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62/743,290 09 October 2018 (09.10.2018) US(71) Applicant: **IDAC HOLDINGS, INC.** [US/US]; 200 Bellevue Parkway, Suite 300, Wilmington, Delaware 19809 (US).(72) Inventors: **PAN, Kyle Jung-Lin**; 2 Huntington Quadrangle, 4th Floor, South Wing, Melville, New York 11747-4508 (US). **XI, Fengjun**; 10838 Aderman Avenue, Apartment 144, San Diego, California 92126 (US). **YE, Chunxuan**; 17247 4S Ranch Parkway, San Diego, California 92127 (US).(74) Agent: **LEONARD, Robert D.**; Volpe and Koenig, P.C., 30 S. 17th Street, Suite 1800, Philadelphia, Pennsylvania 19103 (US).(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,

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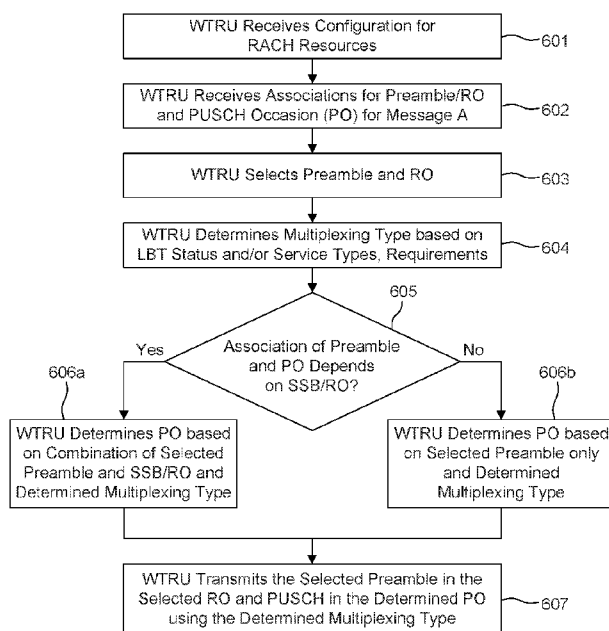


FIG. 6

(57) **Abstract:** Methods and apparatuses for accessing a channel in a New Radio (NR) system are provided. A method comprises receiving a configuration for a random access channel (RACH) occasion (RO), the configuration indicating resources in which to transmit one or more preambles. An indication associating the one or more preambles with one or more physical uplink shared channel (PUSCH) occasions (POs) may be received, and each PO may include resources over which to transmit a radio resource connection (RRC) request. A preamble and an RO may be selected. A multiplexing technique for transmission of the preamble and the RRC request may be determined, and an associated PO over which to transmit the RRC request may be selected. The selected preamble and RRC request may be multiplexed according to the determined technique, and transmitted according to the selected RO and PO, respectively.



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SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,  
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## **SIMPLIFIED PHYSICAL RANDOM ACCESS METHODS AND PROCEDURES FOR NR-U**

### **CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims the benefit of U.S. Provisional Application No. 62/743,290, filed October 9, 2018, the contents of which are incorporated herein by reference.

### **BACKGROUND**

[0002] Based on the general requirements set out by ITU-R, NGMN and 3GPP, use cases for emerging 5G systems may include Enhanced Mobile Broadband (eMBB), Massive Machine Type Communications (mMTC) and Ultra Reliable and Low latency Communications (URLLC). Use cases may focus on different requirements such as higher data rate, higher spectrum efficiency, low power and higher energy efficiency, lower latency and higher reliability. A wide range of spectrum bands ranging from 700 MHz to 80 GHz may be considered for a variety of deployment scenarios.

[0003] As a carrier frequency increases, path loss may impose a critical limitation on coverage. Transmissions in millimetre wave systems could additionally suffer from non-line-of-sight losses, such as diffraction loss, penetration loss, oxygen absorption loss, foliage loss, among other types. During initial access, a base station and WTRU may need to overcome these path losses and discover each other. Utilizing dozens or even hundreds of antenna elements to generate beam-formed signals may be an effective way to compensate for severe path loss by providing significant beamforming gain. Beamforming techniques may include digital, analogue and hybrid beamforming.

### **SUMMARY**

[0004] Methods and apparatuses for accessing a channel in a New Radio (NR) system are provided. A method comprises receiving a configuration for a random access channel (RACH) occasion (RO), the configuration indicating resources in which to transmit one or more preambles. An indication associating the one or more preambles with one or more physical uplink shared channel (PUSCH) occasions (POs) may be received, and each PO may include resources over which to transmit a radio resource control (RRC) request. A preamble and an RO may be selected. A multiplexing technique for transmission of the preamble and the RRC request may be determined, and an associated PO over which to transmit the RRC request may be selected. The selected preamble and RRC request may be multiplexed according to the determined technique, and transmitted according to the selected RO and PO, respectively.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0005] A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings, wherein like reference numerals in the figures indicate like elements, and wherein:

[0006] FIG. 1A is a system diagram illustrating an example communications system in which one or more disclosed embodiments may be implemented;

[0007] FIG. 1B is a system diagram illustrating an example wireless transmit/receive unit (WTRU) that may be used within the communications system illustrated in FIG. 1A according to an embodiment;

[0008] FIG. 1C is a system diagram illustrating an example radio access network (RAN) and an example core network (CN) that may be used within the communications system illustrated in FIG. 1A according to an embodiment;

[0009] FIG. 1D is a system diagram illustrating a further example RAN and a further example CN that may be used within the communications system illustrated in FIG. 1A according to an embodiment;

[0010] FIG. 2 provides a comparison between TDM and FDM transmissions of Msg1 and Msg3;

[0011] FIG. 3 provides a flowchart with an example process for determining the multiplexing technique for transmission of Msg1 and Msg3;

[0012] FIG. 4 shows an example configuration for association and utilization of Msg1 resources and Msg3 resources;

[0013] FIG. 5. provides a method for Msg3 resource allocation based on the selection of a preamble by a WTRU;

[0014] FIG. 6 shows a flowchart describing the overall process for random access according to a simplified method;

[0015] FIG. 7 provides one example scenario for random access where two WTRUs operate within a given cell;

[0016] FIG. 8 the timing of a preamble transmission by a WTRU performing RACH procedures and an UL (data/control) transmission by a WTRU operating in an RRC-connected mode, as in the scenario of FIG. 7;

[0017] FIG. 9 provides a solution to the problem presented in FIG. 10 that involves introducing a guard period;

- [0018] FIG. 10 depicts a worst-case scenario for random access procedures in which two WTRUs are located in close proximity to each other near the boundary of the same cell;
- [0019] FIG. 11 provides a timing diagram showing one WTRU transmitting a preamble and another WTRU sending an UL transmission in the scenario of FIG. 10;
- [0020] FIG. 12 provides an example of how multiple BWPs may be used for RACH procedures;
- [0021] FIG. 13 provides a solution to the problem presented in FIG. 12 that involves indicating a priority order for a WTRU to monitor multiple BWPs during RACH procedures.

### DETAILED DESCRIPTION

[0022] FIG. 1A is a diagram illustrating an example communications system 100 in which one or more disclosed embodiments may be implemented. The communications system 100 may be a multiple access system that provides content, such as voice, data, video, messaging, broadcast, etc., to multiple wireless users. The communications system 100 may enable multiple wireless users to access such content through the sharing of system resources, including wireless bandwidth. For example, the communications systems 100 may employ one or more channel access methods, such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), single-carrier FDMA (SC-FDMA), zero-tail unique-word discrete Fourier transform Spread OFDM (ZT-UW-DFT-S-OFDM), unique word OFDM (UW-OFDM), resource block-filtered OFDM, filter bank multicarrier (FBMC), and the like.

[0023] As shown in FIG. 1A, the communications system 100 may include wireless transmit/receive units (WTRUs) 102a, 102b, 102c, 102d, a radio access network (RAN) 104, a core network (CN) 106, a public switched telephone network (PSTN) 108, the Internet 110, and other networks 112, though it will be appreciated that the disclosed embodiments contemplate any number of WTRUs, base stations, networks, and/or network elements. Each of the WTRUs 102a, 102b, 102c, 102d may be any type of device configured to operate and/or communicate in a wireless environment. By way of example, the WTRUs 102a, 102b, 102c, 102d, any of which may be referred to as a station (STA), may be configured to transmit and/or receive wireless signals and may include a user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a subscription-based unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a netbook, a personal computer, a wireless sensor, a hotspot or Mi-Fi device, an Internet of Things (IoT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, a medical device and applications (e.g., remote surgery), an industrial device and

applications (e.g., a robot and/or other wireless devices operating in an industrial and/or an automated processing chain contexts), a consumer electronics device, a device operating on commercial and/or industrial wireless networks, and the like. Any of the WTRUs 102a, 102b, 102c and 102d may be interchangeably referred to as a UE.

[0024] The communications systems 100 may also include a base station 114a and/or a base station 114b. Each of the base stations 114a, 114b may be any type of device configured to wirelessly interface with at least one of the WTRUs 102a, 102b, 102c, 102d to facilitate access to one or more communication networks, such as the CN 106, the Internet 110, and/or the other networks 112. By way of example, the base stations 114a, 114b may be a base transceiver station (BTS), a NodeB, an eNode B (eNB), a Home Node B, a Home eNode B, a next generation NodeB, such as a gNode B (gNB), a new radio (NR) NodeB, a site controller, an access point (AP), a wireless router, and the like. While the base stations 114a, 114b are each depicted as a single element, it will be appreciated that the base stations 114a, 114b may include any number of interconnected base stations and/or network elements.

[0025] The base station 114a may be part of the RAN 104, which may also include other base stations and/or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, and the like. The base station 114a and/or the base station 114b may be configured to transmit and/or receive wireless signals on one or more carrier frequencies, which may be referred to as a cell (not shown). These frequencies may be in licensed spectrum, unlicensed spectrum, or a combination of licensed and unlicensed spectrum. A cell may provide coverage for a wireless service to a specific geographical area that may be relatively fixed or that may change over time. The cell may further be divided into cell sectors. For example, the cell associated with the base station 114a may be divided into three sectors. Thus, in one embodiment, the base station 114a may include three transceivers, i.e., one for each sector of the cell. In an embodiment, the base station 114a may employ multiple-input multiple output (MIMO) technology and may utilize multiple transceivers for each sector of the cell. For example, beamforming may be used to transmit and/or receive signals in desired spatial directions.

[0026] The base stations 114a, 114b may communicate with one or more of the WTRUs 102a, 102b, 102c, 102d over an air interface 116, which may be any suitable wireless communication link (e.g., radio frequency (RF), microwave, centimeter wave, micrometer wave, infrared (IR), ultraviolet (UV), visible light, etc.). The air interface 116 may be established using any suitable radio access technology (RAT).

[0027] More specifically, as noted above, the communications system 100 may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and the like. For example, the base station 114a in the RAN 104 and the WTRUs 102a, 102b, 102c may implement a radio technology such as Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA), which may establish the air interface 116 using wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet Access (HSPA) and/or Evolved HSPA (HSPA+). HSPA may include High-Speed Downlink (DL) Packet Access (HSDPA) and/or High-Speed Uplink (UL) Packet Access (HSUPA).

[0028] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as Evolved UMTS Terrestrial Radio Access (E-UTRA), which may establish the air interface 116 using Long Term Evolution (LTE) and/or LTE-Advanced (LTE-A) and/or LTE-Advanced Pro (LTE-A Pro).

[0029] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as NR Radio Access, which may establish the air interface 116 using NR.

[0030] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement multiple radio access technologies. For example, the base station 114a and the WTRUs 102a, 102b, 102c may implement LTE radio access and NR radio access together, for instance using dual connectivity (DC) principles. Thus, the air interface utilized by WTRUs 102a, 102b, 102c may be characterized by multiple types of radio access technologies and/or transmissions sent to/from multiple types of base stations (e.g., an eNB and a gNB).

[0031] In other embodiments, the base station 114a and the WTRUs 102a, 102b, 102c may implement radio technologies such as IEEE 802.11 (i.e., Wireless Fidelity (WiFi)), IEEE 802.16 (i.e., Worldwide Interoperability for Microwave Access (WiMAX)), CDMA2000, CDMA2000 1X, CDMA2000 EV-DO, Interim Standard 2000 (IS-2000), Interim Standard 95 (IS-95), Interim Standard 856 (IS-856), Global System for Mobile communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), GSM EDGE (GERAN), and the like.

[0032] The base station 114b in FIG. 1A may be a wireless router, Home Node B, Home eNode B, or access point, for example, and may utilize any suitable RAT for facilitating wireless connectivity in a localized area, such as a place of business, a home, a vehicle, a campus, an industrial facility, an air corridor (e.g., for use by drones), a roadway, and the like. In one

embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In an embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). In yet another embodiment, the base station 114b and the WTRUs 102c, 102d may utilize a cellular-based RAT (e.g., WCDMA, CDMA2000, GSM, LTE, LTE-A, LTE-A Pro, NR etc.) to establish a picocell or femtocell. As shown in FIG. 1A, the base station 114b may have a direct connection to the Internet 110. Thus, the base station 114b may not be required to access the Internet 110 via the CN 106.

[0033] The RAN 104 may be in communication with the CN 106, which may be any type of network configured to provide voice, data, applications, and/or voice over internet protocol (VoIP) services to one or more of the WTRUs 102a, 102b, 102c, 102d. The data may have varying quality of service (QoS) requirements, such as differing throughput requirements, latency requirements, error tolerance requirements, reliability requirements, data throughput requirements, mobility requirements, and the like. The CN 106 may provide call control, billing services, mobile location-based services, pre-paid calling, Internet connectivity, video distribution, etc., and/or perform high-level security functions, such as user authentication. Although not shown in FIG. 1A, it will be appreciated that the RAN 104 and/or the CN 106 may be in direct or indirect communication with other RANs that employ the same RAT as the RAN 104 or a different RAT. For example, in addition to being connected to the RAN 104, which may be utilizing a NR radio technology, the CN 106 may also be in communication with another RAN (not shown) employing a GSM, UMTS, CDMA 2000, WiMAX, E-UTRA, or WiFi radio technology.

