU to the BS-CU, a plurality of configured uplink grant configurations corresponding to a plurality of configured uplink grant configuration identifiers.

95. The method of claim 94, wherein the first configured uplink grant configuration is one of the plurality of configured uplink grant configurations.

96. The method of any of claims 91 to 95, wherein the first configured uplink grant configuration is for data transmission, by the wireless device in the RRC non-connected state, via the first cell.

97. The method of any of claims 91 to 96, wherein the first configured uplink grant configuration further comprises:

radio resource information of the first configured uplink grant;

a start time of the first configured uplink grant; and

periodicity of the first configured uplink grant.

98. The method of any of claims 91 to 97, wherein the first configured uplink grant configuration corresponds to a first configured uplink grant configuration identifier.

99. The method of claim 98, wherein the message indicating release of the first configured uplink grant indicates the first configured uplink grant configuration identifier of the first configured uplink grant configuration.

100. The method of any of claims 98 to 99, wherein the first configured uplink grant configuration identifier comprises at least one of:
- an identity of the configuration of the first configured uplink grant;
 - a radio network temporary identifier, RNTI, of the first configured uplink grant;
 - a resume identity of the wireless device; and
 - a serving temporary mobile subscribe identity, S-TMSI, of the wireless device.
101. The method of any of claims 91 to 100, further comprising communicating, by the BS-DU with the wireless device via the first cell, while the wireless device is in the RRC non-connected state, based on the first configured uplink grant configuration.
102. The method of claim 101, wherein the communicating in the RRC non-connected state is associated with a small data transmission, SDT, procedure of the wireless device.
103. The method of any of claims 91 to 102, wherein the RRC non-connected state is an RRC inactive state or an RRC idle state.
104. The method of any of claims 91 to 103, wherein the message indicating release of the first configured uplink grant configuration indicates a first cell identifier of the first cell.
105. The method of claim 104, wherein the first cell identifier of the first cell comprises a physical cell identity of the first cell
106. The method of any of claims 104 to 105, wherein the first cell identifier of the first cell comprises a physical cell identity of the first cell a global cell identity of the first cell.
107. The method of any of claims 91 to 106, wherein the first configured uplink grant configuration configures a configured grant comprising one or more periodic uplink resources for transmission of uplink data by the wireless device.
108. A base station distributed unit comprising one or more processors and memory storing instructions that, when executed by the one or more processors, cause the base station central unit to perform the method of any of claims 91 to 107.
109. A non-transitory computer-readable medium comprising instructions that, when executed by one or more processors, cause the one or more processors to perform the method of any of claims 91 to 107.
110. A system, comprising:

a base station central unit, BS-CU, comprising: one or more processors and memory storing instructions that, when executed by the one or more processors, cause the BS-CU to:

receive, from a base station distributed unit, BS-DU, associated with the first cell, a first configured uplink grant configuration of the first cell for an RRC non-connected state of a wireless device;

transmit, to a wireless device, a first radio resource control, RRC, release message comprising the first configured uplink grant configuration of the first cell;

receive, from the wireless device via a second cell, a second RRC message comprising a release indication for the first configured uplink grant configuration of the first cell; and

send, to the BS-DU, a message indicating release of the first configured uplink grant configuration; and

the BS-DU, wherein the BS-DU comprises: one or more processors and memory storing instructions that, when executed by the one or more processors, cause the BS-DU to:

transmit, to the BS-CU, the first configured uplink grant configuration of the first cell;

receive, from the BS-CU, the message indicating release of the first configured uplink grant configuration of the first cell; and

release, based on the message, the first configured uplink grant configuration of the first cell.

111. A method comprising:

transmitting, by a wireless device and via a second cell of a base station, a request for a configuration of a configured grant of a first cell;

receiving, from the base station, a radio resource control, RRC, release message comprising the configuration of the configured grant of the first cell; and

transmitting, using the configured grant and via the first cell, one or more uplink packets.

112. The method of claim 111, wherein a cell identity of the first cell is included in at least one of:

the request for the configuration of the configured grant; and

the configuration of the configured grant.

113. The method of any of claims 111 to 112, wherein the cell identity of the first cell comprises at least one of:

- a physical cell identity; or
- a global cell identity.

114. The method of any of claims 111 to 113, wherein the transmitting the request is while:
the second cell is a serving cell of the wireless device; and
the first cell is a non-serving cell of the wireless device.

115. The method of any of claims 111 to 114, wherein the transmitting the request comprises transmitting the request while the wireless device is in an RRC connected state.

116. The method of any of claims 111 to 115, further comprising transitioning, based on the RRC release message, from the RRC connected state to:

- an RRC inactive state; or
- an RRC idle state.

117. The method of claim 116, wherein the transmitting one or more uplink packets comprises transmitting one or more uplink packets while the wireless device is in the RRC inactive state or the RRC idle state.

118. The method of any of claims 116 to 117, wherein the transitioning comprises transitioning after suspending an RRC connection of the wireless device based on a suspend configuration indicating a suspension of an RRC connection.

119. The method of claim 118, wherein the RRC release message further comprises the suspend configuration.

120. The method of any of claims 118 to 119, wherein the suspend configuration comprises a next hop chaining count, NCC, value.

121. The method of claim 120, further comprising deriving, based on the NCC value, a security key of the wireless device.

122. The method of claim 121, wherein the transmitting the one or more uplink packets comprises transmitting the one or more uplink packets using the security key.

123. The method of any of claims 121 to 122, wherein based on the security key, the one or more uplink packets are at least one of:

integrity protected uplink packets; and
ciphered uplink packets.

124. The method of any of claims 111 to 123, wherein the configuration of the configured grant comprises:

an identity of the configuration;
a radio network temporary identifier (RNTI) of the configured grant;
radio resource information of the configured grant;
start time of the configured grant;
periodicity of the configured grant; and
duration of a configured grant window.

125. The method of claim 124, further comprising starting, based on the transmitting the one or more uplink packets, the configured grant window.

126. The method of any of claims 123 to 124, further comprising monitoring a physical downlink control channel for a response to the one or more uplink packets until the configured grant window being expired.

127. The method of any of claims 124 to 126, wherein radio resource information of the configured grant comprises at least one of:

physical uplink shared channel configuration parameters;
physical downlink control channel configuration parameters;
physical uplink control channel configuration parameters;
downlink carrier configuration parameters; and
uplink carrier configuration parameters.

128. The method of any of claims 111 to 127, wherein the second cell is different from the first cell.

129. A wireless device comprising one or more processors and memory storing instructions that, when executed by the one or more processors, cause the wireless device to perform the method of any of claims 111 to 128.

130. A non-transitory computer-readable medium comprising instructions that, when executed by one or more processors, cause the one or more processors to perform the method of any of claims 111 to 128.

131. A method comprising:

receiving, by a base station from a wireless device via a second cell, a request for a configuration of a configured grant of a first cell;

transmitting, to the wireless device, a radio resource control, RRC, release message comprising the configuration of the configured grant of the first cell.

132. The method of claim 131, wherein a cell identity of the first cell is included in at least one of:

the request for the configuration of the configured grant; and

the configuration of the configured grant.

133. The method of any of claims 131 to 132, wherein the cell identity of the first cell comprises at least one of:

a physical cell identity; or

a global cell identity.

134. The method of any of claims 131 to 133, wherein the receiving the request is while:

the second cell is a serving cell of the wireless device; and

the first cell is a non-serving cell of the wireless device.

135. The method of any of claims 131 to 134, wherein the receiving the request comprises receiving the request while the wireless device is in an RRC connected state.

136. The method of any of claims 131 to 135, further comprising transitioning, by the base station and based on the RRC release message, an RRC state of the wireless device from the RRC connected state to:

an RRC inactive state; or

an RRC idle state.

137. The method of claim 136, wherein the receiving one or more uplink packets comprises receiving one or more uplink packets while the wireless device is in the RRC inactive state or the RRC idle state.

138. The method of any of claims 136 to 137, wherein the transitioning comprises transitioning after suspending an RRC connection of the wireless device based on a suspend configuration indicating a suspension of an RRC connection.

139. The method of claim 138, wherein the RRC release message further comprises the suspend configuration.

140. The method of any of claims 138 to 139, wherein the suspend configuration comprises a next hop chaining count, NCC, value.

141. The method of claim 140, further comprising deriving, based on the NCC value, a security key of the wireless device.

142. The method of claim 141, wherein the receiving the one or more uplink packets comprises transmitting the one or more uplink packets using the security key.

143. The method of any of claims 141 to 142, wherein based on the security key, the one or more uplink packets are at least one of:

- integrity protected uplink packets; and
- ciphered uplink packets.

144. The method of any of claims 131 to 143, wherein the configuration of the configured grant comprises:

- an identity of the configuration;
- a radio network temporary identifier (RNTI) of the configured grant;
- radio resource information of the configured grant;
- start time of the configured grant;
- periodicity of the configured grant; and
- duration of a configured grant window.

145. The method of claim 144, further comprising starting, based on the receiving the one or more uplink packets, the configured grant window.

146. The method of any of claims 144 to 145, wherein radio resource information of the configured grant comprises at least one of:

- physical uplink shared channel configuration parameters;
- physical downlink control channel configuration parameters;
- physical uplink control channel configuration parameters;
- downlink carrier configuration parameters; and
- uplink carrier configuration parameters.

147. The method of any of claims 131 to 146, wherein the second cell is different from the first cell.

148. A base station comprising one or more processors and memory storing instructions that, when executed by the one or more processors, cause the base station to perform the method of any of claims 131 to 147.

149. A non-transitory computer-readable medium comprising instructions that, when executed by one or more processors, cause the one or more processors to perform the method of any of claims 131 to 147.

150. A system, comprising:

a wireless device comprising: one or more processors and memory storing instructions that, when executed by the one or more processors, cause the wireless device to:

transmit, via a second cell of a base station, a request for a configuration of a configured grant of a first cell;

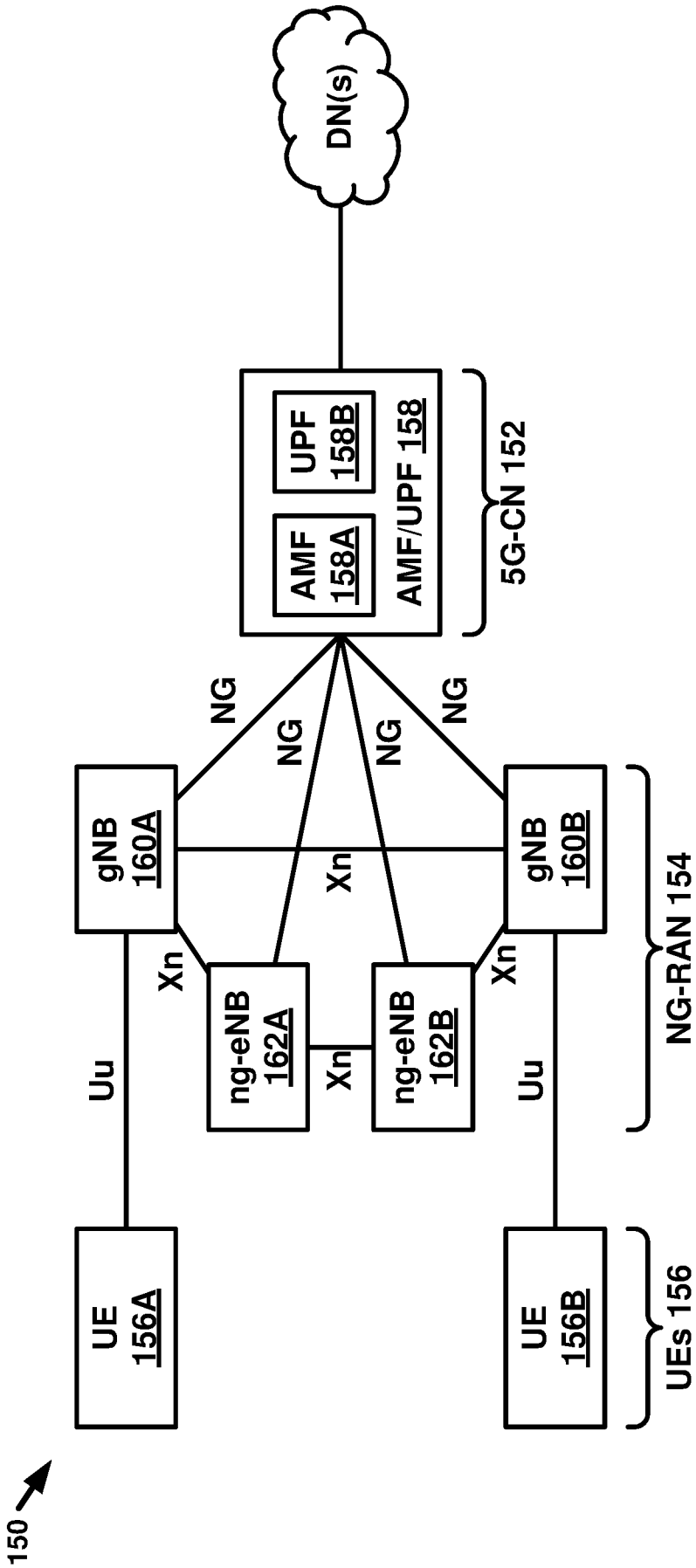
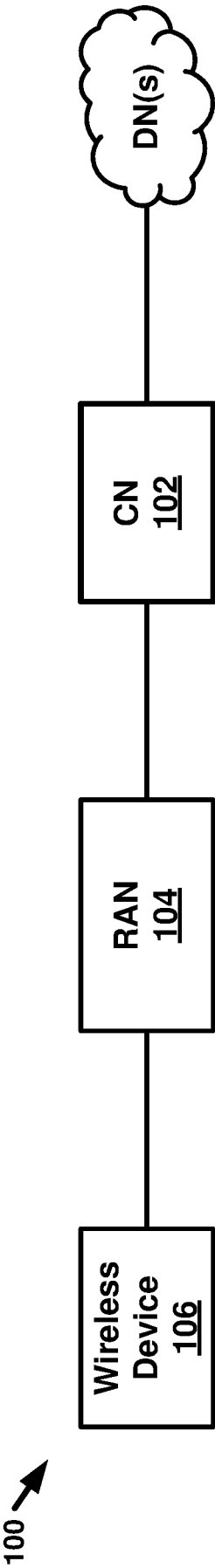
receive, from the base station, a radio resource control, RRC, release message comprising the configuration of the configured grant of the first cell; and

transmit, using the configured grant and via the first cell, one or more uplink packets; and

the base station, wherein the base station comprises: one or more processors and memory storing instructions that, when executed by the one or more processors, cause the base station to:

receive, from the wireless device via the second cell, the request;

transmit, to the wireless device, the RRC release message.



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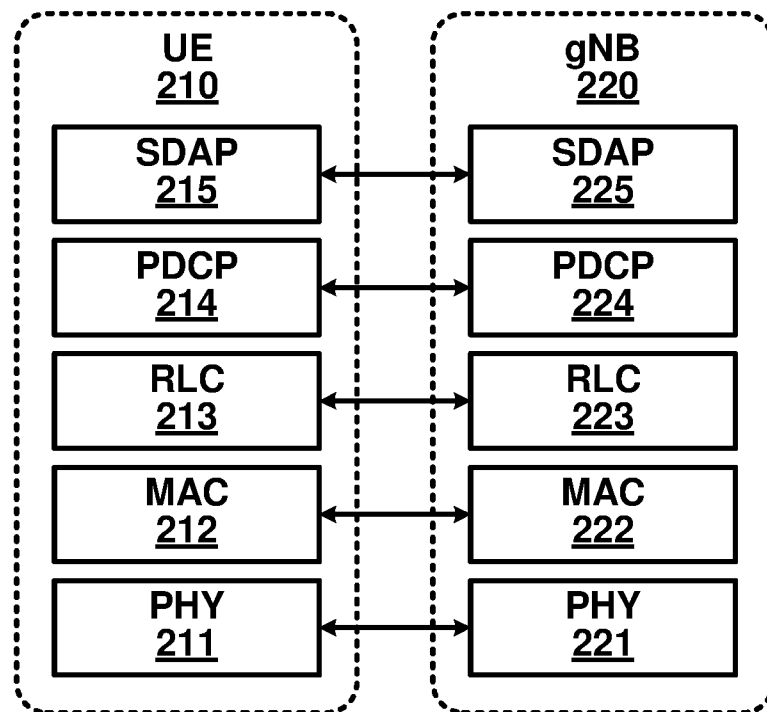


FIG. 2A

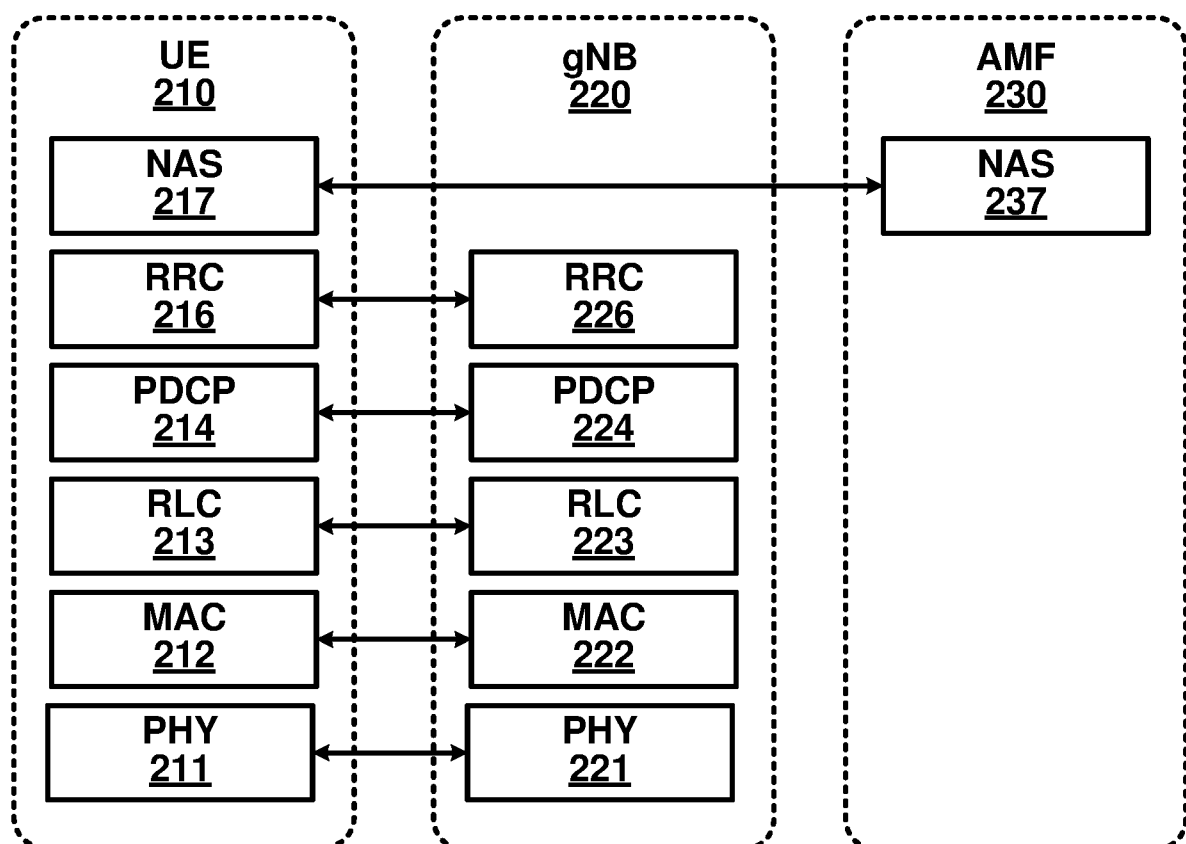


FIG. 2B

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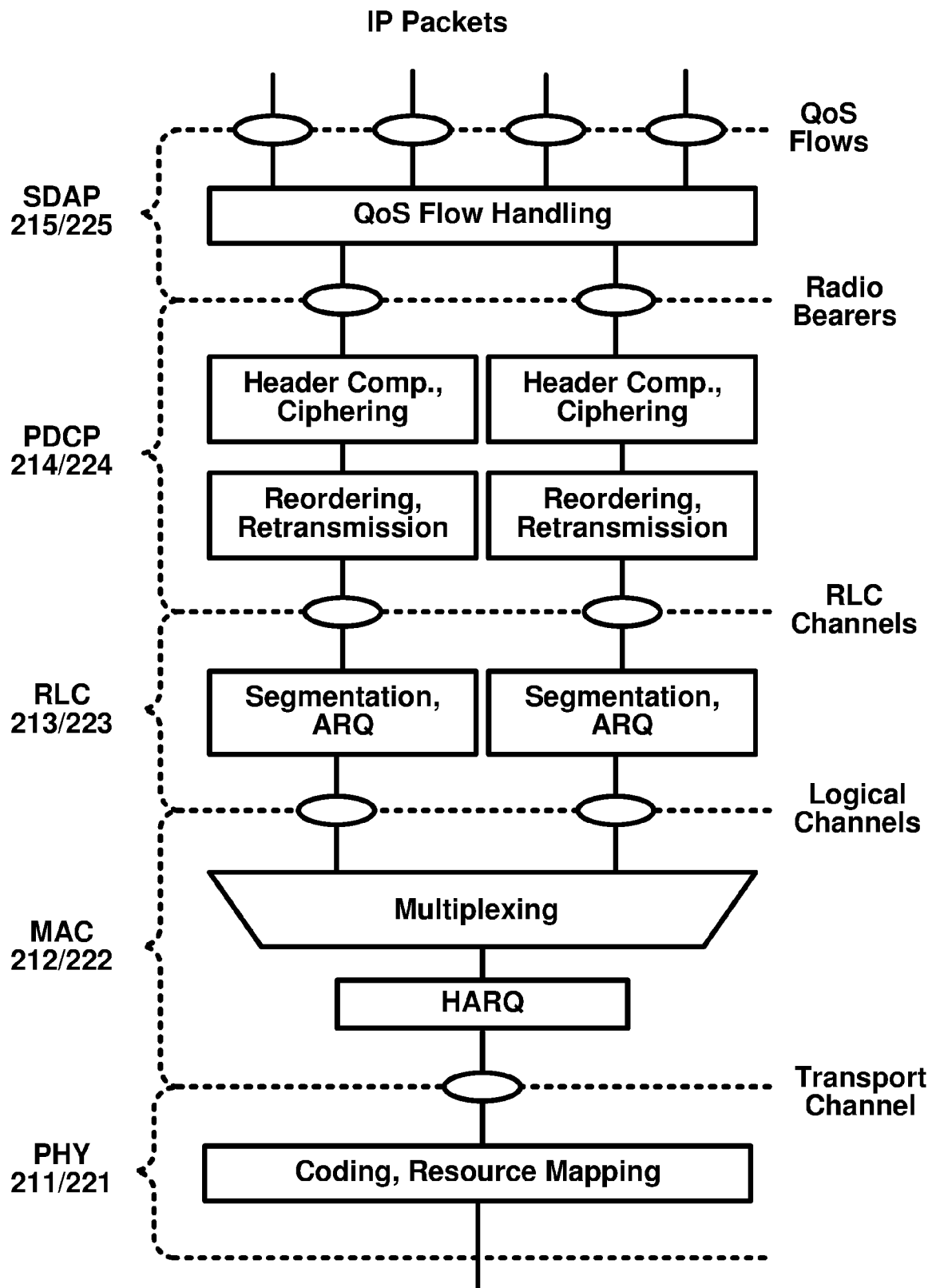