[0034] The CN 106 may also serve as a gateway for the WTRUs 102a, 102b, 102c, 102d to access the PSTN 108, the Internet 110, and/or the other networks 112. The PSTN 108 may include circuit-switched telephone networks that provide plain old telephone service (POTS). The Internet 110 may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and/or the internet protocol (IP) in the TCP/IP internet protocol suite. The networks 112 may include wired and/or wireless communications networks owned and/or operated by other service providers. For example, the networks 112 may include another CN connected to one or more RANs, which may employ the same RAT as the RAN 104 or a different RAT.

[0035] Some or all of the WTRUs 102a, 102b, 102c, 102d in the communications system 100 may include multi-mode capabilities (e.g., the WTRUs 102a, 102b, 102c, 102d may include multiple transceivers for communicating with different wireless networks over different wireless links). For

example, the WTRU 102c shown in FIG. 1A may be configured to communicate with the base station 114a, which may employ a cellular-based radio technology, and with the base station 114b, which may employ an IEEE 802 radio technology.

[0036] FIG. 1B is a system diagram illustrating an example WTRU 102. As shown in FIG. 1B, the WTRU 102 may include a processor 118, a transceiver 120, a transmit/receive element 122, a speaker/microphone 124, a keypad 126, a display/touchpad 128, non-removable memory 130, removable memory 132, a power source 134, a global positioning system (GPS) chipset 136, and/or other peripherals 138, among others. It will be appreciated that the WTRU 102 may include any sub-combination of the foregoing elements while remaining consistent with an embodiment.

[0037] The processor 118 may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), any other type of integrated circuit (IC), a state machine, and the like. The processor 118 may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the WTRU 102 to operate in a wireless environment. The processor 118 may be coupled to the transceiver 120, which may be coupled to the transmit/receive element 122. While FIG. 1B depicts the processor 118 and the transceiver 120 as separate components, it will be appreciated that the processor 118 and the transceiver 120 may be integrated together in an electronic package or chip.

[0038] The transmit/receive element 122 may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station 114a) over the air interface 116. For example, in one embodiment, the transmit/receive element 122 may be an antenna configured to transmit and/or receive RF signals. In an embodiment, the transmit/receive element 122 may be an emitter/detector configured to transmit and/or receive IR, UV, or visible light signals, for example. In yet another embodiment, the transmit/receive element 122 may be configured to transmit and/or receive both RF and light signals. It will be appreciated that the transmit/receive element 122 may be configured to transmit and/or receive any combination of wireless signals.

[0039] Although the transmit/receive element 122 is depicted in FIG. 1B as a single element, the WTRU 102 may include any number of transmit/receive elements 122. More specifically, the WTRU 102 may employ MIMO technology. Thus, in one embodiment, the WTRU 102 may include two or more transmit/receive elements 122 (e.g., multiple antennas) for transmitting and receiving wireless signals over the air interface 116.

[0040] The transceiver 120 may be configured to modulate the signals that are to be transmitted by the transmit/receive element 122 and to demodulate the signals that are received by the transmit/receive element 122. As noted above, the WTRU 102 may have multi-mode capabilities. Thus, the transceiver 120 may include multiple transceivers for enabling the WTRU 102 to communicate via multiple RATs, such as NR and IEEE 802.11, for example.

[0041] The processor 118 of the WTRU 102 may be coupled to, and may receive user input data from, the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128 (e.g., a liquid crystal display (LCD) display unit or organic light-emitting diode (OLED) display unit). The processor 118 may also output user data to the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128. In addition, the processor 118 may access information from, and store data in, any type of suitable memory, such as the non-removable memory 130 and/or the removable memory 132. The non-removable memory 130 may include random-access memory (RAM), read-only memory (ROM), a hard disk, or any other type of memory storage device. The removable memory 132 may include a subscriber identity module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. In other embodiments, the processor 118 may access information from, and store data in, memory that is not physically located on the WTRU 102, such as on a server or a home computer (not shown).

[0042] The processor 118 may receive power from the power source 134, and may be configured to distribute and/or control the power to the other components in the WTRU 102. The power source 134 may be any suitable device for powering the WTRU 102. For example, the power source 134 may include one or more dry cell batteries (e.g., nickel-cadmium (NiCd), nickel-zinc (NiZn), nickel metal hydride (NiMH), lithium-ion (Li-ion), etc.), solar cells, fuel cells, and the like.

[0043] The processor 118 may also be coupled to the GPS chipset 136, which may be configured to provide location information (e.g., longitude and latitude) regarding the current location of the WTRU 102. In addition to, or in lieu of, the information from the GPS chipset 136, the WTRU 102 may receive location information over the air interface 116 from a base station (e.g., base stations 114a, 114b) and/or determine its location based on the timing of the signals being received from two or more nearby base stations. It will be appreciated that the WTRU 102 may acquire location information by way of any suitable location-determination method while remaining consistent with an embodiment.

[0044] The processor 118 may further be coupled to other peripherals 138, which may include one or more software and/or hardware modules that provide additional features, functionality and/or wired or wireless connectivity. For example, the peripherals 138 may include an accelerometer, an

e-compass, a satellite transceiver, a digital camera (for photographs and/or video), a universal serial bus (USB) port, a vibration device, a television transceiver, a hands free headset, a Bluetooth® module, a frequency modulated (FM) radio unit, a digital music player, a media player, a video game player module, an Internet browser, a Virtual Reality and/or Augmented Reality (VR/AR) device, an activity tracker, and the like. The peripherals 138 may include one or more sensors. The sensors may be one or more of a gyroscope, an accelerometer, a hall effect sensor, a magnetometer, an orientation sensor, a proximity sensor, a temperature sensor, a time sensor; a geolocation sensor, an altimeter, a light sensor, a touch sensor, a magnetometer, a barometer, a gesture sensor, a biometric sensor, a humidity sensor and the like.

[0045] The WTRU 102 may include a full duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for both the UL (e.g., for transmission) and DL (e.g., for reception) may be concurrent and/or simultaneous. The full duplex radio may include an interference management unit to reduce and or substantially eliminate self-interference via either hardware (e.g., a choke) or signal processing via a processor (e.g., a separate processor (not shown) or via processor 118). In an embodiment, the WTRU 102 may include a half-duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for either the UL (e.g., for transmission) or the DL (e.g., for reception)).

[0046] FIG. 1C is a system diagram illustrating the RAN 104 and the CN 106 according to an embodiment. As noted above, the RAN 104 may employ an E-UTRA radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 104 may also be in communication with the CN 106.

[0047] The RAN 104 may include eNode-Bs 160a, 160b, 160c, though it will be appreciated that the RAN 104 may include any number of eNode-Bs while remaining consistent with an embodiment. The eNode-Bs 160a, 160b, 160c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In one embodiment, the eNode-Bs 160a, 160b, 160c may implement MIMO technology. Thus, the eNode-B 160a, for example, may use multiple antennas to transmit wireless signals to, and/or receive wireless signals from, the WTRU 102a.

[0048] Each of the eNode-Bs 160a, 160b, 160c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the UL and/or DL, and the like. As shown in FIG. 1C, the eNode-Bs 160a, 160b, 160c may communicate with one another over an X2 interface.

[0049] The CN 106 shown in FIG. 1C may include a mobility management entity (MME) 162, a serving gateway (SGW) 164, and a packet data network (PDN) gateway (PGW) 166. While the foregoing elements are depicted as part of the CN 106, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.

[0050] The MME 162 may be connected to each of the eNode-Bs 162a, 162b, 162c in the RAN 104 via an S1 interface and may serve as a control node. For example, the MME 162 may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, bearer activation/deactivation, selecting a particular serving gateway during an initial attach of the WTRUs 102a, 102b, 102c, and the like. The MME 162 may provide a control plane function for switching between the RAN 104 and other RANs (not shown) that employ other radio technologies, such as GSM and/or WCDMA.

[0051] The SGW 164 may be connected to each of the eNode Bs 160a, 160b, 160c in the RAN 104 via the S1 interface. The SGW 164 may generally route and forward user data packets to/from the WTRUs 102a, 102b, 102c. The SGW 164 may perform other functions, such as anchoring user planes during inter-eNode B handovers, triggering paging when DL data is available for the WTRUs 102a, 102b, 102c, managing and storing contexts of the WTRUs 102a, 102b, 102c, and the like.

[0052] The SGW 164 may be connected to the PGW 166, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices.

[0053] The CN 106 may facilitate communications with other networks. For example, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to circuit-switched networks, such as the PSTN 108, to facilitate communications between the WTRUs 102a, 102b, 102c and traditional land-line communications devices. For example, the CN 106 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the CN 106 and the PSTN 108. In addition, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to the other networks 112, which may include other wired and/or wireless networks that are owned and/or operated by other service providers.

[0054] Although the WTRU is described in FIGS. 1A-1D as a wireless terminal, it is contemplated that in certain representative embodiments that such a terminal may use (e.g., temporarily or permanently) wired communication interfaces with the communication network.

[0055] In representative embodiments, the other network 112 may be a WLAN.

[0056] A WLAN in Infrastructure Basic Service Set (BSS) mode may have an Access Point (AP) for the BSS and one or more stations (STAs) associated with the AP. The AP may have access or

an interface to a Distribution System (DS) or another type of wired/wireless network that carries traffic in to and/or out of the BSS. Traffic to STAs that originates from outside the BSS may arrive through the AP and may be delivered to the STAs. Traffic originating from STAs to destinations outside the BSS may be sent to the AP to be delivered to respective destinations. Traffic between STAs within the BSS may be sent through the AP, for example, where the source STA may send traffic to the AP and the AP may deliver the traffic to the destination STA. The traffic between STAs within a BSS may be considered and/or referred to as peer-to-peer traffic. The peer-to-peer traffic may be sent between (e.g., directly between) the source and destination STAs with a direct link setup (DLS). In certain representative embodiments, the DLS may use an 802.11e DLS or an 802.11z tunneled DLS (TDLS). A WLAN using an Independent BSS (IBSS) mode may not have an AP, and the STAs (e.g., all of the STAs) within or using the IBSS may communicate directly with each other. The IBSS mode of communication may sometimes be referred to herein as an “ad-hoc” mode of communication.

[0057] When using the 802.11ac infrastructure mode of operation or a similar mode of operations, the AP may transmit a beacon on a fixed channel, such as a primary channel. The primary channel may be a fixed width (e.g., 20 MHz wide bandwidth) or a dynamically set width. The primary channel may be the operating channel of the BSS and may be used by the STAs to establish a connection with the AP. In certain representative embodiments, Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) may be implemented, for example in 802.11 systems. For CSMA/CA, the STAs (e.g., every STA), including the AP, may sense the primary channel. If the primary channel is sensed/detected and/or determined to be busy by a particular STA, the particular STA may back off. One STA (e.g., only one station) may transmit at any given time in a given BSS.

[0058] High Throughput (HT) STAs may use a 40 MHz wide channel for communication, for example, via a combination of the primary 20 MHz channel with an adjacent or nonadjacent 20 MHz channel to form a 40 MHz wide channel.

[0059] Very High Throughput (VHT) STAs may support 20MHz, 40 MHz, 80 MHz, and/or 160 MHz wide channels. The 40 MHz, and/or 80 MHz, channels may be formed by combining contiguous 20 MHz channels. A 160 MHz channel may be formed by combining 8 contiguous 20 MHz channels, or by combining two non-contiguous 80 MHz channels, which may be referred to as an 80+80 configuration. For the 80+80 configuration, the data, after channel encoding, may be passed through a segment parser that may divide the data into two streams. Inverse Fast Fourier Transform (IFFT) processing, and time domain processing, may be done on each stream separately. The streams may be mapped on to the two 80 MHz channels, and the data may be

transmitted by a transmitting STA. At the receiver of the receiving STA, the above described operation for the 80+80 configuration may be reversed, and the combined data may be sent to the Medium Access Control (MAC).

[0060] Sub 1 GHz modes of operation are supported by 802.11af and 802.11ah. The channel operating bandwidths, and carriers, are reduced in 802.11af and 802.11ah relative to those used in 802.11n, and 802.11ac. 802.11af supports 5 MHz, 10 MHz, and 20 MHz bandwidths in the TV White Space (TVWS) spectrum, and 802.11ah supports 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz bandwidths using non-TVWS spectrum. According to a representative embodiment, 802.11ah may support Meter Type Control/Machine-Type Communications (MTC), such as MTC devices in a macro coverage area. MTC devices may have certain capabilities, for example, limited capabilities including support for (e.g., only support for) certain and/or limited bandwidths. The MTC devices may include a battery with a battery life above a threshold (e.g., to maintain a very long battery life).

[0061] WLAN systems, which may support multiple channels, and channel bandwidths, such as 802.11n, 802.11ac, 802.11af, and 802.11ah, include a channel which may be designated as the primary channel. The primary channel may have a bandwidth equal to the largest common operating bandwidth supported by all STAs in the BSS. The bandwidth of the primary channel may be set and/or limited by a STA, from among all STAs in operating in a BSS, which supports the smallest bandwidth operating mode. In the example of 802.11ah, the primary channel may be 1 MHz wide for STAs (e.g., MTC type devices) that support (e.g., only support) a 1 MHz mode, even if the AP, and other STAs in the BSS support 2 MHz, 4 MHz, 8 MHz, 16 MHz, and/or other channel bandwidth operating modes. Carrier sensing and/or Network Allocation Vector (NAV) settings may depend on the status of the primary channel. If the primary channel is busy, for example, due to a STA (which supports only a 1 MHz operating mode) transmitting to the AP, all available frequency bands may be considered busy even though a majority of the available frequency bands remains idle.

[0062] In the United States, the available frequency bands, which may be used by 802.11ah, are from 902 MHz to 928 MHz. In Korea, the available frequency bands are from 917.5 MHz to 923.5 MHz. In Japan, the available frequency bands are from 916.5 MHz to 927.5 MHz. The total bandwidth available for 802.11ah is 6 MHz to 26 MHz depending on the country code.

[0063] FIG. 1D is a system diagram illustrating the RAN 104 and the CN 106 according to an embodiment. As noted above, the RAN 104 may employ an NR radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 104 may also be in communication with the CN 106.

[0064] The RAN 104 may include gNBs 180a, 180b, 180c, though it will be appreciated that the RAN 104 may include any number of gNBs while remaining consistent with an embodiment. The gNBs 180a, 180b, 180c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In one embodiment, the gNBs 180a, 180b, 180c may implement MIMO technology. For example, gNBs 180a, 180b may utilize beamforming to transmit signals to and/or receive signals from the gNBs 180a, 180b, 180c. Thus, the gNB 180a, for example, may use multiple antennas to transmit wireless signals to, and/or receive wireless signals from, the WTRU 102a. In an embodiment, the gNBs 180a, 180b, 180c may implement carrier aggregation technology. For example, the gNB 180a may transmit multiple component carriers to the WTRU 102a (not shown). A subset of these component carriers may be on unlicensed spectrum while the remaining component carriers may be on licensed spectrum. In an embodiment, the gNBs 180a, 180b, 180c may implement Coordinated Multi-Point (CoMP) technology. For example, WTRU 102a may receive coordinated transmissions from gNB 180a and gNB 180b (and/or gNB 180c).

[0065] The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using transmissions associated with a scalable numerology. For example, the OFDM symbol spacing and/or OFDM subcarrier spacing may vary for different transmissions, different cells, and/or different portions of the wireless transmission spectrum. The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using subframe or transmission time intervals (TTIs) of various or scalable lengths (e.g., containing a varying number of OFDM symbols and/or lasting varying lengths of absolute time).

[0066] The gNBs 180a, 180b, 180c may be configured to communicate with the WTRUs 102a, 102b, 102c in a standalone configuration and/or a non-standalone configuration. In the standalone configuration, WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c without also accessing other RANs (e.g., such as eNode-Bs 160a, 160b, 160c). In the standalone configuration, WTRUs 102a, 102b, 102c may utilize one or more of gNBs 180a, 180b, 180c as a mobility anchor point. In the standalone configuration, WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using signals in an unlicensed band. In a non-standalone configuration WTRUs 102a, 102b, 102c may communicate with/connect to gNBs 180a, 180b, 180c while also communicating with/connecting to another RAN such as eNode-Bs 160a, 160b, 160c. For example, WTRUs 102a, 102b, 102c may implement DC principles to communicate with one or more gNBs 180a, 180b, 180c and one or more eNode-Bs 160a, 160b, 160c substantially simultaneously. In the non-standalone configuration, eNode-Bs 160a, 160b, 160c may serve as a mobility anchor for

WTRUs 102a, 102b, 102c and gNBs 180a, 180b, 180c may provide additional coverage and/or throughput for servicing WTRUs 102a, 102b, 102c.

[0067] Each of the gNBs 180a, 180b, 180c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the UL and/or DL, support of network slicing, DC, interworking between NR and E-UTRA, routing of user plane data towards User Plane Function (UPF) 184a, 184b, routing of control plane information towards Access and Mobility Management Function (AMF) 182a, 182b and the like. As shown in FIG. 1D, the gNBs 180a, 180b, 180c may communicate with one another over an Xn interface.

[0068] The CN 106 shown in FIG. 1D may include at least one AMF 182a, 182b, at least one UPF 184a, 184b, at least one Session Management Function (SMF) 183a, 183b, and possibly a Data Network (DN) 185a, 185b. While the foregoing elements are depicted as part of the CN 106, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.

[0069] The AMF 182a, 182b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 104 via an N2 interface and may serve as a control node. For example, the AMF 182a, 182b may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, support for network slicing (e.g., handling of different protocol data unit (PDU) sessions with different requirements), selecting a particular SMF 183a, 183b, management of the registration area, termination of non-access stratum (NAS) signaling, mobility management, and the like. Network slicing may be used by the AMF 182a, 182b in order to customize CN support for WTRUs 102a, 102b, 102c based on the types of services being utilized WTRUs 102a, 102b, 102c. For example, different network slices may be established for different use cases such as services relying on ultra-reliable low latency (URLLC) access, services relying on enhanced massive mobile broadband (eMBB) access, services for MTC access, and the like. The AMF 182a, 182b may provide a control plane function for switching between the RAN 104 and other RANs (not shown) that employ other radio technologies, such as LTE, LTE-A, LTE-A Pro, and/or non-3GPP access technologies such as WiFi.

[0070] The SMF 183a, 183b may be connected to an AMF 182a, 182b in the CN 106 via an N11 interface. The SMF 183a, 183b may also be connected to a UPF 184a, 184b in the CN 106 via an N4 interface. The SMF 183a, 183b may select and control the UPF 184a, 184b and configure the routing of traffic through the UPF 184a, 184b. The SMF 183a, 183b may perform other functions, such as managing and allocating UE IP address, managing PDU sessions, controlling policy

enforcement and QoS, providing DL data notifications, and the like. A PDU session type may be IP-based, non-IP based, Ethernet-based, and the like.

[0071] The UPF 184a, 184b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 104 via an N3 interface, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices. The UPF 184, 184b may perform other functions, such as routing and forwarding packets, enforcing user plane policies, supporting multi-homed PDU sessions, handling user plane QoS, buffering DL packets, providing mobility anchoring, and the like.

[0072] The CN 106 may facilitate communications with other networks. For example, the CN 106 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the CN 106 and the PSTN 108. In addition, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to the other networks 112, which may include other wired and/or wireless networks that are owned and/or operated by other service providers. In one embodiment, the WTRUs 102a, 102b, 102c may be connected to a local DN 185a, 185b through the UPF 184a, 184b via the N3 interface to the UPF 184a, 184b and an N6 interface between the UPF 184a, 184b and the DN 185a, 185b.

[0073] In view of FIGs. 1A-1D, and the corresponding description of FIGs. 1A-1D, one or more, or all, of the functions described herein with regard to one or more of: WTRU 102a-d, Base Station 114a-b, eNode-B 160a-c, MME 162, SGW 164, PGW 166, gNB 180a-c, AMF 182a-b, UPF 184a-b, SMF 183a-b, DN 185a-b, and/or any other device(s) described herein, may be performed by one or more emulation devices (not shown). The emulation devices may be one or more devices configured to emulate one or more, or all, of the functions described herein. For example, the emulation devices may be used to test other devices and/or to simulate network and/or WTRU functions.

[0074] The emulation devices may be designed to implement one or more tests of other devices in a lab environment and/or in an operator network environment. For example, the one or more emulation devices may perform the one or more, or all, functions while being fully or partially implemented and/or deployed as part of a wired and/or wireless communication network in order to test other devices within the communication network. The one or more emulation devices may perform the one or more, or all, functions while being temporarily implemented/deployed as part of a wired and/or wireless communication network. The emulation device may be directly coupled to

another device for purposes of testing and/or performing testing using over-the-air wireless communications.

[0075] The one or more emulation devices may perform the one or more, including all, functions while not being implemented/deployed as part of a wired and/or wireless communication network. For example, the emulation devices may be utilized in a testing scenario in a testing laboratory and/or a non-deployed (e.g., testing) wired and/or wireless communication network in order to implement testing of one or more components. The one or more emulation devices may be test equipment. Direct RF coupling and/or wireless communications via RF circuitry (e.g., which may include one or more antennas) may be used by the emulation devices to transmit and/or receive data.

[0076] Cell search is the procedure by which a WTRU acquires time and frequency synchronization with a cell and detects the Cell ID of that cell. Synchronization signals may be transmitted in the 0th and 5th subframes of every radio frame and may be used for time and frequency synchronization during initialization. As part of the system acquisition process, a WTRU synchronizes sequentially to the OFDM symbol, slot, subframe, half-frame, and radio frame based on the synchronization signals. The two synchronization signals are Primary Synchronization Signal (PSS) and Secondary Synchronization Signal (SSS).

[0077] A PSS may be used to obtain slot, subframe and half-frame boundary. It also provides physical layer cell identity (PCI) within the cell identity group.

An SSS may be used to obtain the radio frame boundary. It also may enable the WTRU to determine the cell identity group, which may range from 0 to 167.

[0078] Following a successful synchronization and PCI acquisition, the WTRU may decode the Physical Broadcast Channel (PBCH) with the help of CRS and acquire the MIB information regarding system bandwidth, System Frame Number (SFN) and PHICH configuration. The synchronization signals and PBCH may be transmitted continuously according to the standardized periodicity.

[0079] An eNB and/or a WTRU may use a random access procedure for one or more of the following: WTRU initial access (for example to a cell or eNB), reset of UL timing (for example to reset or align WTRU UL timing with respect to a certain cell), or reset of timing during handover (for example to reset or align WTRU timing with respect to the handover target cell). The WTRU may transmit a certain physical random access channel (PRACH) preamble sequence at a certain power PPRACH, which may be based on configured parameters and/or measurements. The WTRU may

transmit the preamble using a certain time-frequency resource or resources. The configured parameters, which may be provided or configured by the eNB, may include one or more of initial preamble power (e.g., `preambleInitialReceivedTargetPower`), a preamble format based offset (e.g., `deltaPreamble`), a random access response window (e.g., `ra-ResponseWindowSize`), a power ramping factor (e.g., `powerRampingStep`), and a maximum number of retransmissions (e.g., `preambleTransMax`). The PRACH resources (which may include preambles, sets of preambles, or time/frequency resources which may be used for preamble transmission) may be provided or configured by the eNB. The measurements may include pathloss. The time-frequency resource(s) may be chosen by the WTRU from an allowed set or may be chosen by the eNB and signaled to the WTRU. Following WTRU transmission of a preamble, if the eNB may detect the preamble, it may respond with a random access response (RAR). If the WTRU is unable to receive or does not receive an RAR for the transmitted preamble (which may, for example, correspond to a certain preamble index and/or time/frequency resource), within an allotted time (for example, `ra-ResponseWindowSize`), the WTRU may send another preamble at a later time, at a higher power (for example, higher than the previous preamble transmission by `powerRampingStep`). The transmission power may be limited by a maximum power, for example a WTRU configured maximum power, which may be for the WTRU as a whole (for example `PCMAX`) or for a certain serving cell of the WTRU (for example `PCMAX,c`). The WTRU may wait again for receipt of an RAR from the eNB. This sequence of transmitting and waiting may continue until the eNB may respond with an RAR or until the maximum number of random access preamble transmissions (for example, `preambleTransMax`) may have been reached. The eNB may transmit and the WTRU may receive the RAR in response to a single preamble transmission.

[0080] A particular instance of a random access procedure may be contention-based or contention-free. A contention-free procedure may be initiated by a request, for example from an eNB. The initiating request may, for example, be provided via physical layer signaling such as a PDCCH order or by higher layer signaling such as an RRC reconfiguration message (e.g., an RRC connection reconfiguration message) which may include mobility control information and may, for example, indicate or correspond to a handover request. In one example of a contention-free procedure, the procedure may be initiated by a PDCCH order in subframe  $n$ , the PRACH preamble may be transmitted in the first subframe (or the first subframe available for PRACH)  $n + k2$ , where  $k2$  may be  $\geq 6$ . When initiated by an RRC command, there may be other delays which may be specified. For instance, there may be minimum and/or maximum required or allowed delays. The WTRU may autonomously initiate a contention-based procedure for reasons which may include

initial access, restoration of UL synchronization, or recovery from radio link failure. For certain events, such as events other than recovery from radio link failure, it may not be defined or specified as to how long after such an event the WTRU may send the PRACH preamble.

[0081] For a contention-free random access procedure, a network-signaled PRACH preamble may be used, e.g., by a WTRU. For a contention-based random access procedure, the WTRU may autonomously choose a preamble where the preamble format and/or the time/frequency resource(s) available for preamble transmissions may be based on an indication or index (e.g., a parameter such as PRACH Configuration\_Index) which may be provided or signaled by an eNB. One or more preambles transmitted at the progressively higher transmit powers may be detected by the eNB. An RAR may be sent by the eNB in response to a detected preamble. A PRACH preamble may be considered a PRACH resource. For example, PRACH resources may include a PRACH preamble, time, and/or frequency resources. The terms RACH resources and PRACH resources may be used interchangeably. Further, the terms random access, RA, RACH, and PRACH may be used interchangeably.

[0082] In wireless communication systems in which a central node (e.g. gNB) serves a set of WTRUs, the opportunity to send transport blocks (TBs) from those WTRUs to the central node is administered by the central node. For instance, the gNB may schedule an individual WTRU uplink (UL) transmission by assigning separate time-frequency resources to each WTRU and granting each resource to one WTRU. Such an arrangement for UL transmission may be referred to as grant-based UL transmission. On the other hand, a gNB may announce the presence of one or more time-frequency resources and allow a set of WTRUs to use each resource, hence allowing access without a specific UL grant.

[0083] Use cases considered during development of 3GPP New Radio (NR) include ultra-reliable low-latency communication (URLLC), massive machine-type communication (mMTC or MMTC), and enhanced mobile broadband (eMBB or EMBB) communication. URLLC may enable devices and machines to communicate with ultra-reliability, very low latency and high availability, making it ideal for vehicular communication, industrial control, factory automation, remote surgery, smart grids and public safety applications. EMBB focuses on enhancements to variety of parameters such as data rate, delay and coverage of mobile broadband access. MMTC is designed to enable communication between devices that are low-cost, massive in number and battery-driven and is intended to support applications such as smart metering, logistics, and field and body sensors

[0084] In unlicensed bands, a gNB or a WTRU may need to perform a listen-before-talk (LBT) procedure before accessing the unlicensed wireless channel. Depending on the regulatory

requirements of the unlicensed channel, the parameters for LBT procedures may vary. An LBT procedure may consist of a fixed and/or random-duration interval in which a wireless node (e.g. a gNB or a WTRU) listens to a medium. If the energy level detected from the medium exceeds a threshold specified by a regulatory body, the gNB or WTRU may refrain from transmitting any wireless signal. Otherwise the wireless node may transmit its desired signal after completion of the LBT procedure.