FIG. 3

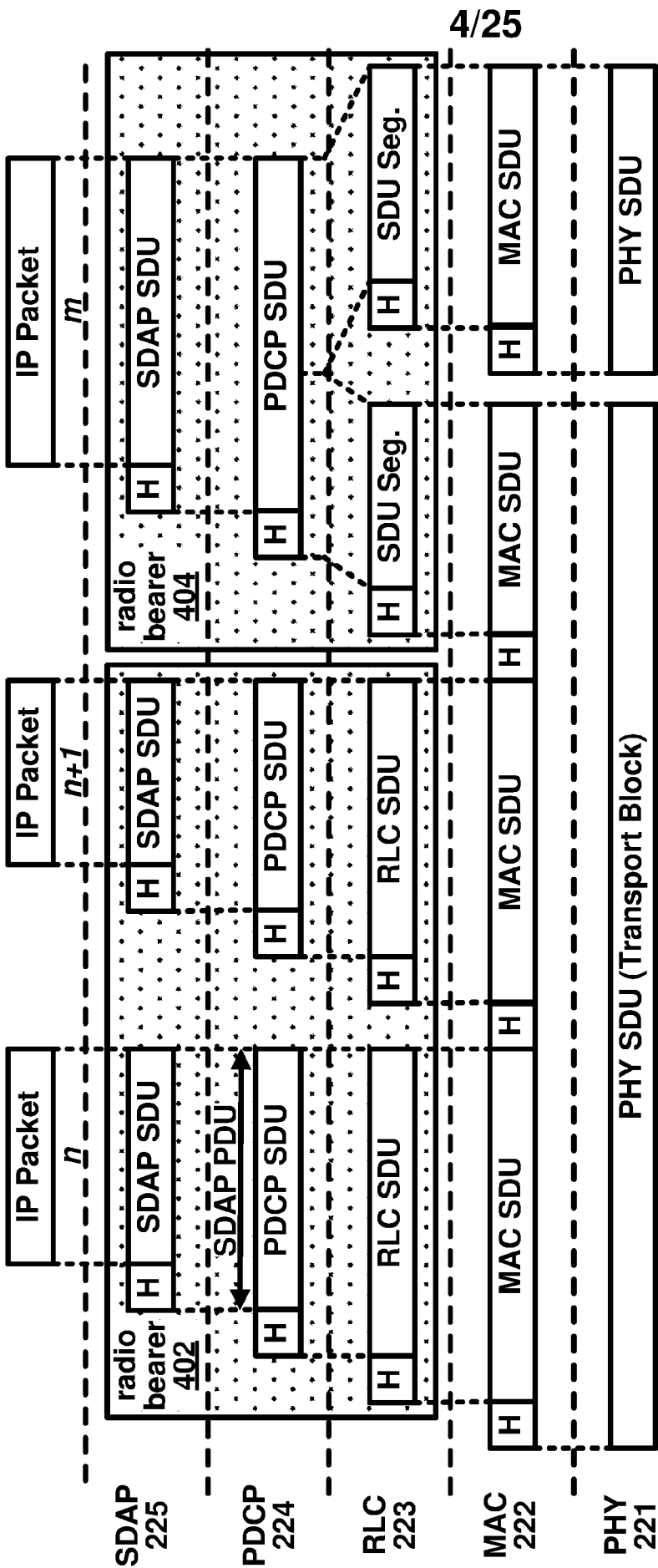


FIG. 4A

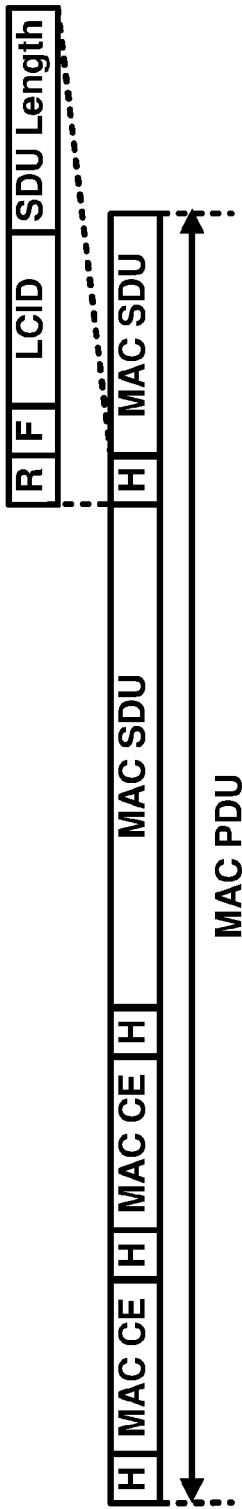


FIG. 4B

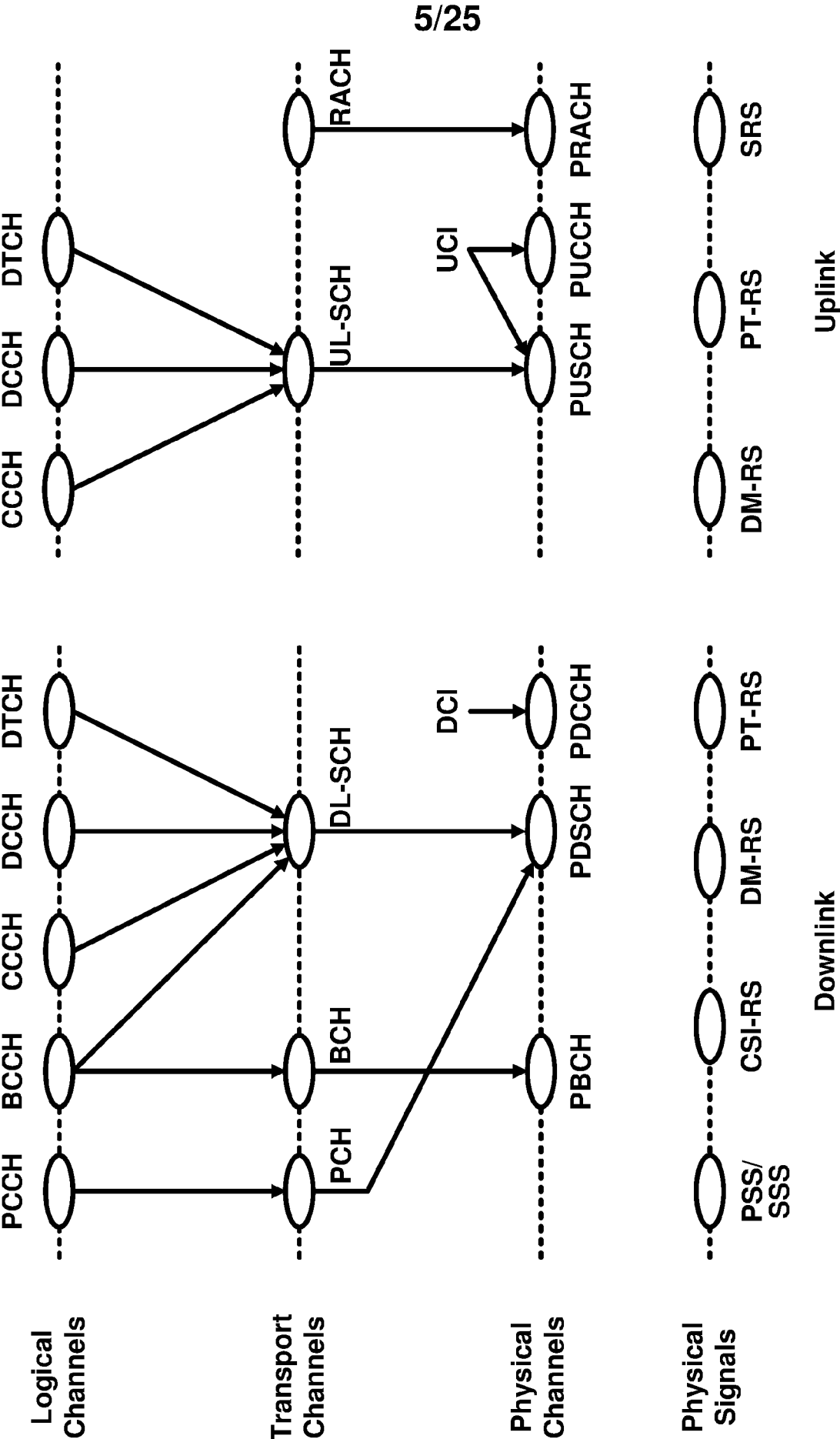


FIG. 5A

FIG. 5B

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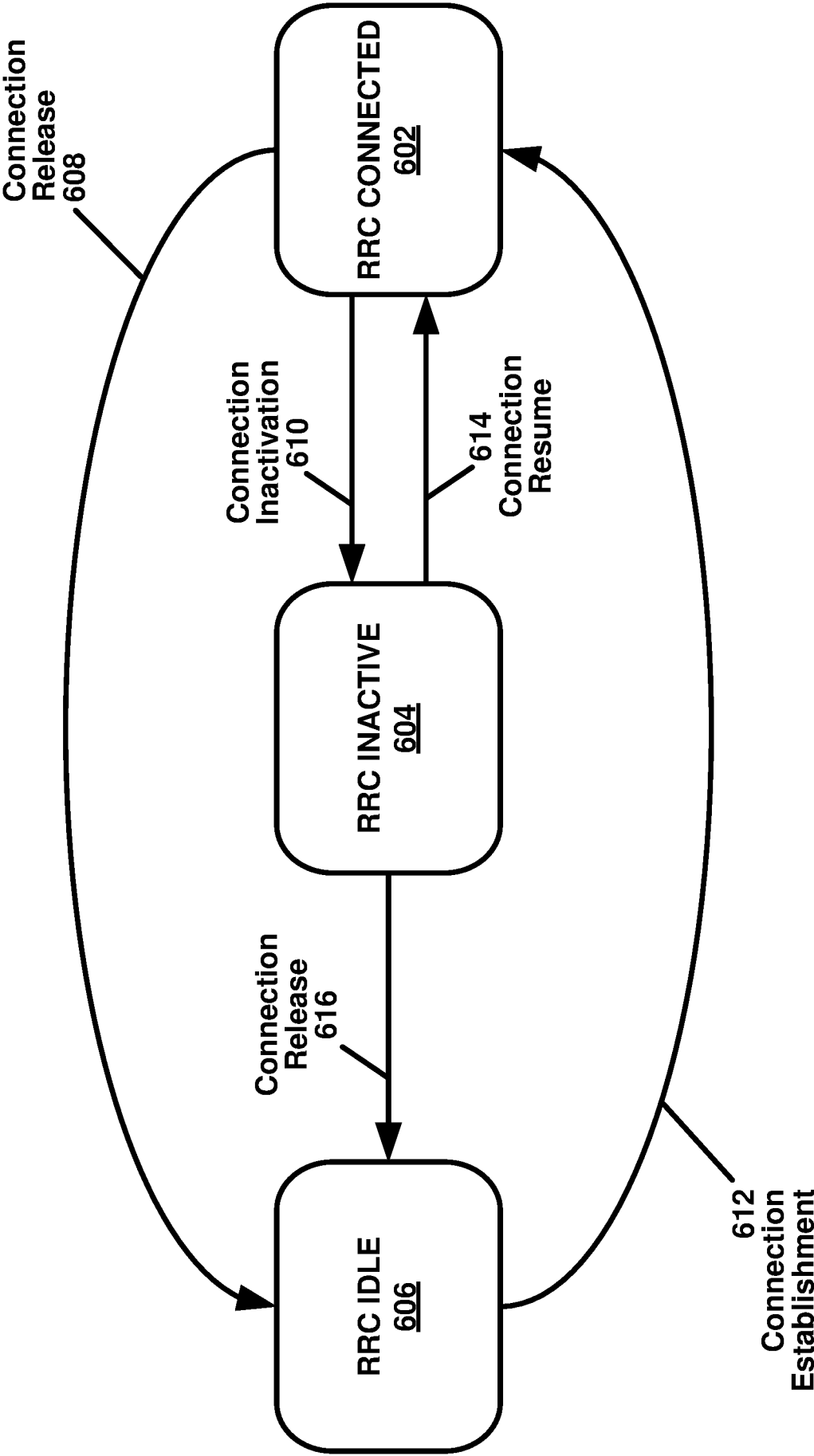