[0085] In some regulatory regimes, LBT procedures are mandatory for unlicensed channel usage, and as a consequence, the various LBT categories were adopted in 3GPP LAA (Release 13), eLAA (Release 14) and feLAA (Release 15). The LBT Category 4 (CAT 4) scheme, adopted in LAA/eLAA, has been identified as a scheme appropriate for many use cases. The LBT CAT 4 procedure starts when an eNB or gNB (and in some cases a WTRU) wants to transmit control or data in an unlicensed channel. The device may conduct an initial clear channel assessment (CCA), in which the device determines whether the channel is idle for a period of time. The period of time for assessment may be a sum of a fixed period of time and a pseudo-random duration. The availability of the channel may be determined by comparing the level of energy detected (ED) across the bandwidth of the unlicensed channel to an energy threshold that is determined by the regulatory body.

[0086] If the channel is determined to be available or free, the transmission may proceed. If not, the device may conduct a slotted random back-off procedure. In a random back-off procedure, a random number may be selected from a specified interval called the contention window. A back-off countdown may be obtained and the channel may be verified if idle or not. The transmission may be initiated when the back-off counter goes to zero. After the eNB or gNB has gained access to the channel, it may be allowed to transmit for a limited duration referred to as the maximum channel occupancy time (MCOT). The CAT 4 LBT procedure with random back-off and variable contention window sizes may enable fair channel access and coexistence with other Radio Access Technologies (RATs) such as Wi-Fi and other LAA networks.

[0087] In licensed operation assisted—or non-standalone—access, an unlicensed band operation could rely on the assistance of a primary component carrier in a licensed band. In contrast, in NR-U standalone operations, all functionalities and features should be fulfilled on unlicensed bands including initial access. Initial access is essential for standalone operation. Due to spectrum characteristics and regulatory requirements, such as the uncertainty of channel availability and the Occupied Channel Bandwidth (OCB) requirement, designs are needed to enable initial access in a licensed band to be compatible with unlicensed band operation.

[0088] NR supports multiple RACH preamble formats, including long PRACH formats with preamble length 839 and short PRACH formats with preamble length 139. The cell range for unlicensed band operation may be smaller than that of licensed band operation due to transmission power constraints. The short PRACH format may be better suited to small cells, such as those used in NR-U unlicensed bands. During a random access procedure, LBT procedures may need to be performed. Failure of LBT procedures could lead to performance degradation of RACH performance. For instance, if LBT procedures fail before a PRACH preamble is transmitted, configuration of RACH resources may also be impacted. And, in any case, a PRACH preamble transmission should fulfil applicable OCB requirements. Therefore, those who implement RACH and preamble transmission procedures in unlicensed bands should consider the impact of LBT procedures and the requirement of OCB for NR-U.

[0089] Random access methods and procedures may be simplified as described herein. When a four-step random access procedure is used in a NR unlicensed spectrum, a corresponding LBT procedure may need to be performed for each step during RACH procedures. The required overhead and delay of random access associated with LBT operations may need to be considered. For example, since more LBTs are needed, the overhead associated with LBT procedures may be higher. In addition, since LBT may be required to be performed for each RACH step, the delay caused by LBT may be larger. The RACH transmission may be delayed due to channel access failure arising from larger volume of LBT processes. Thus, reducing the number of steps for random access procedures may be beneficial for NR unlicensed spectrum. If the number of steps for random access is reduced, the number of required LBTs may also be reduced. The corresponding delay, latency and overhead for random access of WTRUs may be mitigated and reduced. A reduced-step method for random access—e.g., a two-step method—may be designed for NR-U.

[0090] When a two-step RACH is used, for example, in the first step, a preamble (Msg1) and an RRC connection request (Msg3) may be transmitted simultaneously or consecutively. In this case, an additional LBT procedure for transmitting Msg3 may not be necessary since Msg1 and Msg3 are combined into a single step. A combination of Msg1 and Msg3 may be referred to MsgA. Msg1 may be preamble in MsgA and Msg3 may be PUSCH in MsgA. In other words, MsgA may consist of two parts, preamble and PUSCH, where PUSCH may carry a data payload. A Msg1 and Msg3 transmission can be multiplexed through frequency-division (FDM) or time-division (TDM) techniques. A time-division multiplexed Msg1 and Msg3 may be allocated such that the transmission gap between Msg1 and Msg3 is small. For example, it may be specified that the transmission gap  $X \mu s$  is zero or a number less than  $16 \mu s$ . The transmission gap between Msg1

and Msg3 may be predetermined, configured or indicated. For example, the transmission gap of X  $\mu$ s may be indicated in remaining minimum system information (RMSI), other system information (OSI), or other signals or channels. Msg1 in a 2-step RACH procedure may be the same, similar or different from the Msg1 in 4-step RACH. Msg3 in a 2-step RACH procedure may be the same, similar or different from the Msg3 in 4-step RACH. Msg1 and preamble may be used interchangeably. Msg3 and PUSCH may be used interchangeably.

[0091] FIG. 2 provides a comparison between TDM and FDM transmissions of Msg1 and Msg3. Instance 201 shows an example of a TDM signal, where Msg1 is transmitted via a RACH occasion #w and an associated PUSCH occasion #0 carries Msg3 after a transmission gap. In this scenario, when the transmission gap is sufficiently long, two separate LBT procedures may be necessary. Instance 202, on the other hand, provides another example of a TDM signal where RACH occasion #w and PUSCH occasion #0 carry Msg1 and Msg3 without a transmission gap. Here, only a single LBT procedure is necessary. Finally, instance 203 shows an example of an FDM signal where only a single LBT procedure is performed. Since Msg1 and Msg3 may be sent concurrently in different frequency resources via RACH occasion #w and PUSCH occasion #0, a WTRU need only monitor for collision avoidance once.

[0092] FIG. 3 provides a flowchart with an example process for determining the technique by which to multiplex the preamble and PUSCH of MsgA or to multiplex the Msg1 and Msg3 transmissions. In one embodiment, whether LBT procedures fail or succeed may be used to determine the multiplexing type to be used for preamble and PUSCH transmission. At step 301, a WTRU may determine whether LBT procedures have succeeded or failed. For example, LBT procedures may fail when a WTRU determines that a channel is blocked by one or more ongoing UL transmissions. In this case, at step 302a, the WTRU may determine that the appropriate multiplexing type for transmission of Msg1 and Msg3 or the appropriate multiplexing type for transmission the preamble and PUSCH is FDM. Otherwise, if the WTRU determines through LBT procedures that the channel is open, the WTRU may determine to multiplex Msg1 and Msg3 or multiplex the preamble and PUSCH via TDM, shown by step 302b.

[0093] In another embodiment, the WTRU may determine the multiplexing technique via other factors such as service type or service requirement. In another instance, the WTRU may consider LBT procedure success or failure in connection with the above-mentioned factors to determine the multiplexing technique.

[0094] One example for association and utilization of PRACH resources and Msg3 resources is shown in FIG. 4. PRACH resources may also be referred to as a RACH occasion (RO), while the

resources for Msg3 may be referred to as a PUSCH occasion (PO). Both an RO and PO may include resources in time domain and frequency domain that are available for their respective transmissions. In the context of FIG. 4, Msg1 and Msg3 may be transmitted according to a predefined, configured or indicated resource location for RO and Msg3 resource, and the RACH occasion may be configured by the PRACH\_configuration\_index parameter in a similar way as in NR. Since Msg3 may be transmitted together with Msg1, Msg3 may be transmitted without an UL grant. In this case, the resource over which Msg3 may be transmitted may need to be defined or indicated. For example, the resources for a WTRU that transmits a preamble together with Msg3 may be configured or indicated.

[0095] The association between the resources for preamble transmission and Msg3 transmission may be used to implement a two-step RACH procedure. The association between the resources for preamble transmission and Msg3 or PUSCH transmission may be predetermined, configured or indicated, and may be based on frequency, for example. For instance, the association between the resources for preamble transmission and Msg3 or PUSCH transmission may be based on frequency range or frequency band. One association (e.g., association type 1) may be used for frequency range 1 (e.g., FR1) and another association (e.g., association type 2) may be used for another frequency range (e.g., FR2).

[0096] As shown in FIG. 4, the association between the resources for Msg1 (or preamble) transmission, 402, and the resources for Msg3 (or PUSCH) transmission, 401, may be a function of a number of SSBs and/or the resources designated in a RACH occasion. For instance, PO #0 may be associated with a first group of preambles 0-15 based on information transmitted in an SSB in addition to the resources designated for transmission of the preamble—RO #w. On the other hand, a second group of preambles 16-31 may be associated with PO #1 without regard to an SSB or RO. In this case, preamble associations with PO may be mapped on a one-to-one, many-to-one, or one-to-many basis. The associations between Msg1 (preamble) and Msg3 (PUSCH) may be predetermined, configured or indicated. In a PUSCH transmission, there may be demodulation reference signal (DMRS). The DMRS may have a DMRS port and DMRS sequence. The preamble may be associated with the PUSCH resources (or PO), DMRS port and DMRS sequence. The preamble associations with the PO, DMRS port and DMRS sequence may be mapped on a one-to-one, many-to-one, or one-to-many basis. The preamble associations with a PO may be a function of RO (e.g., RO index) and/or SSB (e.g., SSB index).

[0097] A preamble may be associated with a PUSCH as well as DMRS port and DMRS sequence of a PUSCH, or a combination of these elements. The preamble associations with PO,

DMRS port, and DMRS sequence may be a function of RO (e.g., RO index) and/or SSB (e.g., SSB index).

[0098] Further to the above example, the associations between the resources for preamble transmission and Msg3 or PUSCH transmission may be based on actually transmitted SSBs or a maximum number of SSBs, L. For example, one association (e.g., association type 1) may be used for one SSB transmission (e.g., L=4) and another association (e.g., association type 2) may be used for another SSB transmission (e.g., L=64).

[0099] FIG 5. provides a method for Msg3 resource allocation based on the selection of a preamble by a WTRU. For an RO 501, there may be up to 64 preambles that a WTRU may use to transmit Msg1 simultaneously thanks to the correlation feature of the Zadoff-Chu (ZC) sequence. Thus, the Msg3 resources 511, 512, 513, and 514 may be associated with one of several ranges of preamble indices, 521, 522, 523, and 524. However, one resource allocation may only support transmission of Msg3 by one WTRU if code division multiplexing is not used. In this way, compared with resource allocation of Msg1, configuring a Msg3 resource for each preamble index may be resource inefficient or infeasible. Hence, as shown in FIG. 5, the selection of Msg3 resources may be defined by a rule, such as that the Msg3 resources may be associated with the selected preamble or Msg1. For example, a WTRU that selects preamble index 0 may transmit Msg3 in Msg3 Resource 0. There may be collision between Msg3 transmissions if two or more WTRUs transmit the preambles that are associated with the same Msg3 resources. Various measures may be deployed to prevent such collisions from occurring. For example, a cover code may be added to the Msg3 or PUSCH transmission based on the preamble index to make the Msg3 transmissions are orthogonal to each other. A scrambling code may be added to the Msg3 or PUSCH transmission based on the preamble index, DMRS port index and/or DMRS sequence index to ensure the Msg3 or PUSCH transmissions are orthogonal to each other. A scrambling code or cover code that is added to the Msg3 or PUSCH transmission may depend on a preamble index, DMRS port index and/or DMRS sequence index or other index or the like. A scrambling code or cover code that is added to a Msg3 or PUSCH transmission may be a function of a preamble index, DMRS port index, DMRS sequence index, WTRU ID, RNTI (e.g., RA-RNTI, MsgB-RNTI) or any other index or the like.

[0100] A flowchart describing the overall process for random access according to a simplified method is shown in FIG. 6. At step 601, a WTRU receives a configuration for RACH resources. At step 602, a WTRU receives associations between an RO and a PUSCH occasion (PO), which may carry Msg3 (or a data payload of MsgA). The WTRU may then select a preamble and RO at step 603. At step 604, the WTRU may determine the multiplexing technique for the Msg1 (or preamble)

and Msg3 (or PUSCH) transmissions. At step 605, the WTRU may assess whether the association between the preamble and PO is a function of a received SSB and/or the RO. If so, at step 606a, the WTRU may determine the specific PO based on a combination of factors including the selected preamble, the SSB/RO, and the multiplexing type determined in step 604. If the WTRU has determined the association is not a function of a received SSB/RO, at step 606b, the WTRU may instead determine the specific PO for transmission based on the selected preamble and determined multiplexing type. At step 607, the WTRU may transmit the selected preamble in the selected RO and the PUSCH in the determined PO using the determined multiplexing type.

[0101] After a WTRU transmits Msg1 (or preamble) and Msg3 (or PUSCH), a gNB may need to detect and decode Msg1 (or preamble) and Msg3 (or PUSCH). There may be three cases for this step. In case 1, a gNB may detect neither Msg1 nor Msg3. In case 2, a gNB may detect Msg1 but not Msg3. This may happen when Msg3 transmission collision occurs—for example, when multiple WTRUs choose the same resource for Msg3 transmission, or when propagation channel or link quality is poor. In case 3, a gNB may detect both Msg1 and Msg3. The gNB may need to associate the detected preamble of Msg1 and Msg3. Hence, in Msg3, the information needed for the gNB to associate the corresponding preamble and Msg3 may be included. For instance, Msg3 may include a preamble index or a relative preamble index.

[0102] Possible solutions for the above three cases may include the following. For Case 1, gNB may be unable to reply with Msg2 and Msg4 (or MsgB) since neither Msg1 nor Msg3 (or MsgA) has been received. In this case, the WTRU may retransmit the preambles. For Case 2, according to the detected preamble, the gNB may have received an indication that a WTRU is performing RACH procedures in order to access the network, but the corresponding Msg3 (or PUSCH of MsgA) may be missed. The gNB may transmit Msg2 (or MsgB) with an UL grant to WTRU for Msg3 retransmission corresponding to the detected preambles. This may allow the WTRU to fall back from a 2-step RACH procedure to a 4-step RACH or allow a reduced-step RACH procedure to become a full-step RACH procedure. Msg2 and MsgB may share the same format and may be multiplexed together. For example, the format of MsgB may be used as a common format for both Msg2 and MsgB. Inside the MsgB format, there may be an indication to indicate which message is carried—namely, Msg2 (a random access response (RAR)) or MsgB. An RAR may be a successful RAR, e.g., for MsgB, or fallback RAR, e.g., for Msg2. For Case 3, a gNB may send back Msg2 and Msg4 (or MsgB) simultaneously for each detected preamble. MsgB may be a combination of Msg2 and Msg4. MsgB is the second step of a two-step RACH procedure, which is a downlink transmission and MsgA is the first step of a two-step RACH procedure which is an uplink transmission.

[0103] Considering one scenario, shown in FIG. 7, a gNB 701, a WTRU 702, and a WTRU 703 may be operating in a cell 700. WTRU 702 may be performing random access procedures in conjunction with gNB 701. WTRU 703 may be operating in a RRC-connected mode. WTRU 702 may have a shorter propagation delay for communications with the gNB 701 than WTRU 703, for example, because it is closer in distance to the gNB 701 than WTRU 703, as FIG. 7 shows.

[0104] FIG. 8 depicts the timing of a preamble transmission by a WTRU performing RACH procedures and an UL (data/control) transmission by a WTRU operating in an RRC-connected mode, as in the scenario of FIG. 7. As shown in FIG. 8, gNB 801 may transmit an SSB 811. WTRU 802 may be attempting initial access, and WTRU 803 may be operating in RRC-connected mode. WTRU 802 may have a time delay of  $T_1$ , and WTRU 803 may have a time delay of  $T_2$ , which in this case, is greater than  $T_1$ . Thus WTRU 803 may receive the transmitted SSBs at a later point in time than WTRU 802, as shown by SSBs 812 and 813. As WTRU 802 is performing RACH procedures, it may determine to transmit a preamble 821. WTRU 803 may be scheduled to transmit UL data or control information 822, however, at the same time slot. WTRU 803 may transmit the UL data 822 with a timing advance (TA) equal to  $T_2$ , while WTRU 802 may not know the TA. WTRU 802 may perform LBT based on the timing of its detected SSB 812, commencing such procedures after delay  $T_1$ . The time offset between the conclusion of LBT procedures by the connected WTRU 803 and the reception 823 of WTRU 803's UL transmission by WTRU 802 may be measured by  $T_3$ . The time offset between the beginning of the UL transmission by WTRU 803 and the preamble transmission by WTRU 802 may be defined by  $T_1 + T_2$ . Here,  $T_3$  is less than  $T_1 + T_2$ , and the transmission of UL data by WTRU 803 may interfere with LBT procedures conducted by WTRU 802, causing LBT to fail and thus blocking the preamble transmission by WTRU 802.

[0105] FIG. 9 provides a solution to the problem presented in FIG. 8. Similar to the scenario in FIG. 8, gNB 901 may transmit an SSB, which may be received by WTRUs 902 and 903. WTRU 902 may be scheduled to transmit a preamble 921 in the same time slot as a scheduled UL transmission 922 by WTRU 903. In this case, however, WTRU 903 may introduce a guard period 912 between the end of the LBT procedure 911 and the beginning of the UL transmission 922. Because the time represented by  $T_3$  plus the guard period is greater than  $T_1 + T_2$ , WTRU 902 is allowed to complete LBT procedures before receiving WTRU 903's UL transmission at 923.

[0106] FIG. 10 depicts a worst-case scenario in which two WTRUs are located in close proximity to each other near the boundary of the same cell 1000. As in the scenario presented in FIG. 7, WTRU 1002 may be attempting RACH procedures, and WTRU 1003 may be operating in an RRC-

connected mode. The time delay from the boundary of the cell 1000 to the gNB 1001 may be defined as  $T_{\text{cell}}$ .

[0107] FIG. 11 provides a timing diagram showing the WTRU 1102 transmitting a preamble 1121 and WTRU 1103 sending UL transmission 1122. As in the scenario defined in FIG. 10, because both WTRUs are located in close proximity, time delays 1111 and 1112 from the gNB 1101 to WTRUs 1102 and 1103 may be close to equal, and may be defined as  $T_{\text{cell}}$ . Thus, because there is little-to-no delay between the transmission 1122 of UL signals and the reception 1123 by WTRU 1102 of the UL transmission,  $T_3$  may approach zero. To avoid blocking the preamble transmission of WTRU 1102, a guard time duration may be inserted or used at the beginning of WTRU 1103's UL transmission, and the guard time may have a duration equal to  $2T_{\text{cell}}$ . The guard time duration may be, for example, several OFDM symbols in duration.

[0108] Multiple BWPs may be used for RACH procedures, as depicted in FIG. 12. As shown, to increase the number of transmission opportunities during RACH procedures, a WTRU may perform LBT procedures 1211, 1212, or 1213 in different BWPs 1201, 1202, or 1203. The WTRU may then transmit the preamble in a BWP that is available or free in any of ROs 1221, 1222, or 1223. A gNB may perform LBT procedures 1231, 1232, and 1233 in different BWPs and may send back RARs 1241, 1242, or 1243 in the BWP that is available or free. In this way, as long as one BWP is available or free, a preamble and RAR may be transmitted. However, if gNB 1201 is capable of transmitting a RAR in any available BWP, a WTRU may need to be capable of monitoring all BWPs simultaneously in order to receive the RAR over a PDCCH or PDSCH. Considering that some WTRUs may not have such capability, a RAR may be transmitted over a PDCCH or PDSCH in any available BWP and may be detected by WTRUs possessing even narrow band capability.

[0109] FIG. 13 provides a solution to the problem presented in FIG. 12. As shown in FIG. 13, a WTRU may perform LBT procedures in different BWP and transmit the preamble at the BWP that is available. A gNB may perform LBT procedures in BWPs 1301, 1302, and 1303, and send a RAR at the BWP that is available. Here, however, the WTRU may monitor BWPs according to a preconfigured or indicated order. A network may preconfigure or indicate a priority order for different or multiple BWPs. For example, the use, monitoring or detection of BWPs may follow the priority as BWP2  $\rightarrow$  BWP1  $\rightarrow$  BWP3. The gNB may repeatedly transmit a RAR over a PDCCH in a control resource set (CORESET) according to the preconfigured or indicated order for BWPs. BWP 1302, for example, may have the highest priority if it is free. The gNB may transmit the RAR over a PDCCH 1312 only once in BWP 1302, and the WTRU may monitor BWP 1302 first to see if there is a PDCCH transmission carrying a RAR for the WTRU. If BWP 1302 is not free, the gNB may

transmit RARs 1311a and 1311b via a PDCCH—e.g., twice in BWP 1301. After monitoring BWP 1302, WTRU may not find the corresponding RAR, and the WTRU may switch to BWP 1301 to monitor the PDCCH for the RAR. Similarly, if BWP 1301 and BWP 1302 are not available, and BWP 1303 is free, the gNB may transmit the RAR over the PDCCH in BWP 1303 with, for example, three repetitions 1313a, 1313b, and 1313c. After monitoring BWP 1302 and BWP 1301, the WTRU may not detect the corresponding PDCCH carrying the RAR, and the WTRU may switch to BWP 1303 to monitor the third PDCCH for a RAR in BWP 1303.

[0110] Different types of LBT procedures may be used for different types of UL transmissions. For example, for a signature-based UL transmission, if energy-based LBT is used, then a system may not fully benefit from any advantages provided by code division multiplexing. On the other hand, for data-based UL transmissions, if signature-based LBT procedures are used, they may increase the detection complexity because signature-based LBT procedures requires correlation to be performed for all possible signatures or sequences. Energy-based LBT procedures, on the other hand, may be sufficient for data-based transmission. There may be a trade-off between signature-based LBT and energy-based LBT in terms of complexity and performance. Therefore, LBT types such as signature-based LBT and energy-based LBT may be selected depending on an UL transmission type, signal or channel. Which LBT type, signature-based LBT and energy-based LBT is to be selected may be indicated by another signal or channel, configured by network or gNB, or predetermined or based on an association between LBT type and UL transmission (e.g., UL signal, channel, etc).

[0111] In one solution, sequence-based LBT procedures (which may be considered a subset of signature-based LBT procedures) may be used for monitoring the resources employing code division multiplexing while energy-based LBT may be used for monitoring the resources employing payload-based transmission. Payload-based transmissions may include, for example, data transmissions and/or control information transmissions. Sequence-based transmissions may include, for instance, PRACH preambles, transmissions over a PUCCH using ZC sequences, demodulation reference signals (DMRSs) using ZC sequences, and sounding reference signals (SRSs) using ZC sequences, among others. A WTRU may select the proper LBT procedure type for the resources, which may be based on sequence-based transmission or payload-based transmission. Considering each of these, mechanisms may be designed to improve collision avoidance, optimize channel occupancy, and reduce channel blocking and delay due to uncertainty in an unlicensed band.

[0112] Although features and elements are described above in particular combinations, one of ordinary skill in the art will appreciate that each feature or element can be used alone or in any combination with the other features and elements. In addition, the methods described herein may be implemented in a computer program, software, or firmware incorporated in a computer-readable medium for execution by a computer or processor. Examples of computer-readable media include electronic signals (transmitted over wired or wireless connections) and computer-readable storage media. Examples of computer-readable storage media include, but are not limited to, a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, and optical media such as CD-ROM disks, and digital versatile disks (DVDs). A processor in association with software may be used to implement a radio frequency transceiver for use in a WTRU, UE, terminal, base station, RNC, or any host computer.

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## CLAIMS

### What is Claimed:

1. A method for accessing a channel in a New Radio (NR) network, the method comprising:
  - receiving a configuration for a random access channel (RACH) occasion (RO), the configuration indicating frequency resources and time resources in which to transmit one or more preambles;
  - receiving an indication associating the one or more preambles with one or more physical uplink shared channel (PUSCH) occasions (POs), each PO including frequency resources and time resources over which to transmit a radio resource connection (RRC) request;
  - selecting a preamble and a RO in which to perform listen-before-talk (LBT) procedures to determine a channel availability;
  - determining a multiplexing technique for transmission of the preamble and RRC request;
  - selecting, based on the selected preamble and determined multiplexing technique, an associated PO over which to transmit the RRC request;
  - multiplexing the selected preamble and the RRC request according to the determined multiplexing technique; and
  - transmitting the multiplexed preamble in the selected RO and the multiplexed RRC request in the selected PO.
2. The method of claim 1, wherein the determined multiplexing technique is based on at least one of the channel availability, a service type, or a service requirement.
3. The method of claim 1, wherein the one or more preambles are associated with the one or more POs based on at least one of a received synchronization signal block (SSB) or the configured RO.
4. The method of claim 3, wherein selecting an associated PO is further based on a combination of a selected preamble, the received SSB, the configured RO, and the determined multiplexing technique.
5. The method of claim 1, wherein, on a condition a channel is not available, the determined multiplexing technique is frequency-division multiplexing (FDM), and, on a condition a channel is available, the determined multiplexing technique is time-division multiplexing (TDM).

6. The method of claim 1, further comprising transmitting the multiplexed preamble in the selected RO and the multiplexed RRC request in the selected PO simultaneously or consecutively.

7. A WTRU for use in a New Radio (NR) network, the WTRU comprising:

a receiver configured to receive a configuration for a random access channel (RACH) occasion (RO), the configuration indicating frequency resources and time resources in which to transmit one or more preambles; receive an indication associating the one or more preambles with one or more physical uplink shared channel (PUSCH) occasions (POs), each PO including frequency resources and time resources over which to transmit a radio resource connection (RRC) request;

a processor configured to select a preamble and an RO in which to perform listen-before-talk (LBT) procedures to establish a channel availability; determine a multiplexing technique for transmission of the preamble and the RRC request; select, based on the selected preamble and determined multiplexing technique, an associated PO over which to transmit the RRC request; and multiplex the selected preamble and RRC request according to the determined multiplexing technique; and

a transmitter configured to transmit the multiplexed preamble in the selected RO and the multiplexed RRC request in the selected PO.

8. The WTRU of claim 7, further configured to determine the multiplexing technique based on at least one of the channel availability, a service type, or a service requirement.

9. The WTRU of claim 7, further configured to determine an association of the one or more POs with the selected preamble based on at least one of a received synchronization signal block (SSB) or the configured RO.

10. The WTRU of claim 9, further configured to select an associated PO based on a combination of the selected preamble, the SSB, the configured RO, and the determined multiplexing technique.

11. The WTRU of claim 7, further configured to, on a condition a channel is not available, multiplex the preamble and RRC request transmissions via frequency-division multiplexing (FDM), and, on a condition a channel is available, multiplex the preamble and RRC request transmissions via time-division multiplexing (TDM).

12. The WTRU of claim 7, further configured to transmit the multiplexed preamble in the selected RO and the multiplexed RRC request in the selected PO simultaneously or consecutively.

13. A gNB for use in a New Radio (NR) network, the gNB comprising  
a transmitter configured to transmit a configuration for a random access channel (RACH) occasion (RO), the configuration indicating frequency resources and time resources in which to transmit a preamble; transmit an indication associating the preamble with a physical uplink shared channel (PUSCH) occasions (PO), the PO including frequency resources and time resources over which to transmit a radio resource connection (RRC) request; and  
a receiver configured to receive the preamble transmission in the provided RO and the RRC request transmission in the PO.

14. The gNB of claim 13, further configured to transmit, on a condition that the gNB has received the preamble but not the RRC request, an uplink (UL) grant requesting retransmission of the RRC request.