FIG. 6

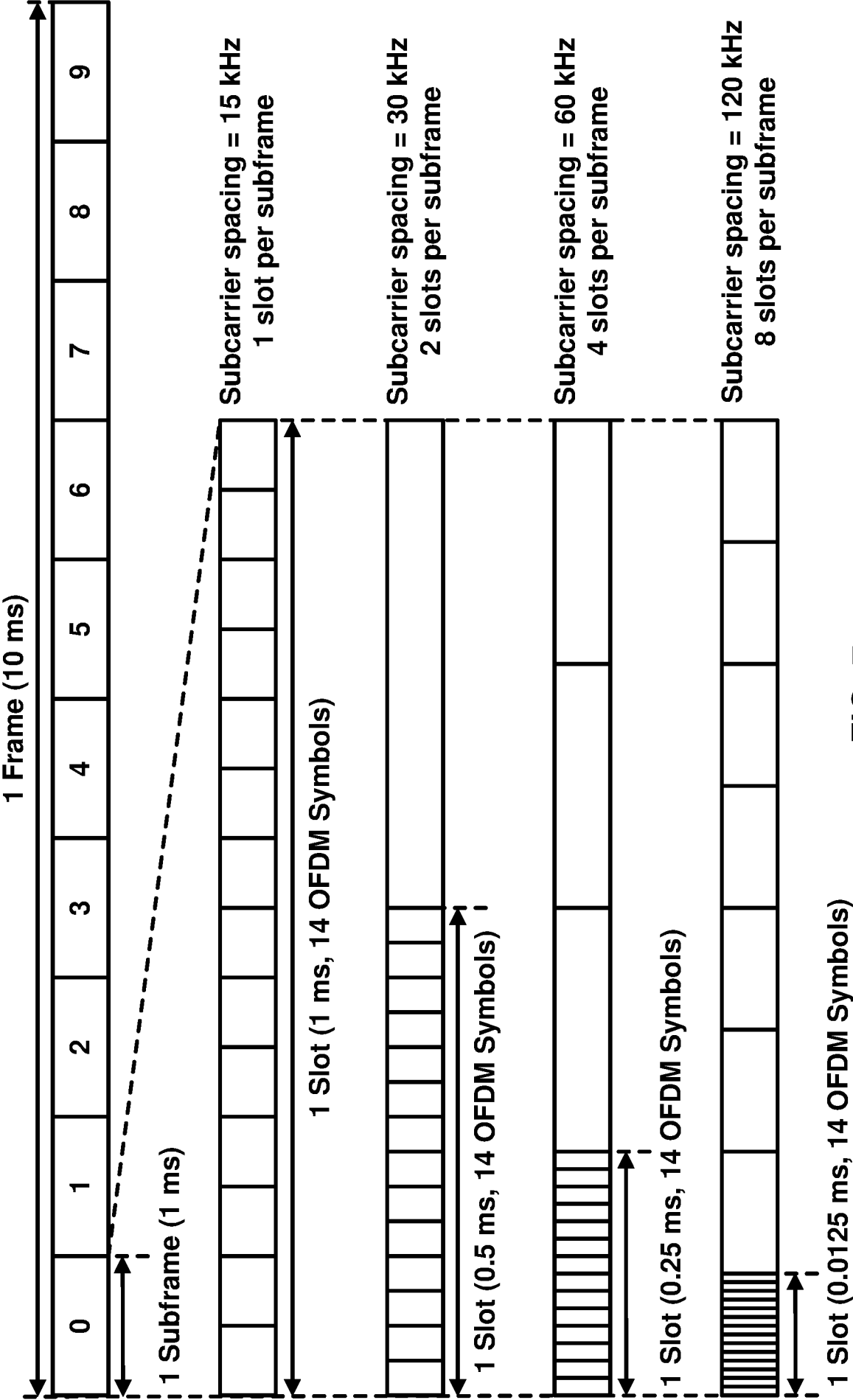


FIG. 7

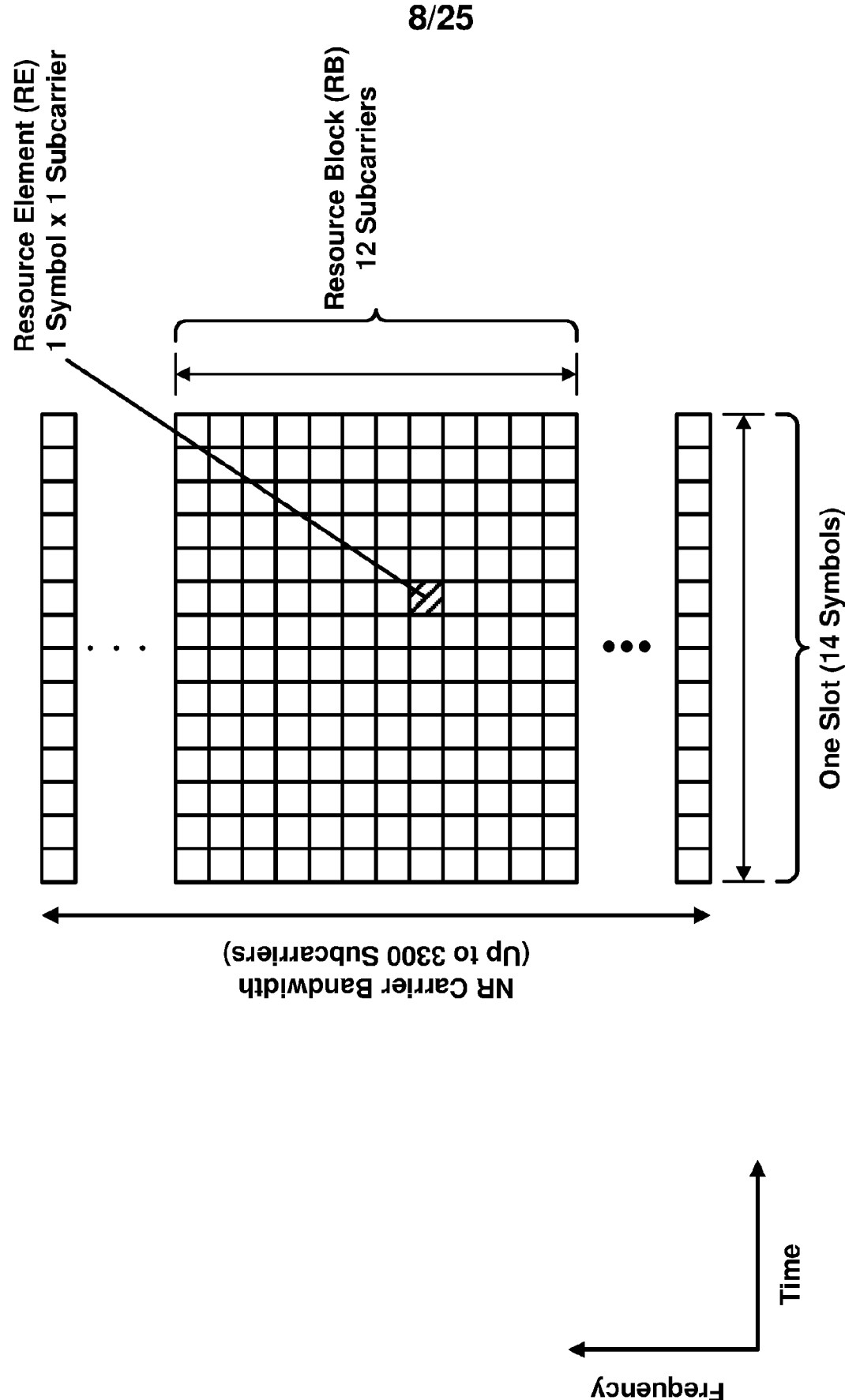


FIG. 8

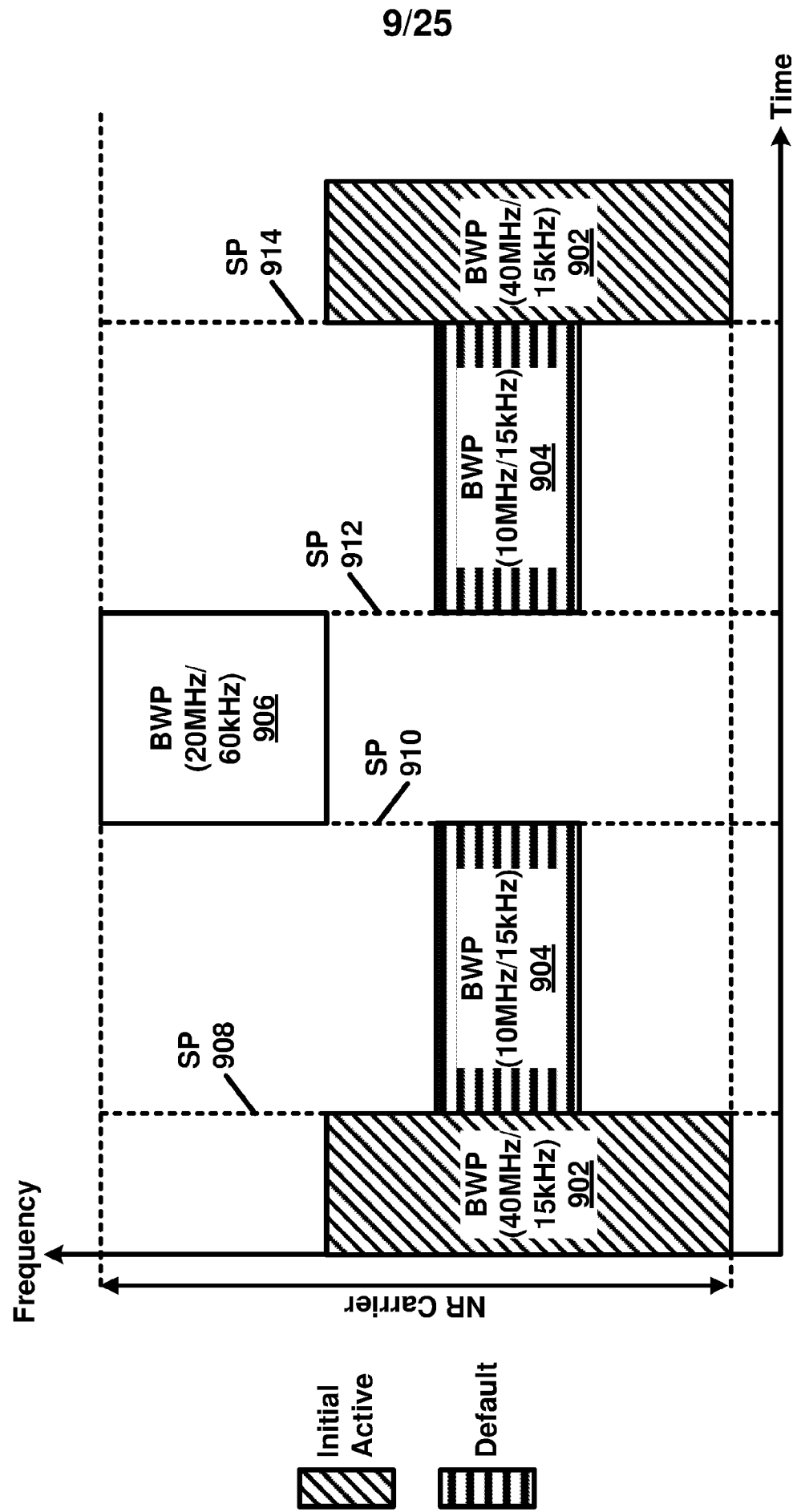
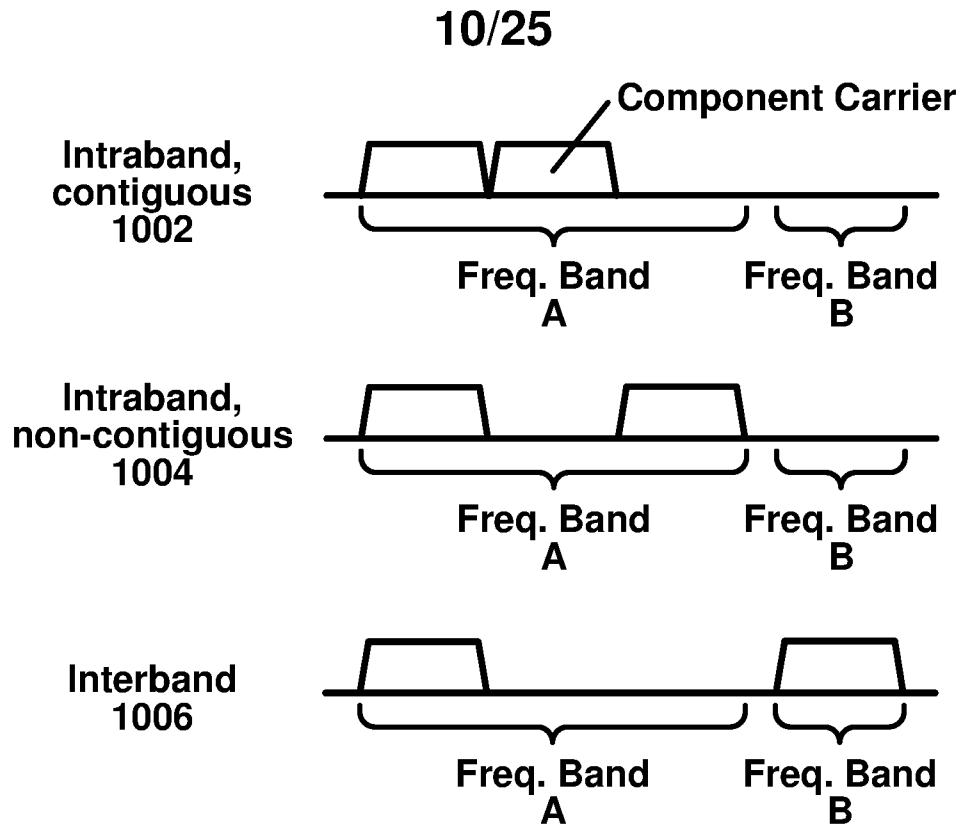
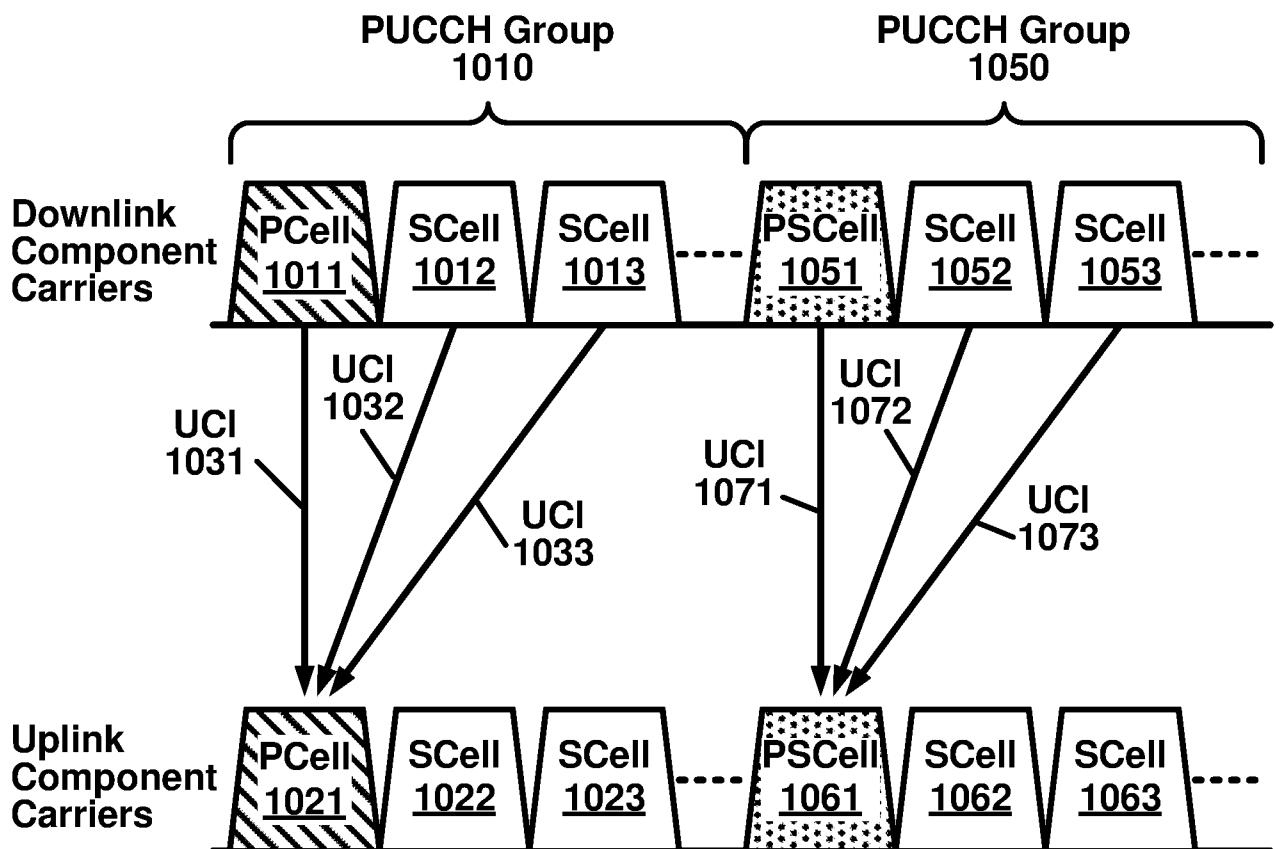


FIG. 9

**FIG. 10A****FIG. 10B**

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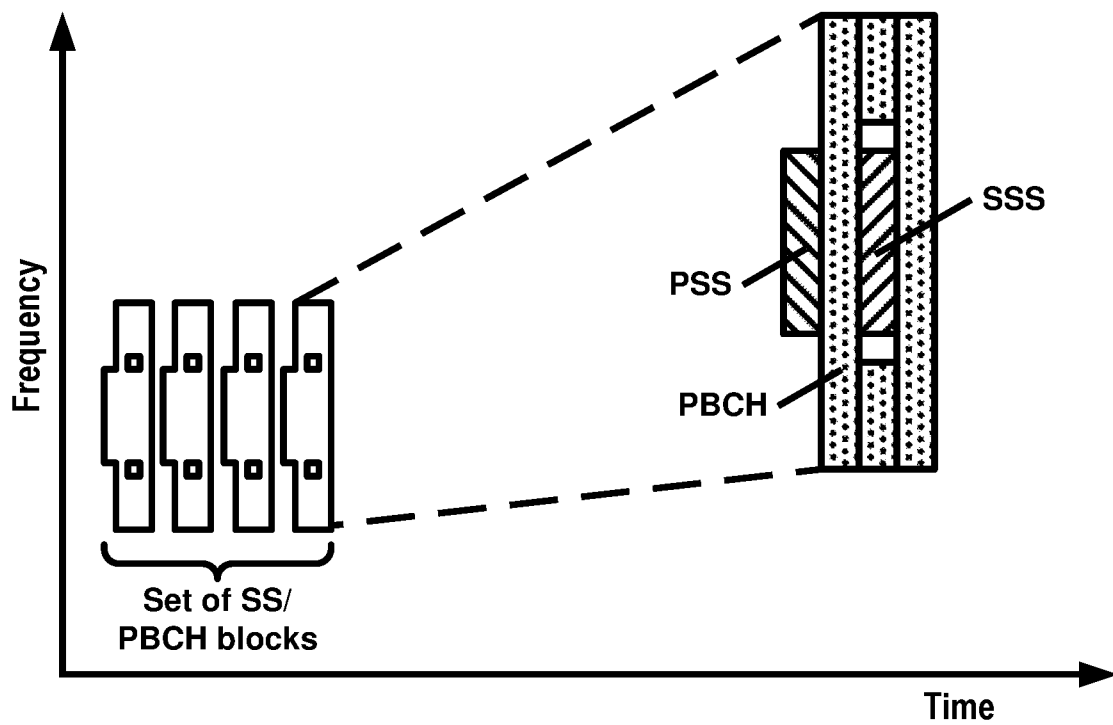