15. The gNB of claim 13, further configured to associate the received preamble and RRC request transmissions based on at least one of an implicit indication or a field included in the preamble transmission.

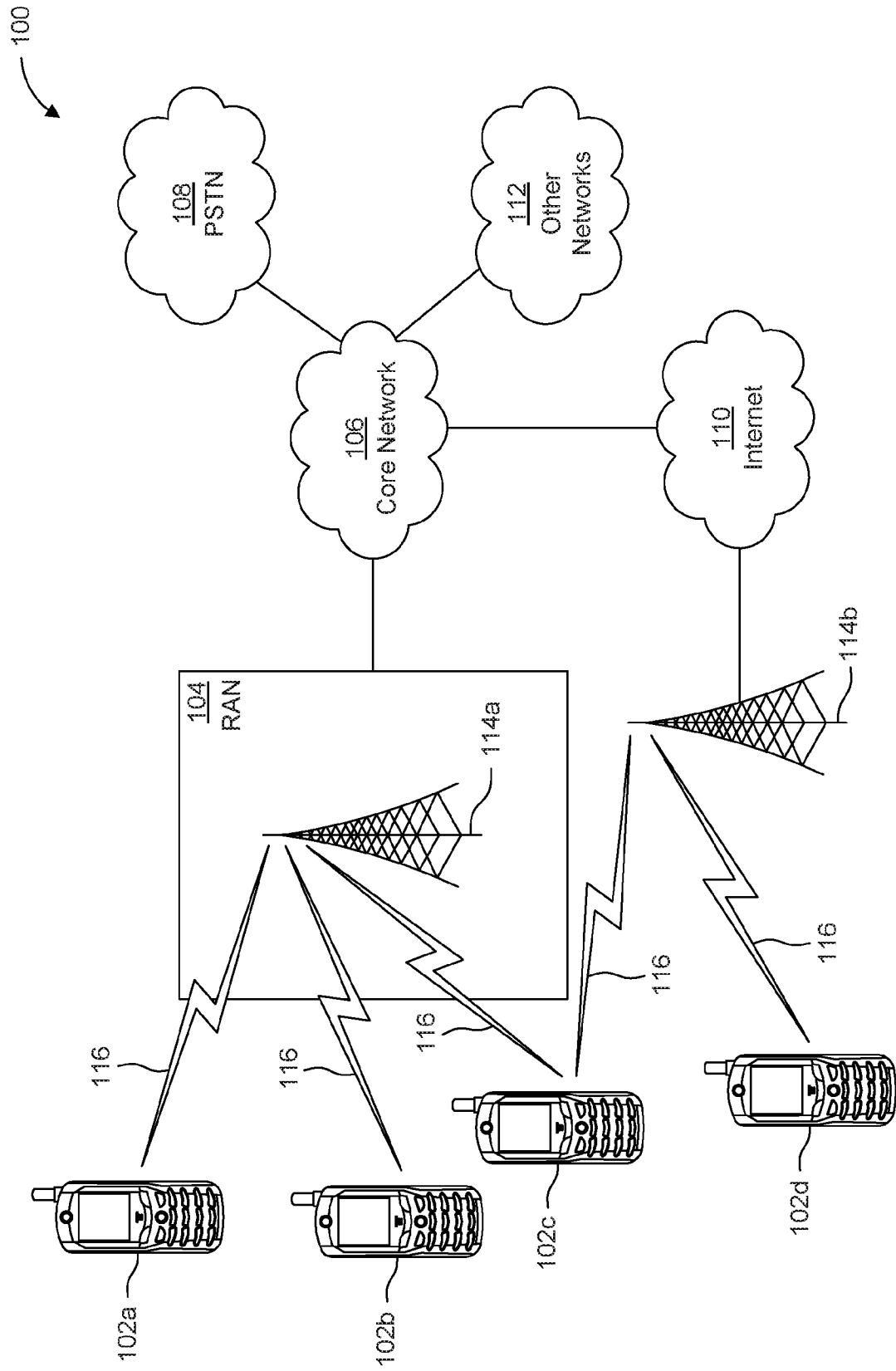


FIG. 1A

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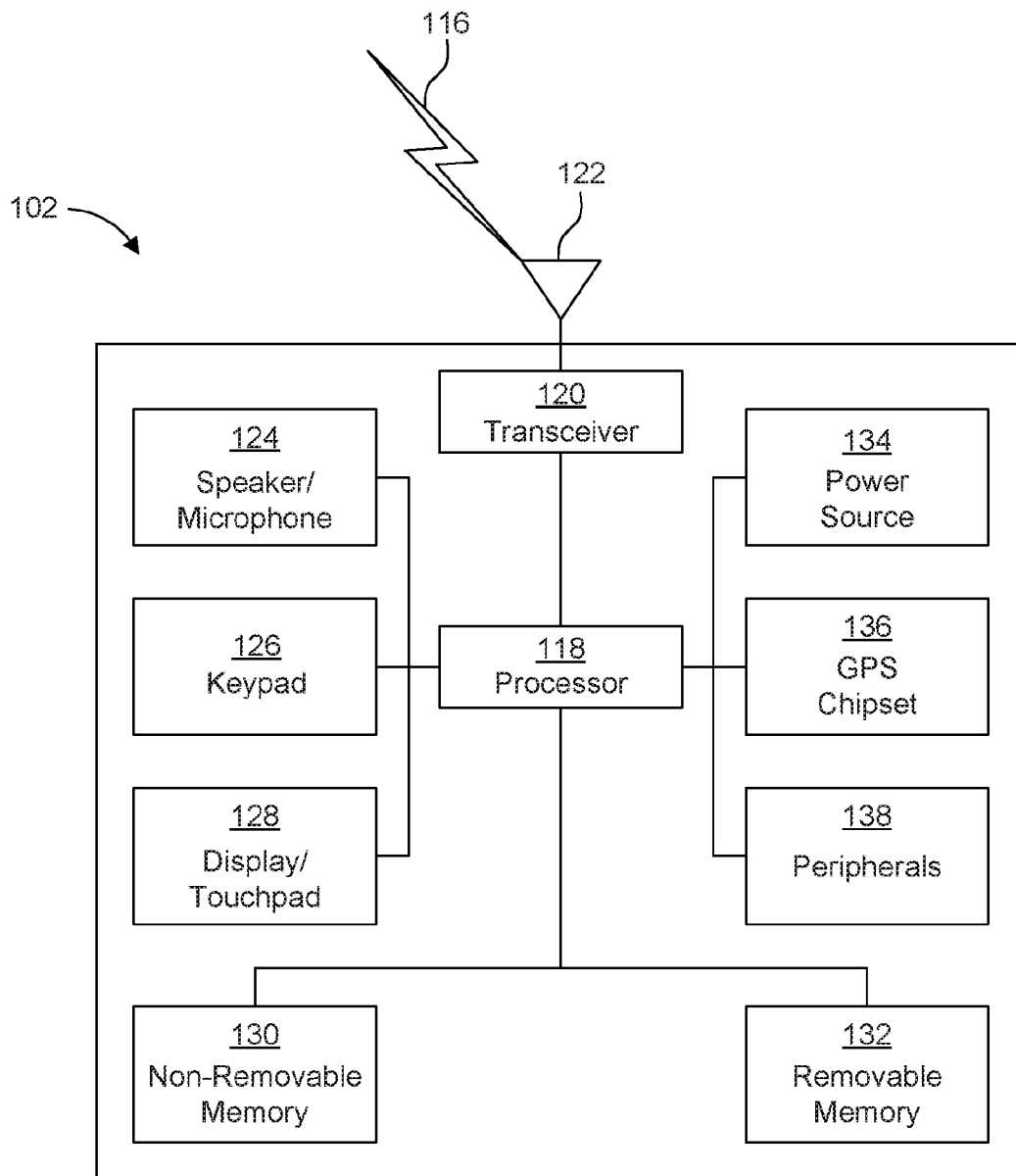


FIG. 1B

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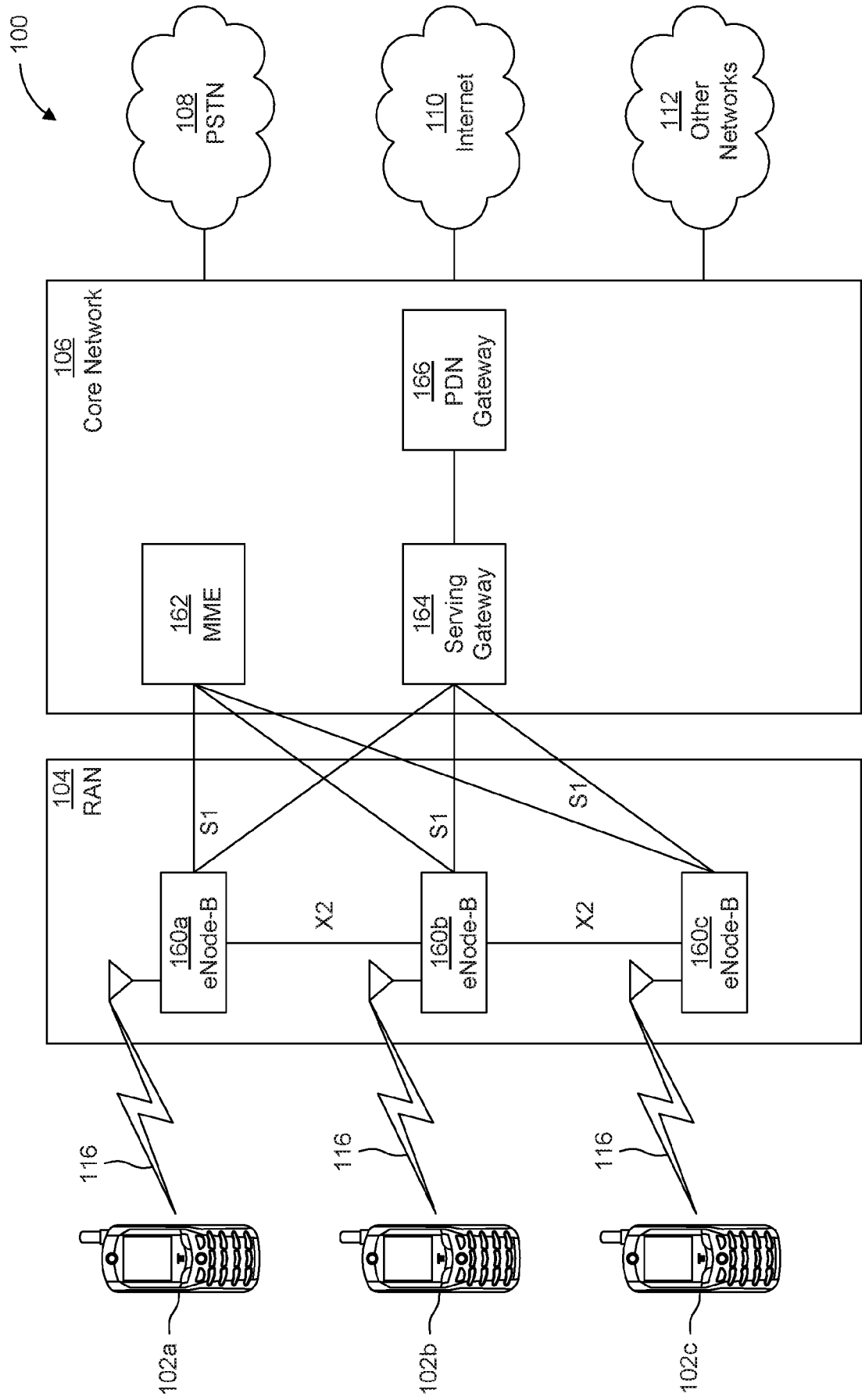


FIG. 1C

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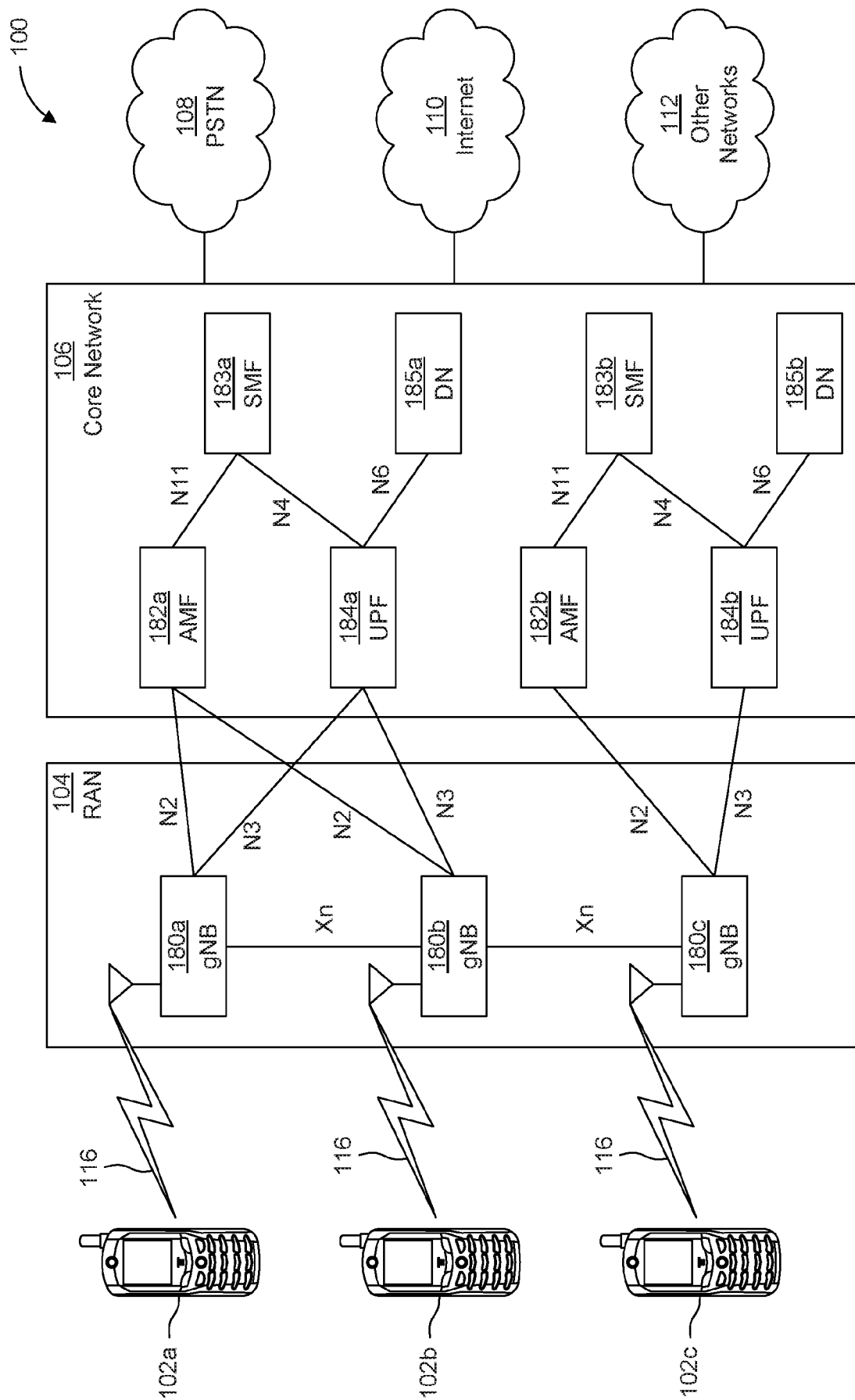


FIG. 1D

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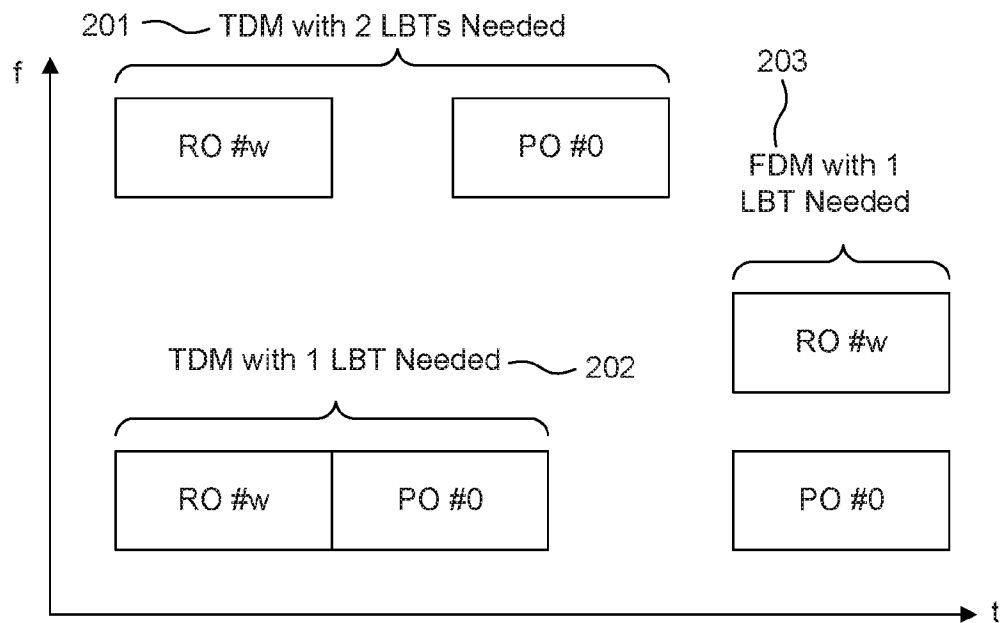
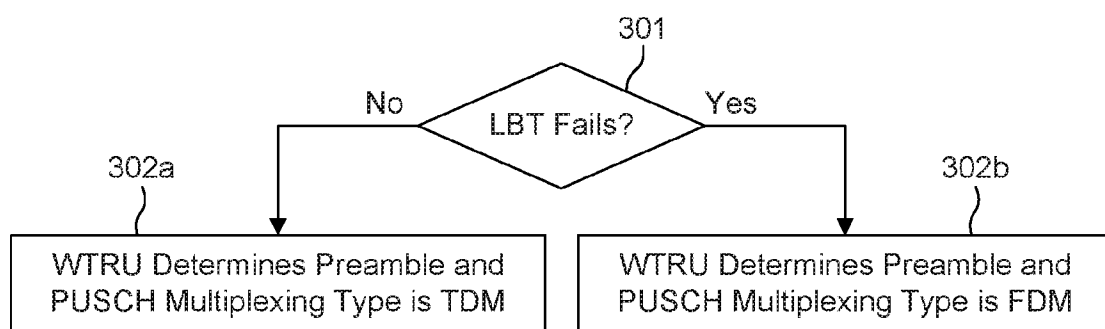


FIG. 2



Multiplexing Type may also be based on Service Types, Service Req'ts, etc.

FIG. 3

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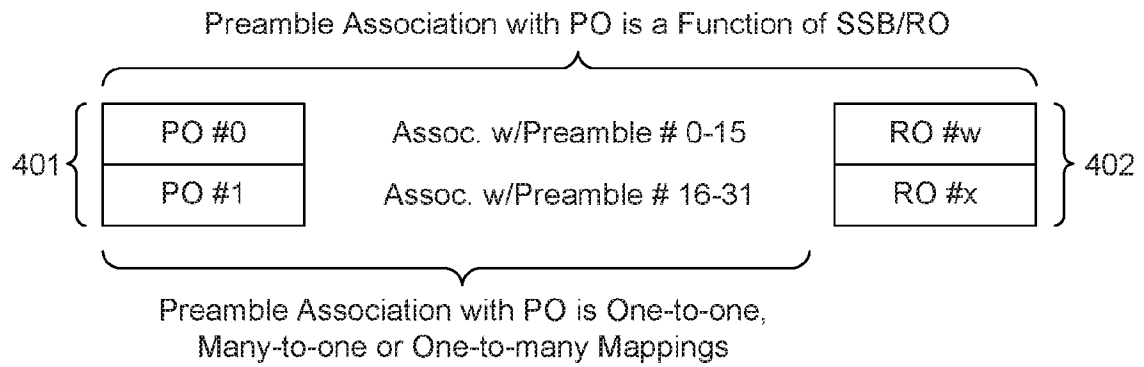


FIG. 4

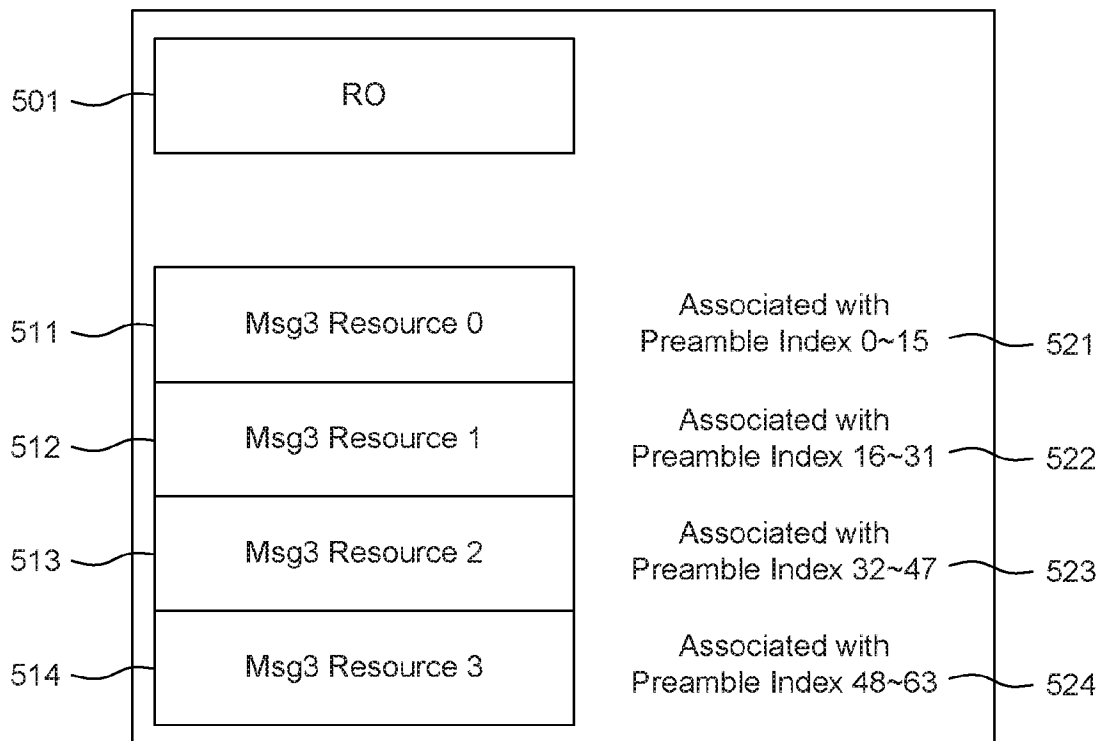


FIG. 5

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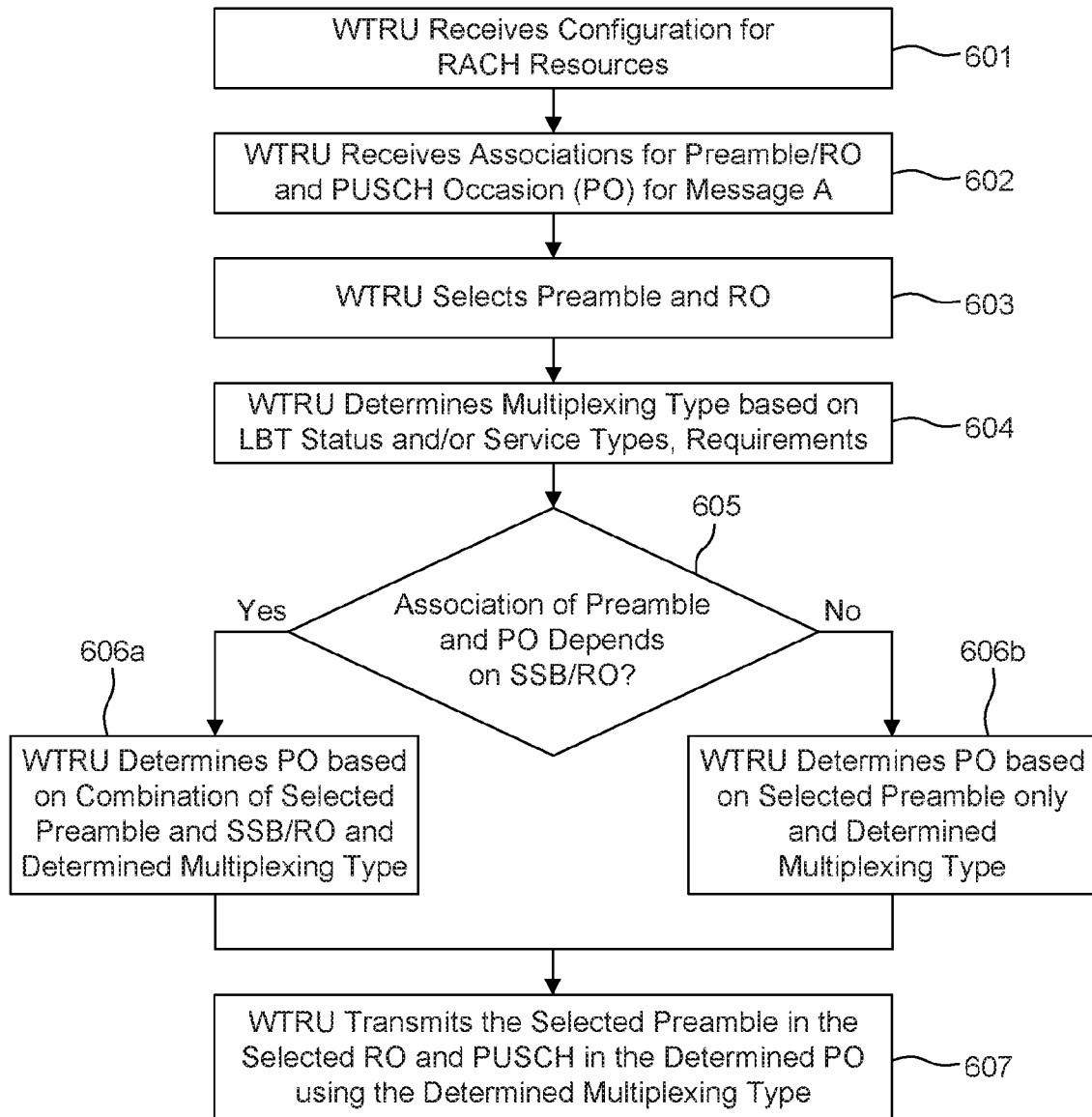