FIG. 11A

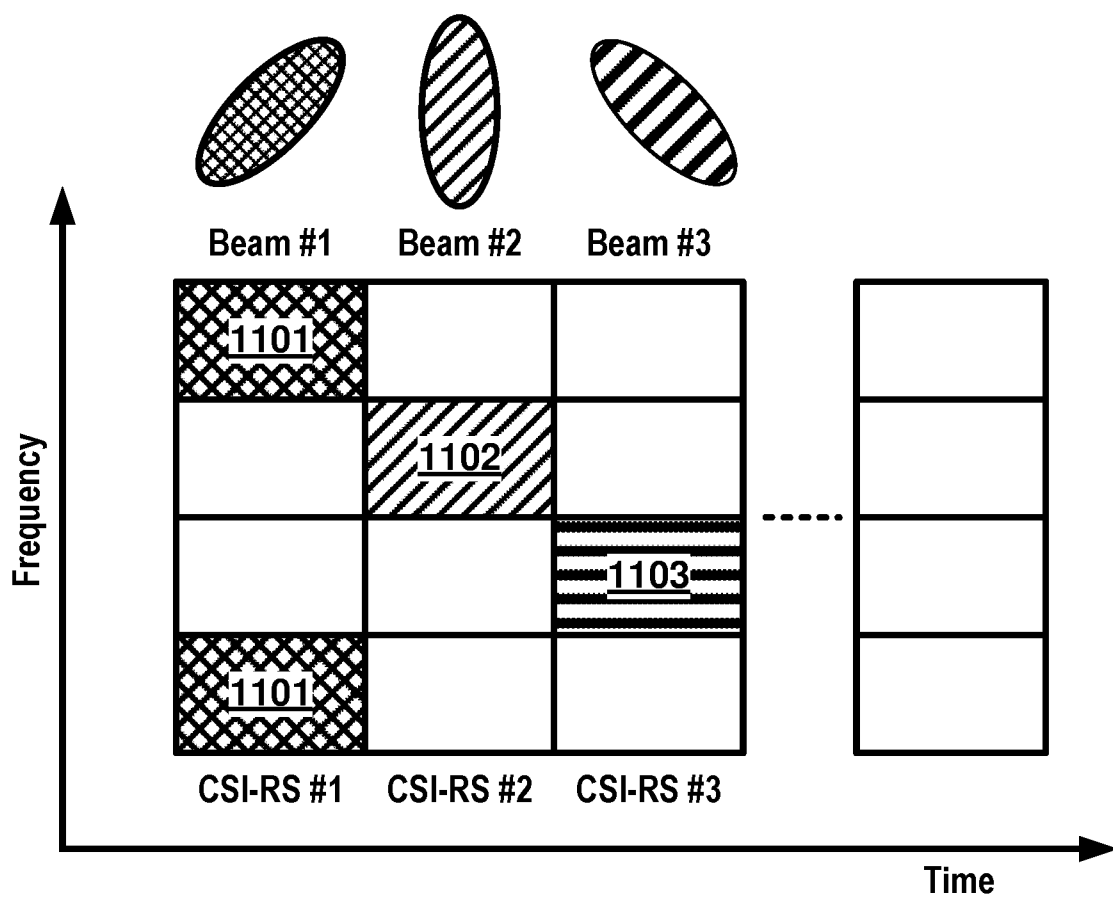


FIG. 11B

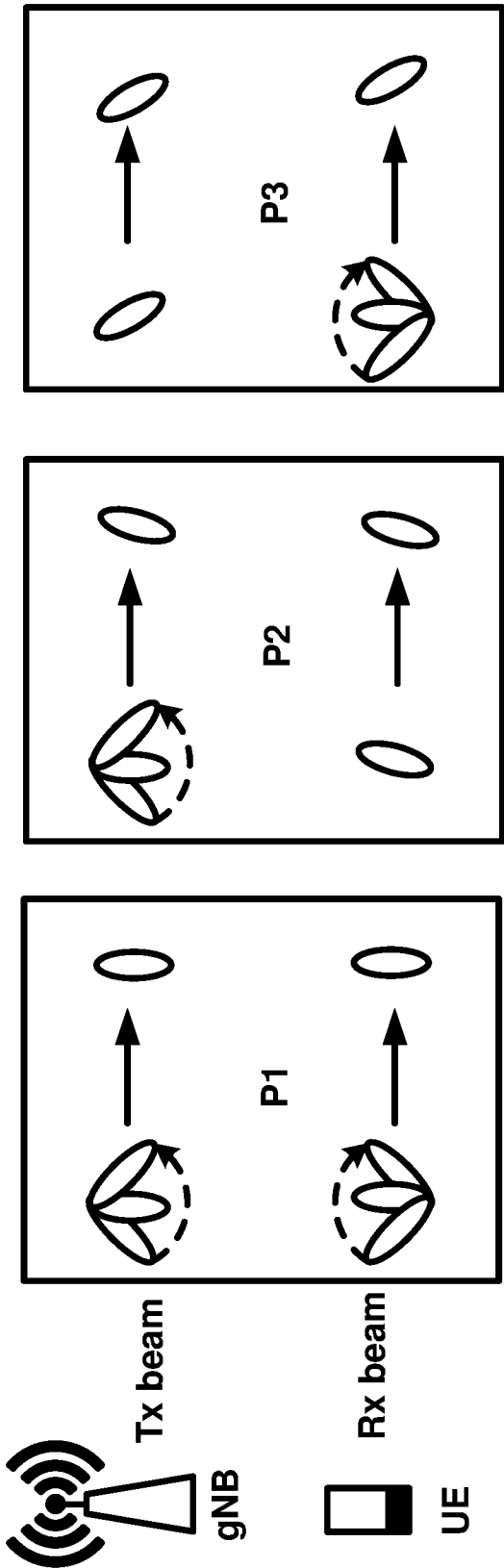


FIG. 12A

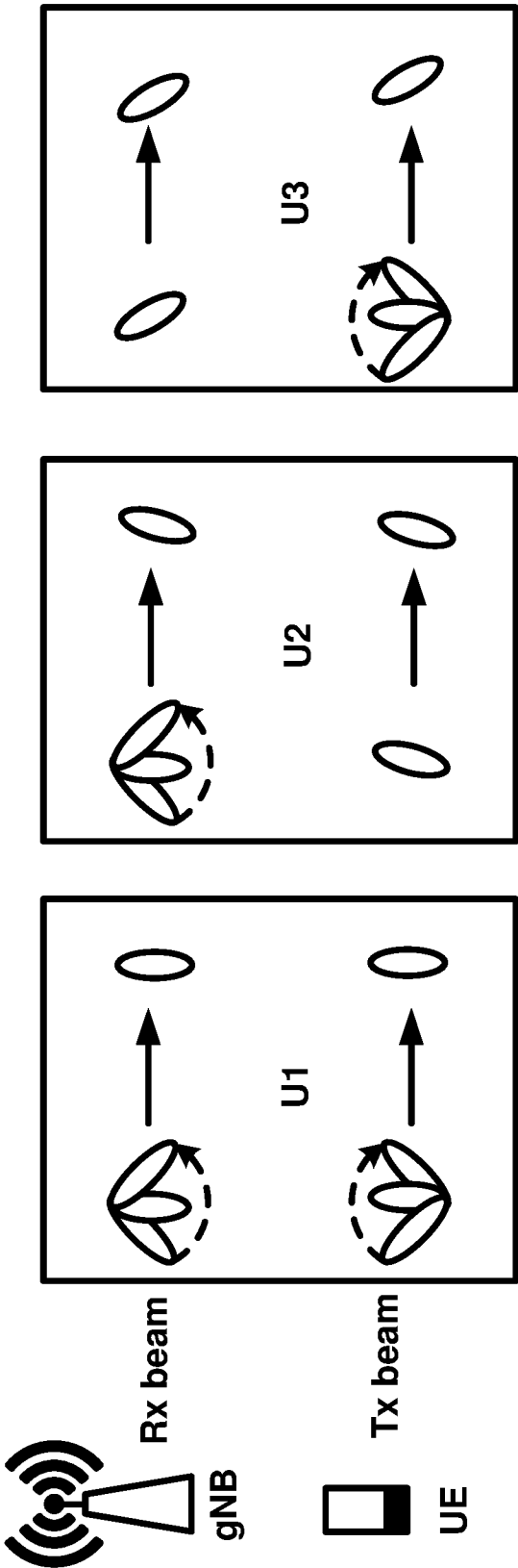


FIG. 12B

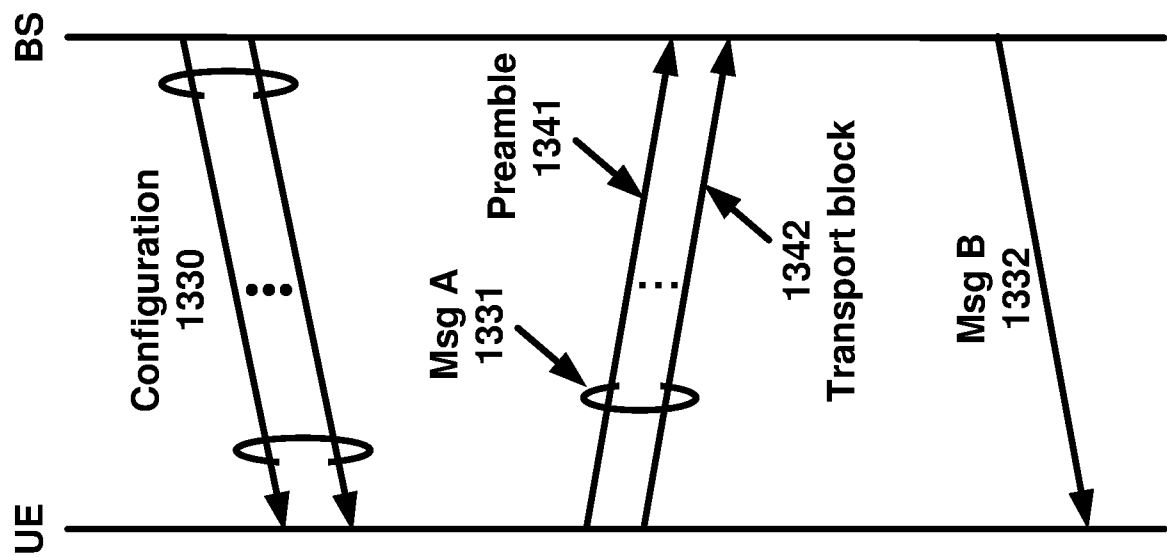


FIG. 13C

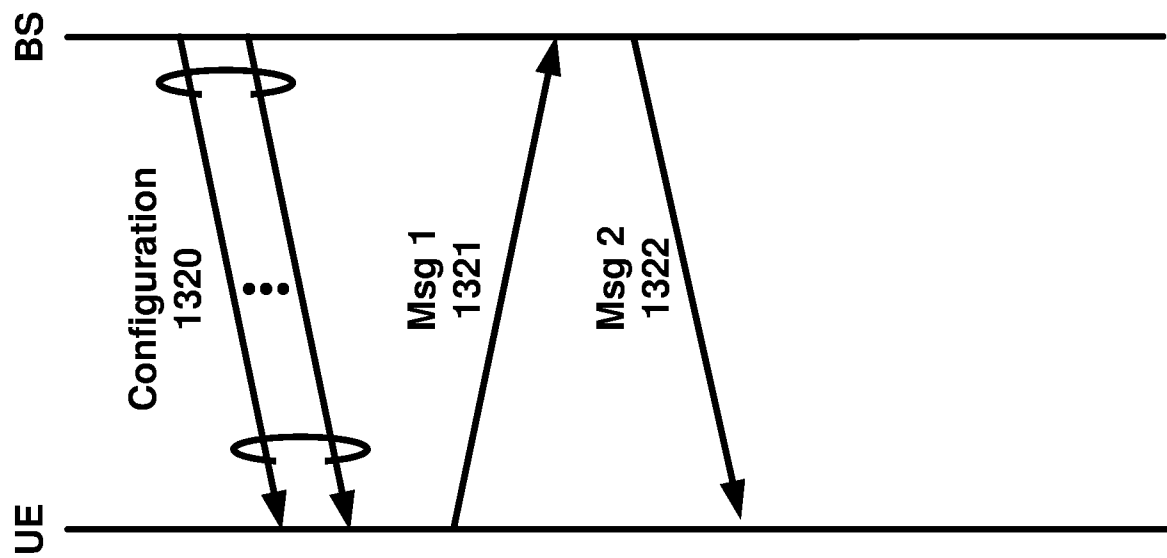


FIG. 13B

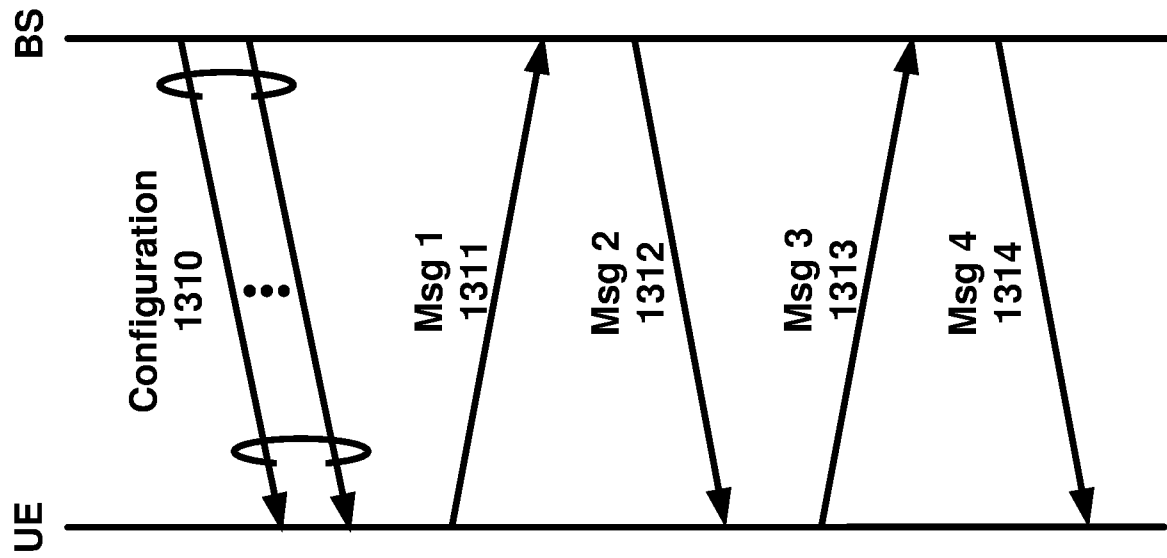


FIG. 13A

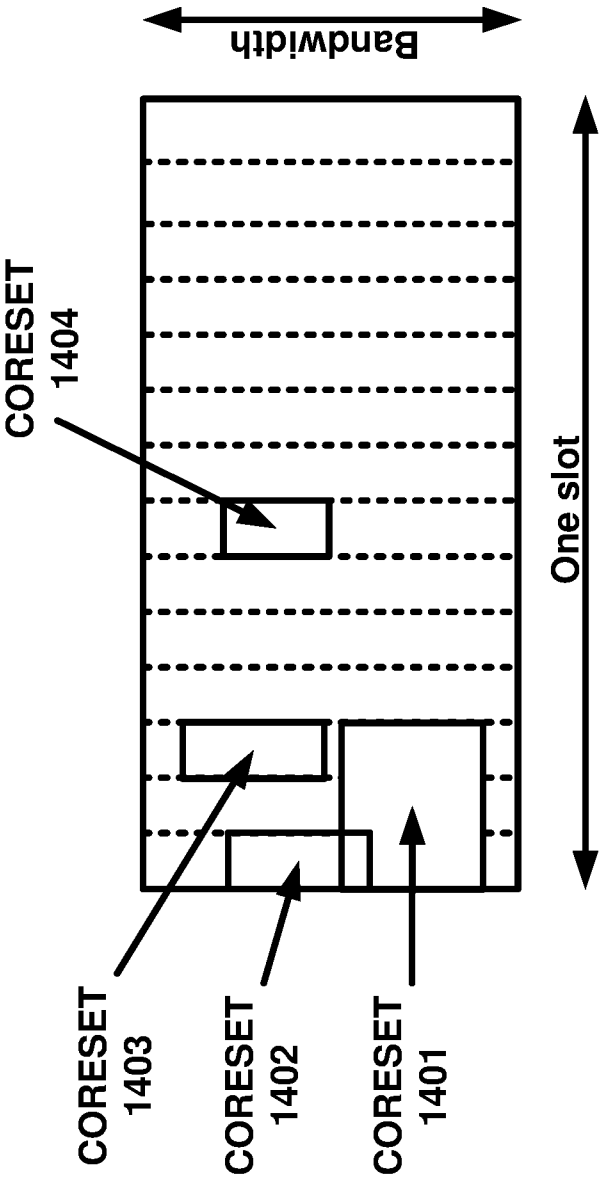


FIG. 14A

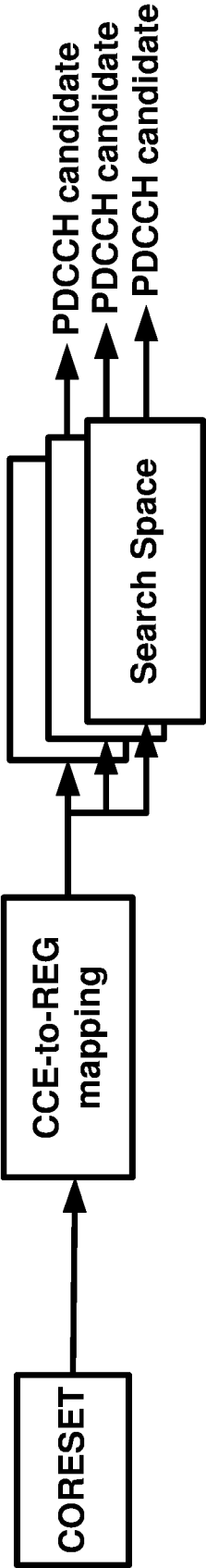


FIG. 14B

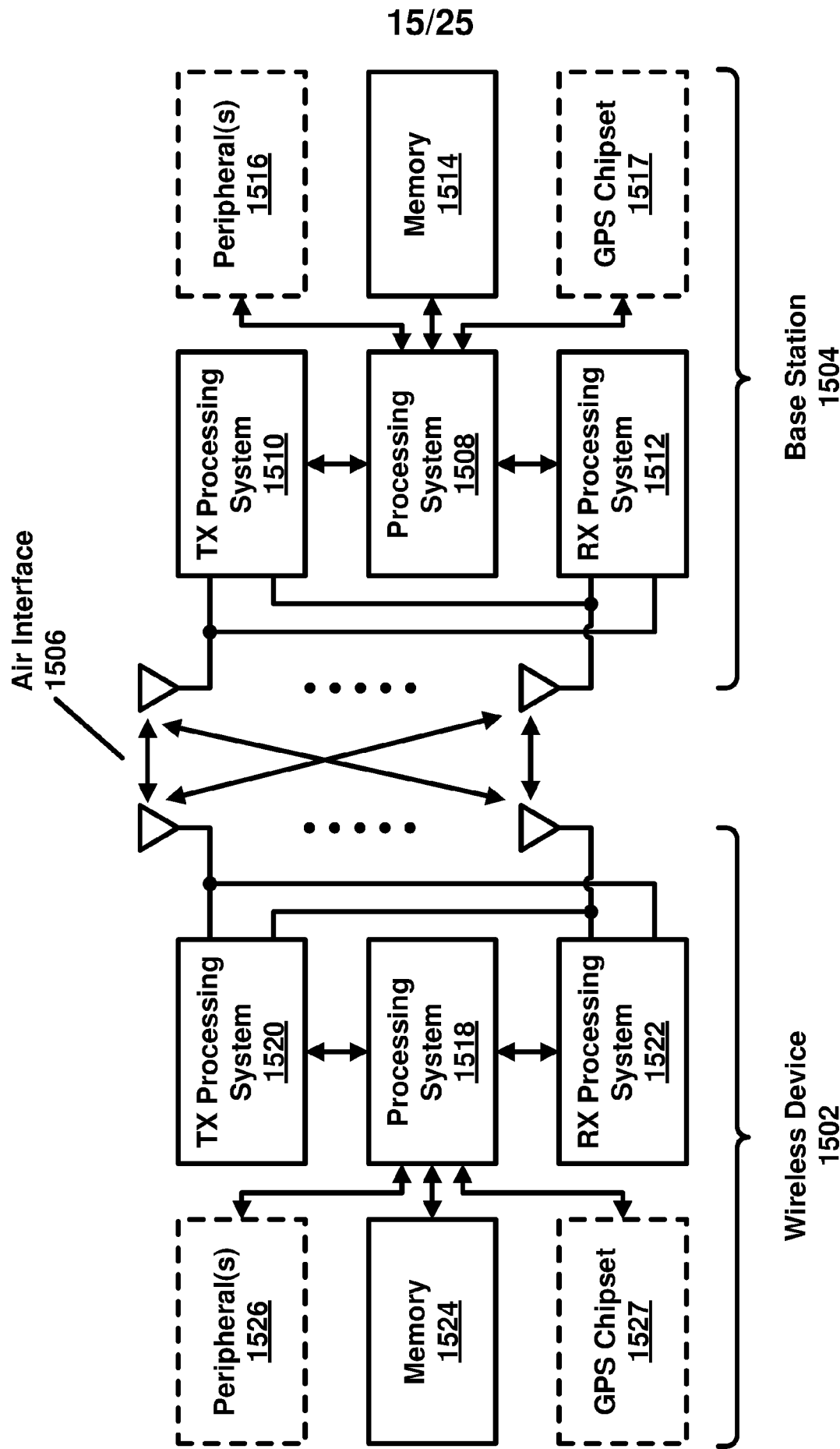


FIG. 15

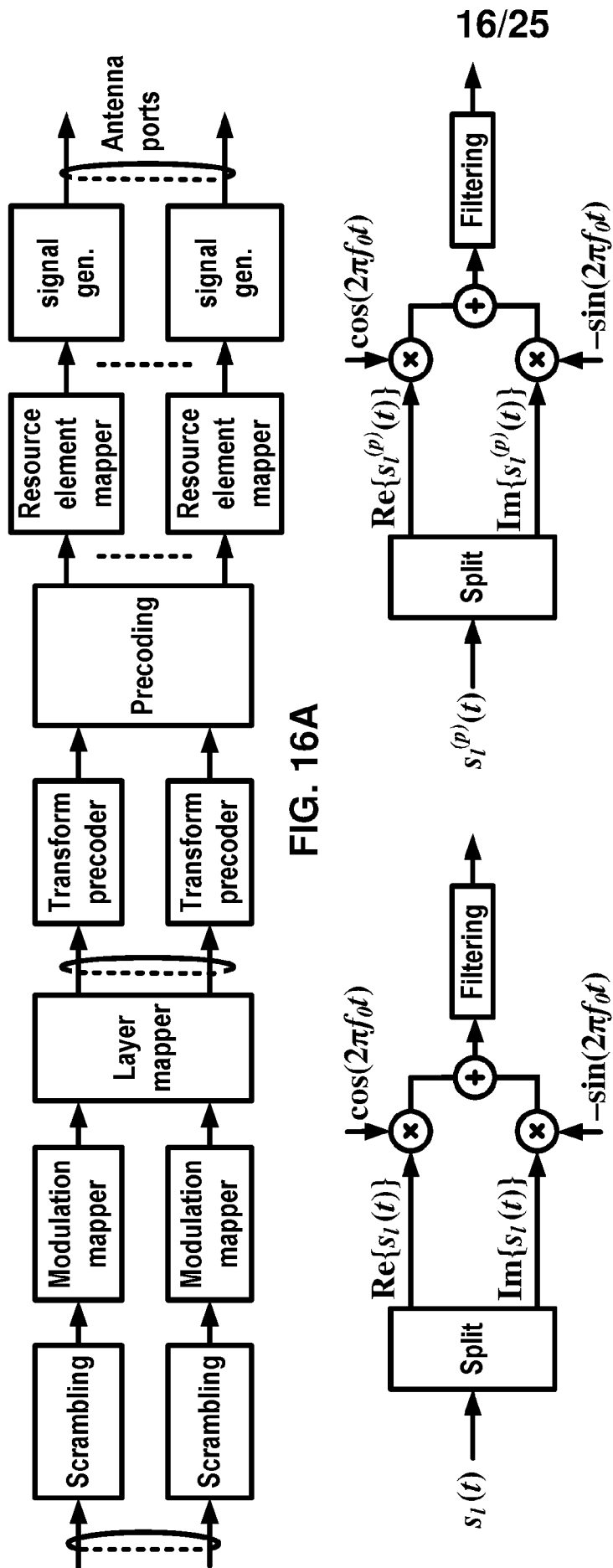
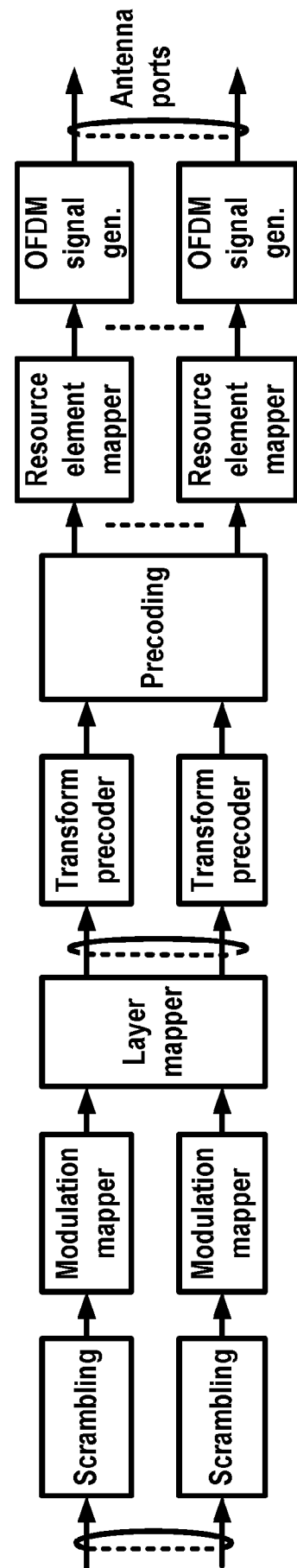


FIG. 16D



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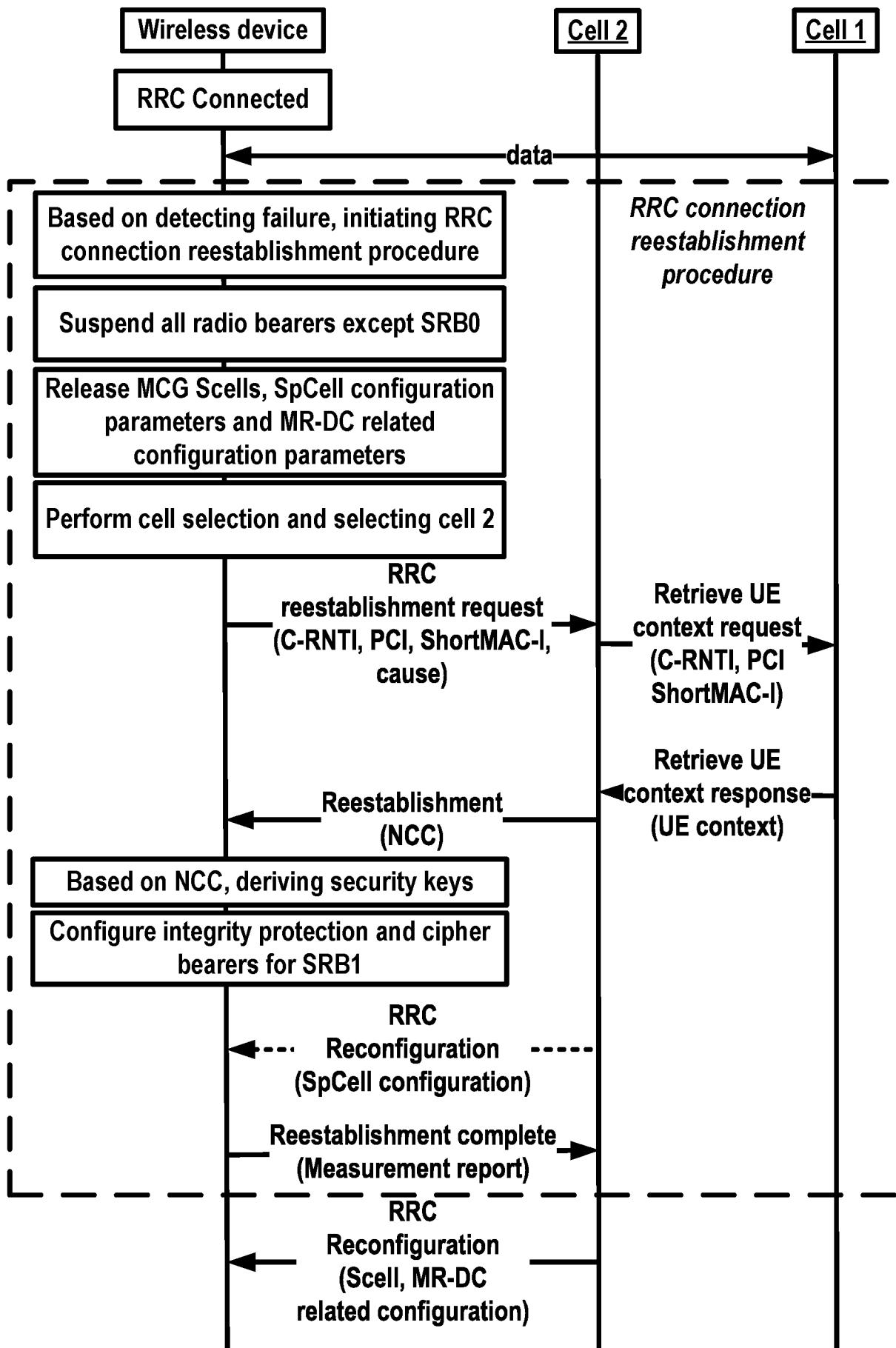


FIG. 17

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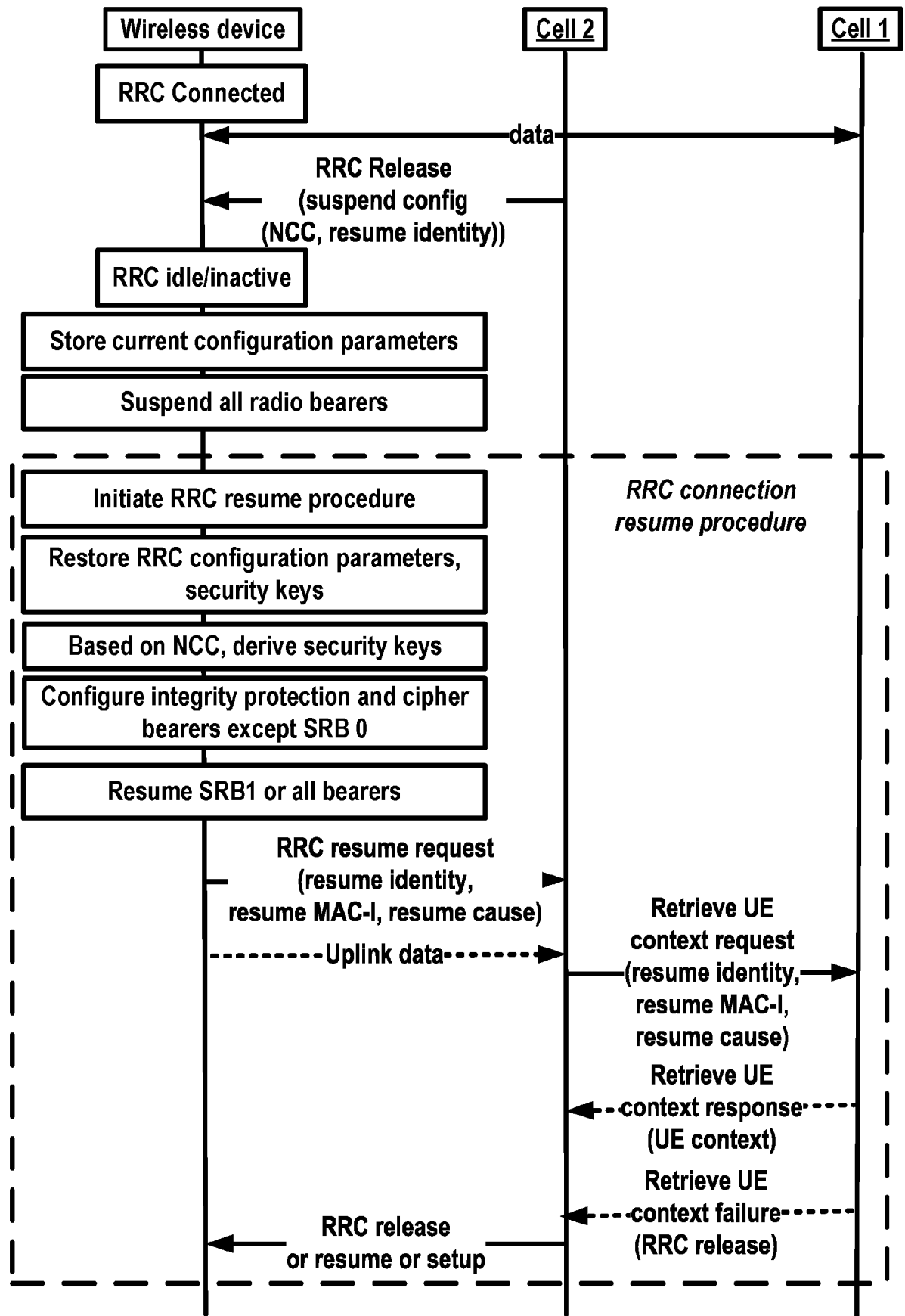


FIG. 18

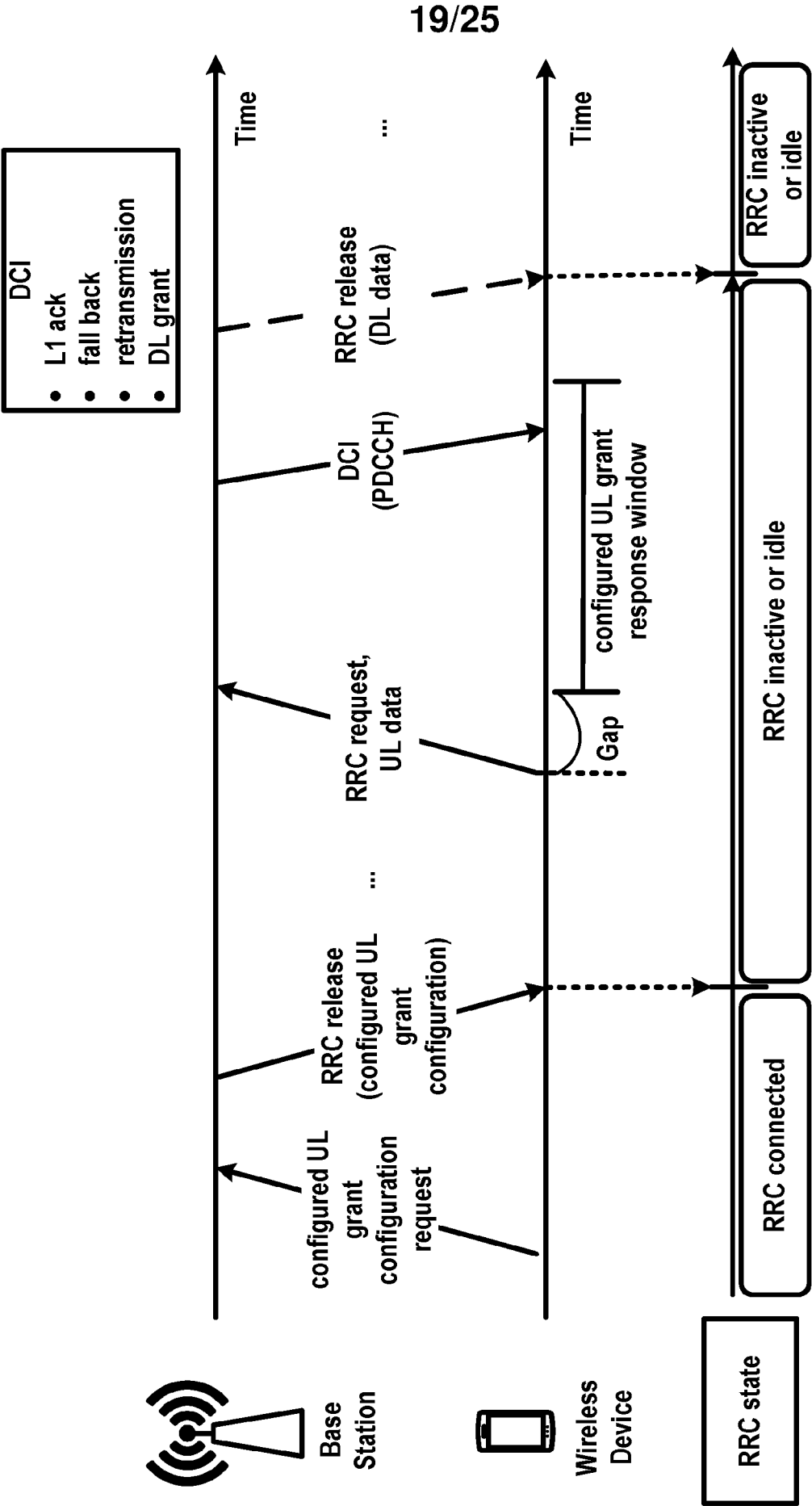


FIG. 19

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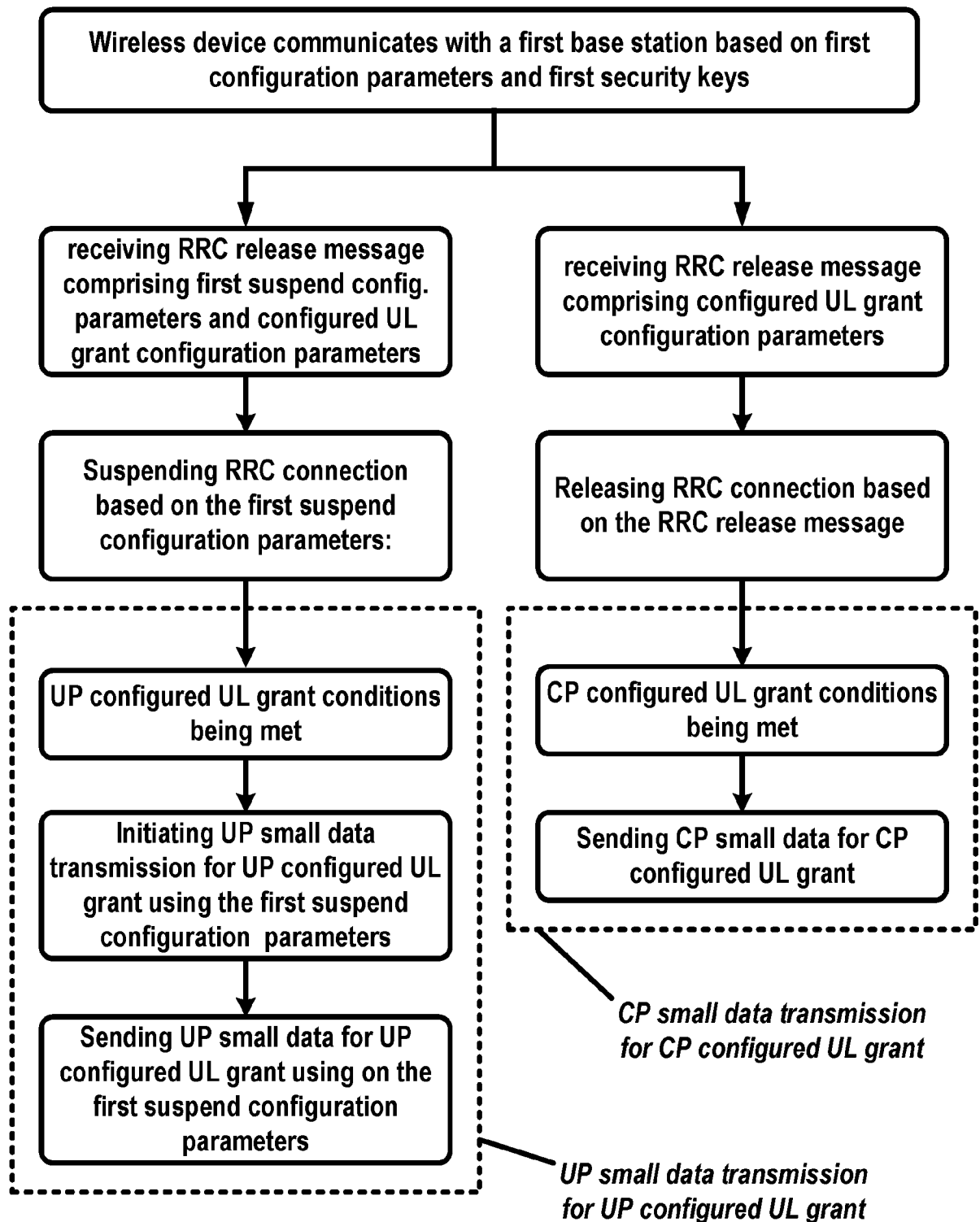


FIG. 20

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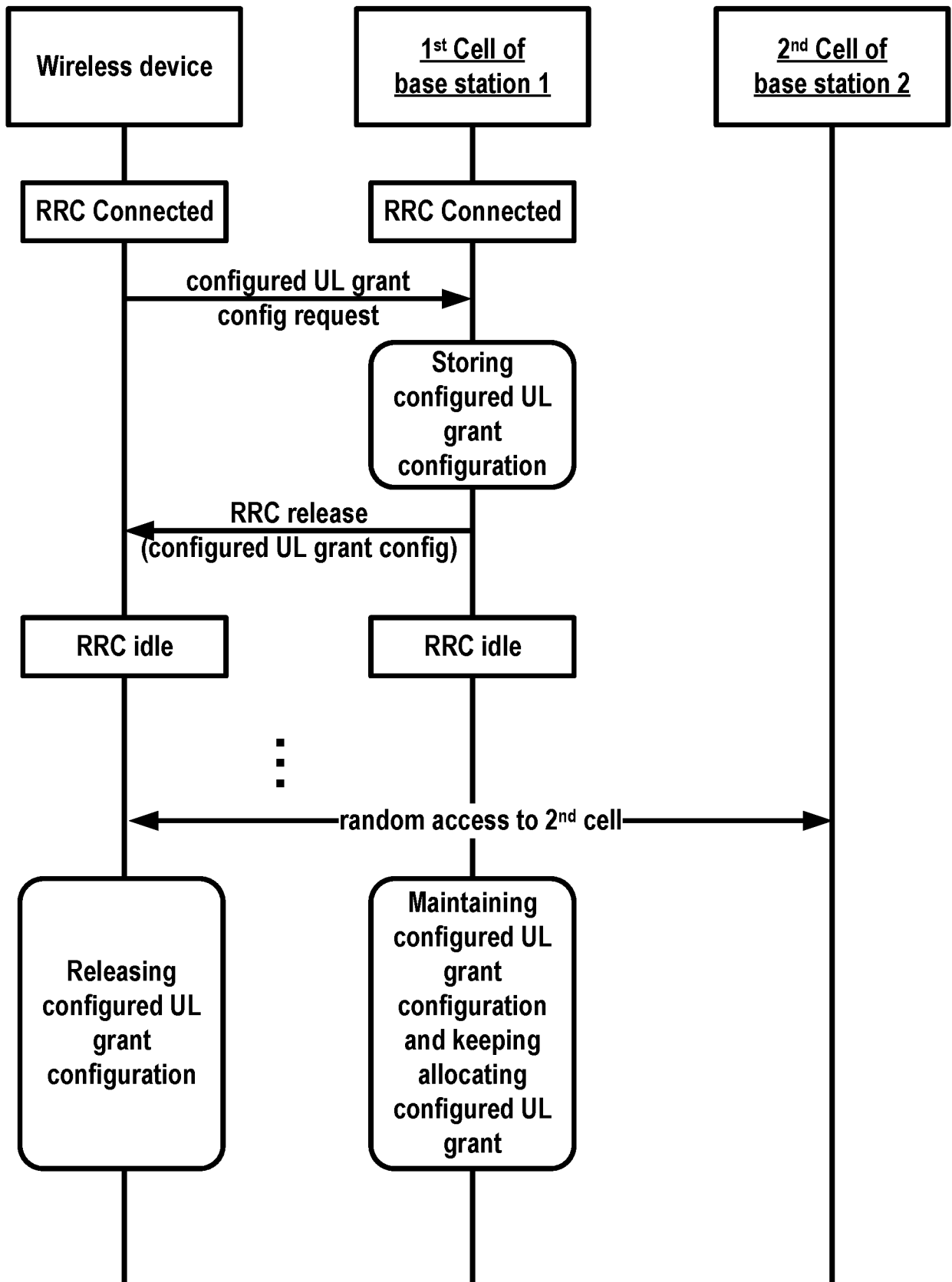


FIG. 21

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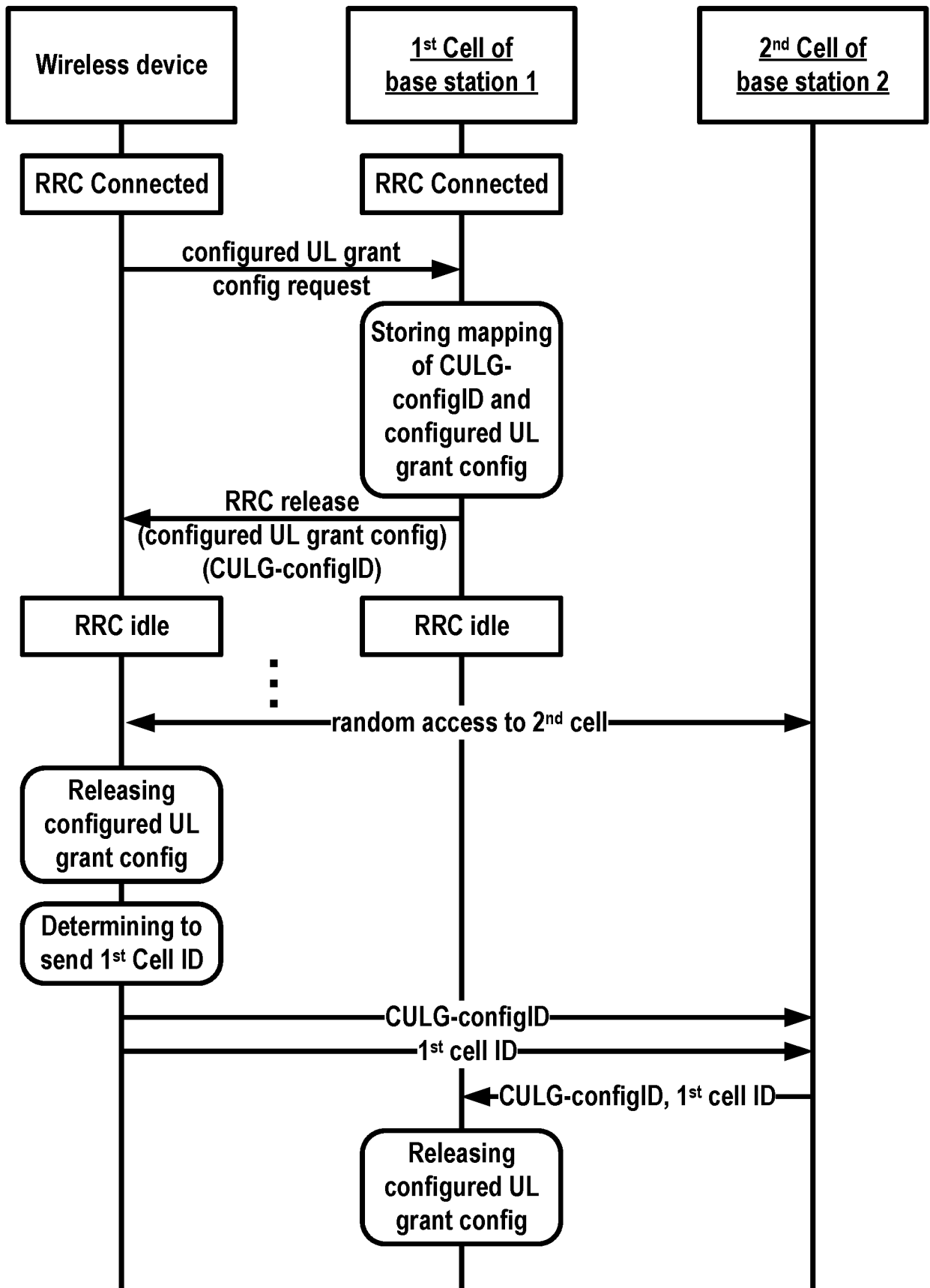


FIG. 22

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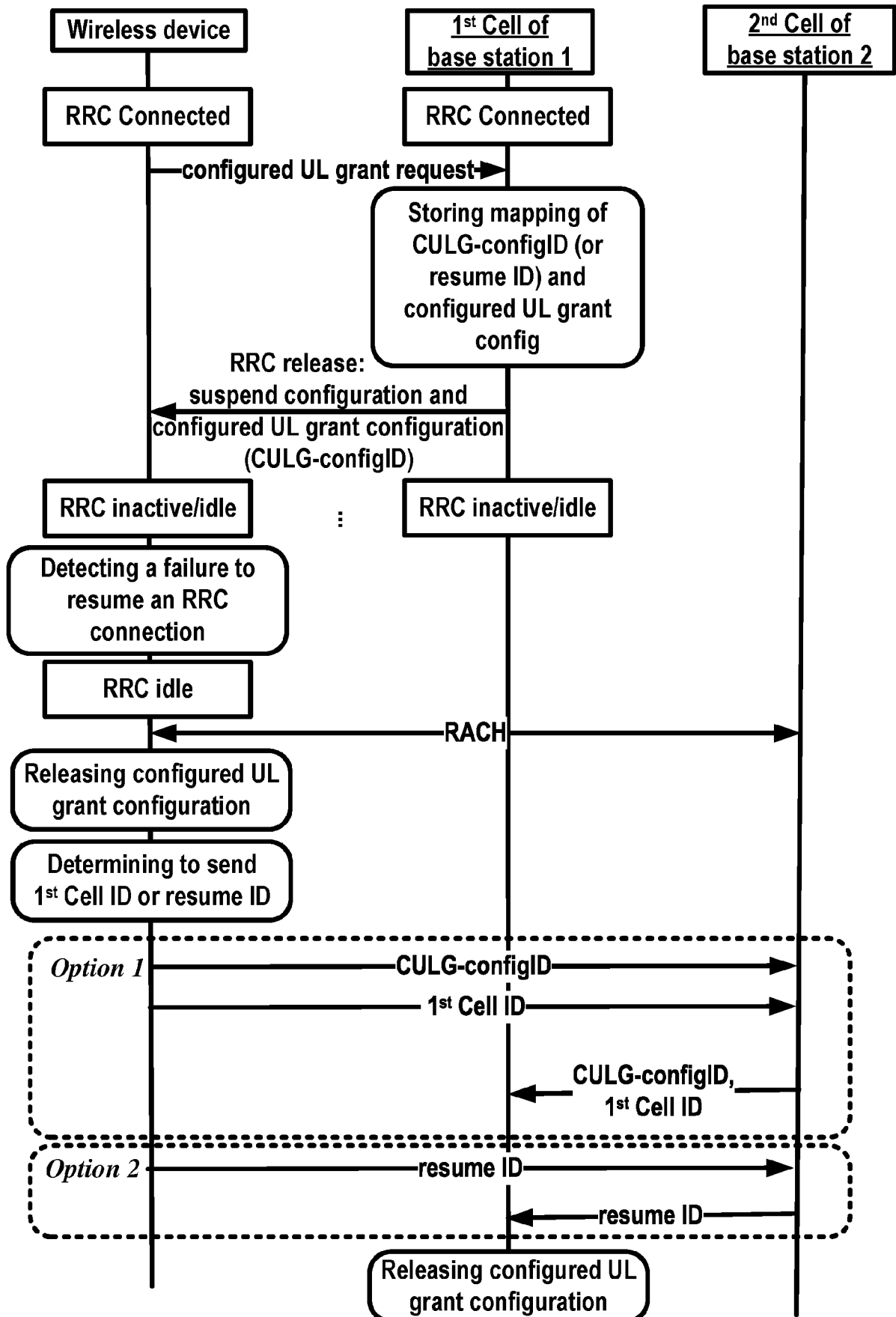


FIG. 23

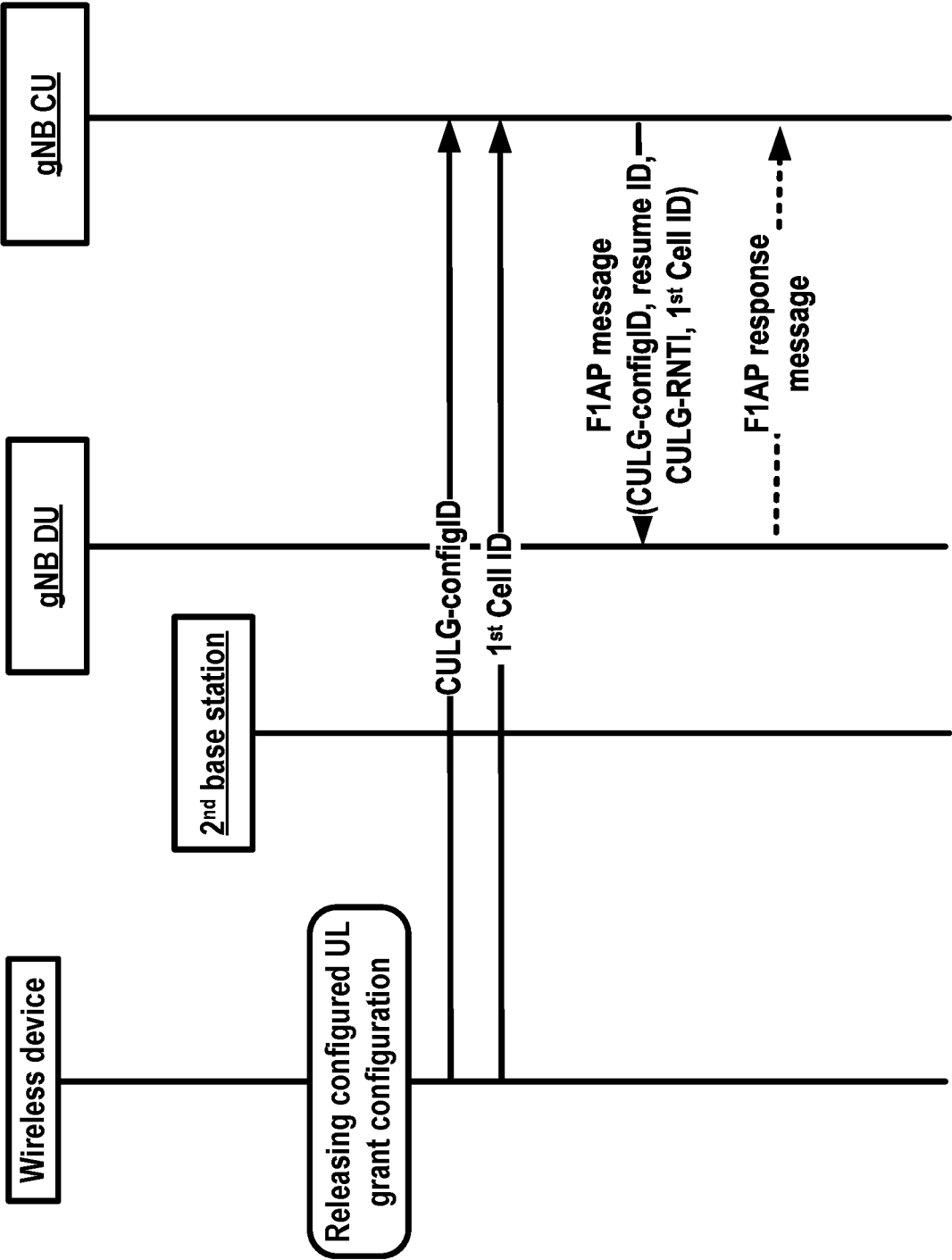


FIG. 24

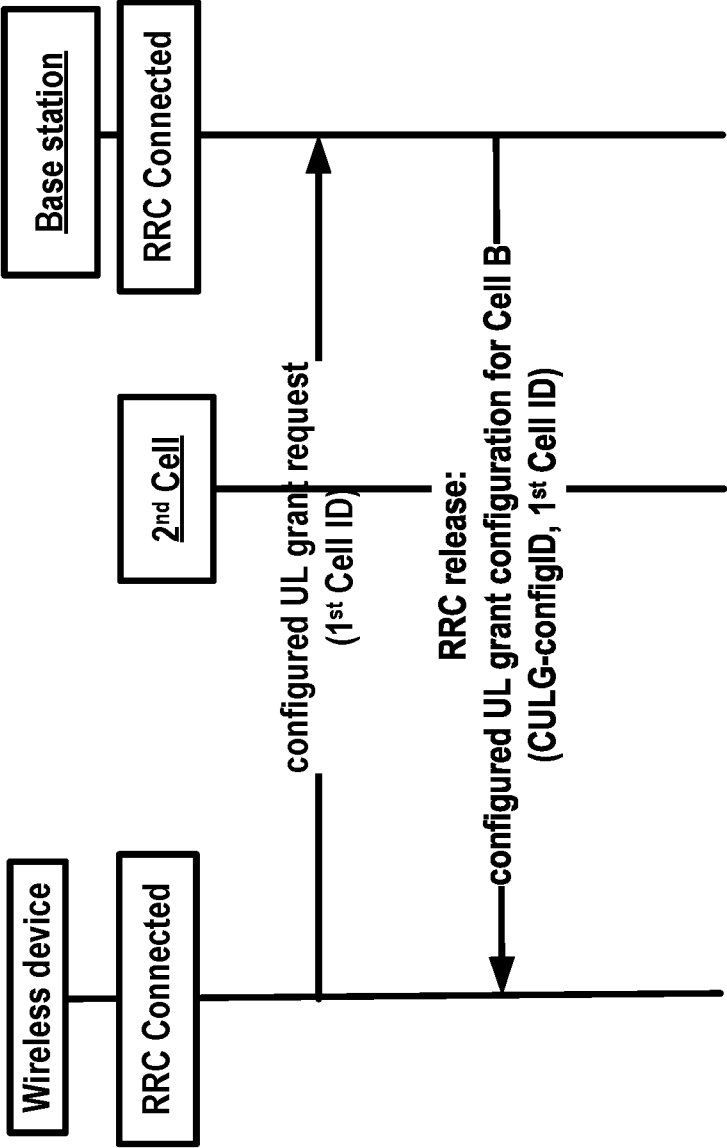


FIG. 25

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2021/043615

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W76/27 H04W76/19 H04W76/30
ADD. H04W72/04 H04W52/02 H04W36/00

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

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)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2020/100318 A1 (SENGUPTA AYAN [US] ET AL) 26 March 2020 (2020-03-26) paragraphs [0002] - [0063], [0075] - [0260]; figures 1-16 ----- -/--	1-150



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

5 October 2021

Date of mailing of the international search report

14/10/2021

Name and mailing address of the ISA/

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Authorized officer

Jaster, Nicole

INTERNATIONAL SEARCH REPORT

International application No

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ZTE CORPORATION ET AL: "Further consideration on UL aspects of D-PUR in IDLE", 3GPP DRAFT; R2-1903485 FURTHER CONSIDERATION ON UL ASPECTS OF D-PUR IN IDLE, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CE , vol. RAN WG2, no. Xi'an, China; 20190408 - 20190412 6 April 2019 (2019-04-06), XP051700829, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings%5F3GP P%5FSYNC/RAN2/Docs/R2%2D1903485%2Ezip [retrieved on 2019-04-06] sections 1-3	1-150
X	----- WO 2020/034571 A1 (ZTE CORP [CN]) 20 February 2020 (2020-02-20) page 1, paragraph 3, to page 3, paragraph 4; page 4, paragraph 4, to page 31, paragraph 2; figures 1, 2, 5-13	1-150
X	----- WO 2020/067711 A1 (LG ELECTRONICS INC [KR]) 2 April 2020 (2020-04-02)	111-150
A	paragraphs [1] - [14], [32] - [34], [46] - [332]; figures 1-13	1-110
X	----- EP 3 522 647 A1 (COMCAST CABLE COMM LLC [US]) 7 August 2019 (2019-08-07)	111-150
A	paragraphs [0004], [0011] - [0077], [0093] - [0197]; figures 1-23 -----	1-110

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2021/043615

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2020100318 A1	26-03-2020	CN 112740821 A	30-04-2021
		CN 112740822 A	30-04-2021
		CN 112740823 A	30-04-2021
		CN 112753278 A	04-05-2021
		EP 3858094 A1	04-08-2021
		EP 3858095 A1	04-08-2021
		EP 3858097 A1	04-08-2021
		EP 3858098 A1	04-08-2021
		TW 202015454 A	16-04-2020
		TW 202015466 A	16-04-2020
		TW 202017418 A	01-05-2020
		TW 202025833 A	01-07-2020
		US 2020100318 A1	26-03-2020
		US 2020100320 A1	26-03-2020
		US 2020100321 A1	26-03-2020
		US 2020137825 A1	30-04-2020
		WO 2020069097 A1	02-04-2020
		WO 2020069099 A1	02-04-2020
		WO 2020069101 A1	02-04-2020
		WO 2020069102 A1	02-04-2020

WO 2020034571 A1	20-02-2020	CA 3126402 A1	20-02-2020
		CN 113316923 A	27-08-2021
		KR 20210111852 A	13-09-2021
		SG 11202107611Q A	30-08-2021
		WO 2020034571 A1	20-02-2020

WO 2020067711 A1	02-04-2020	US 2021266958 A1	26-08-2021
		WO 2020067711 A1	02-04-2020

EP 3522647 A1	07-08-2019	CA 3032474 A1	02-08-2019
		EP 3522647 A1	07-08-2019
		US 2019246420 A1	08-08-2019
		US 2021022174 A1	21-01-2021