FIG. 6

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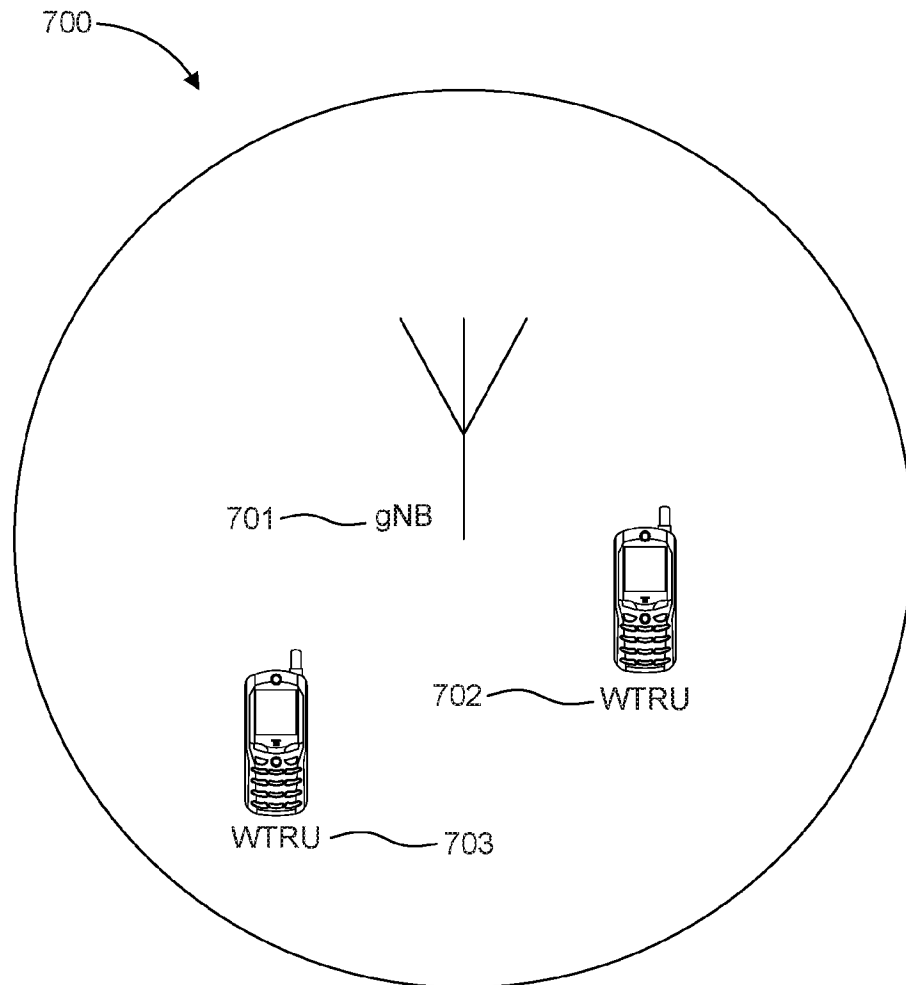


FIG. 7

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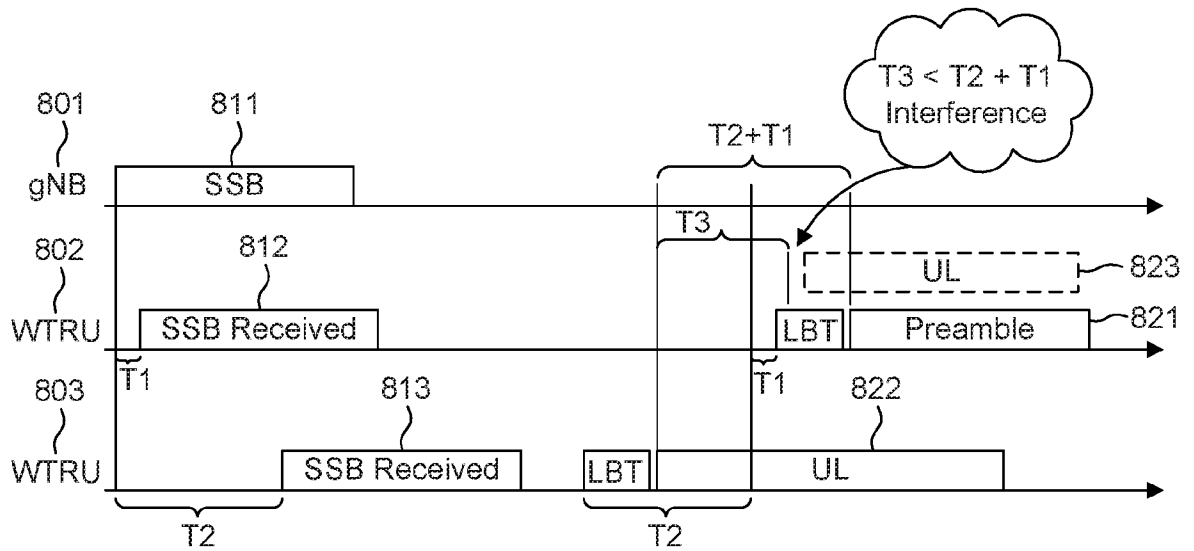


FIG. 8

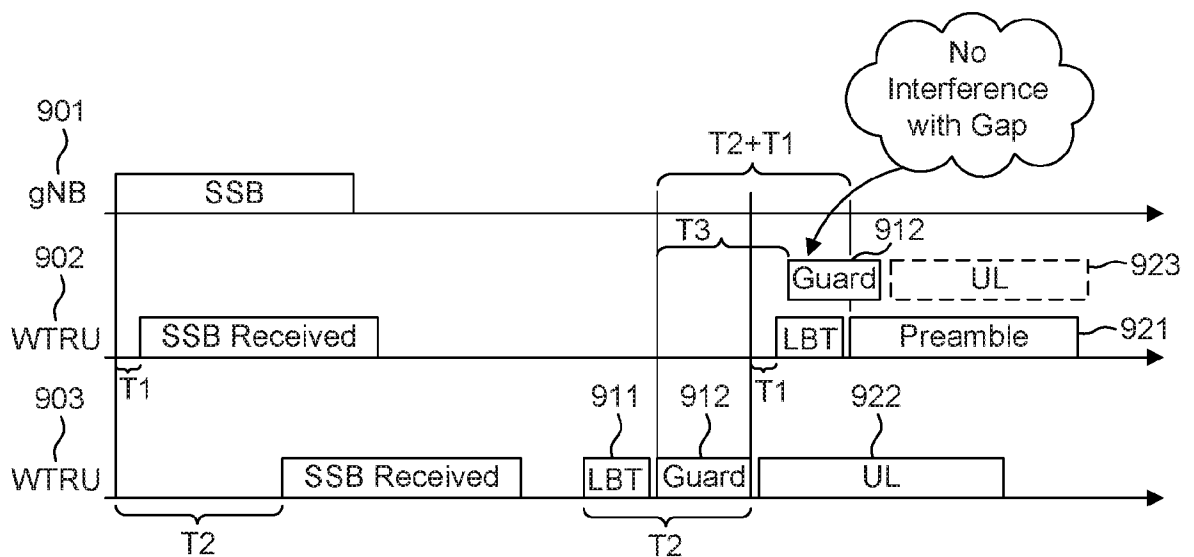


FIG. 9

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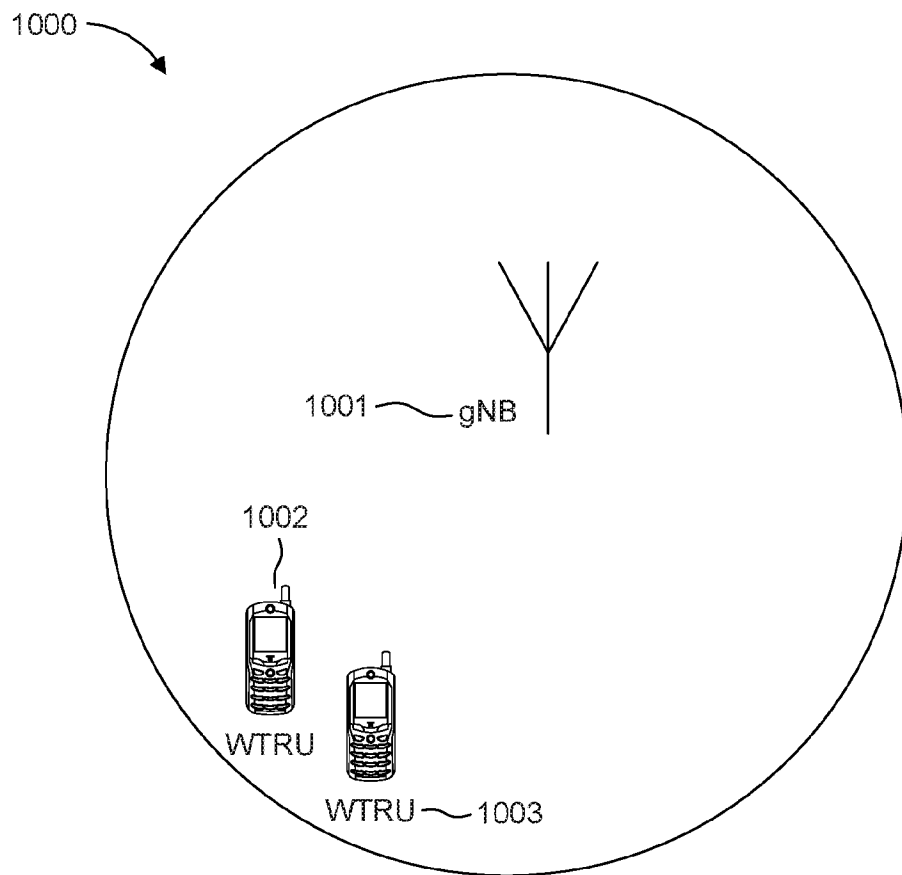


FIG. 10

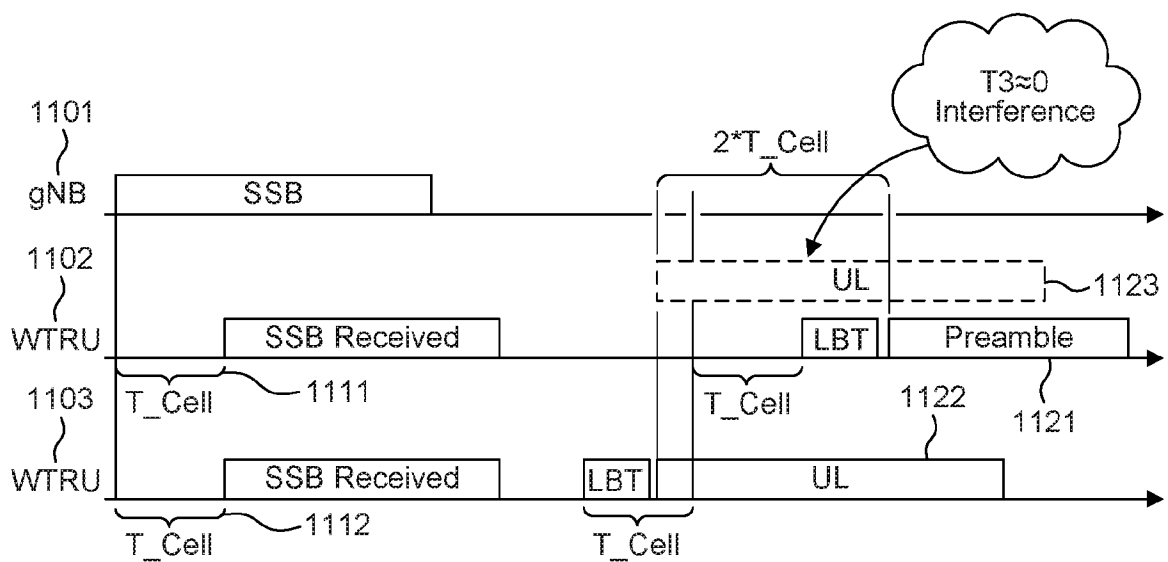


FIG. 11

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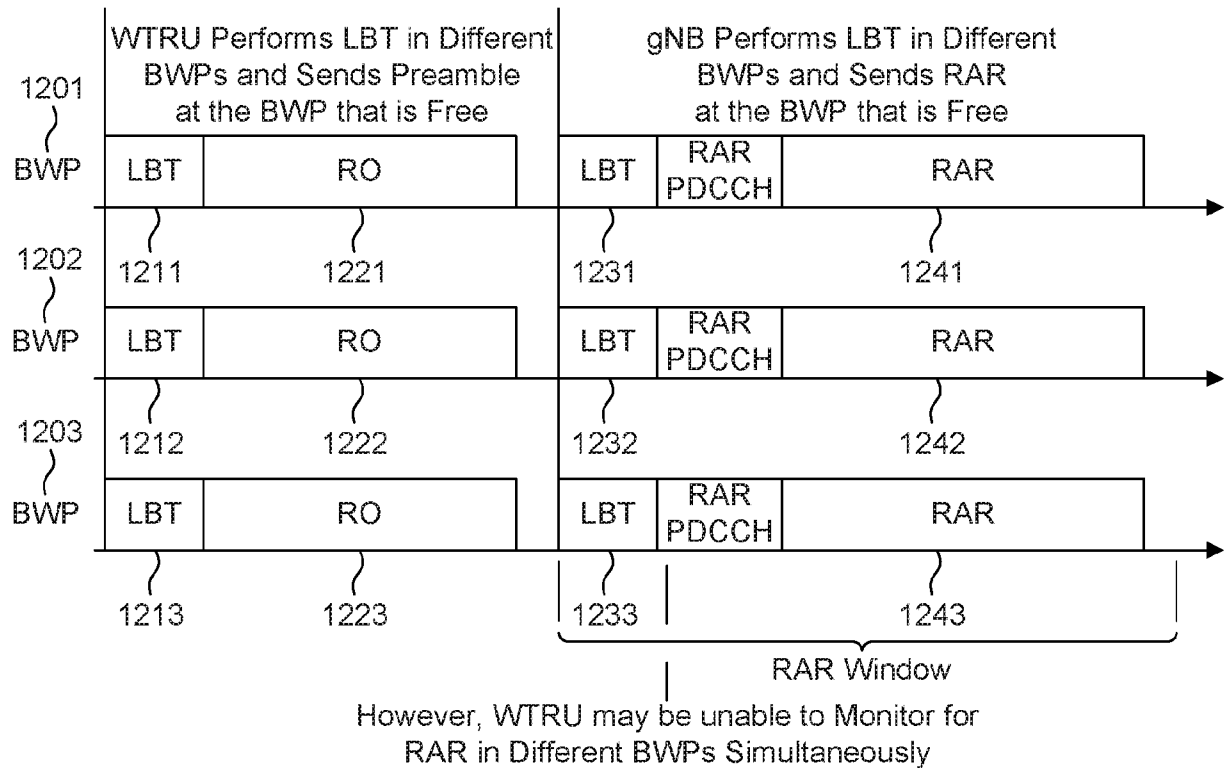


FIG. 12

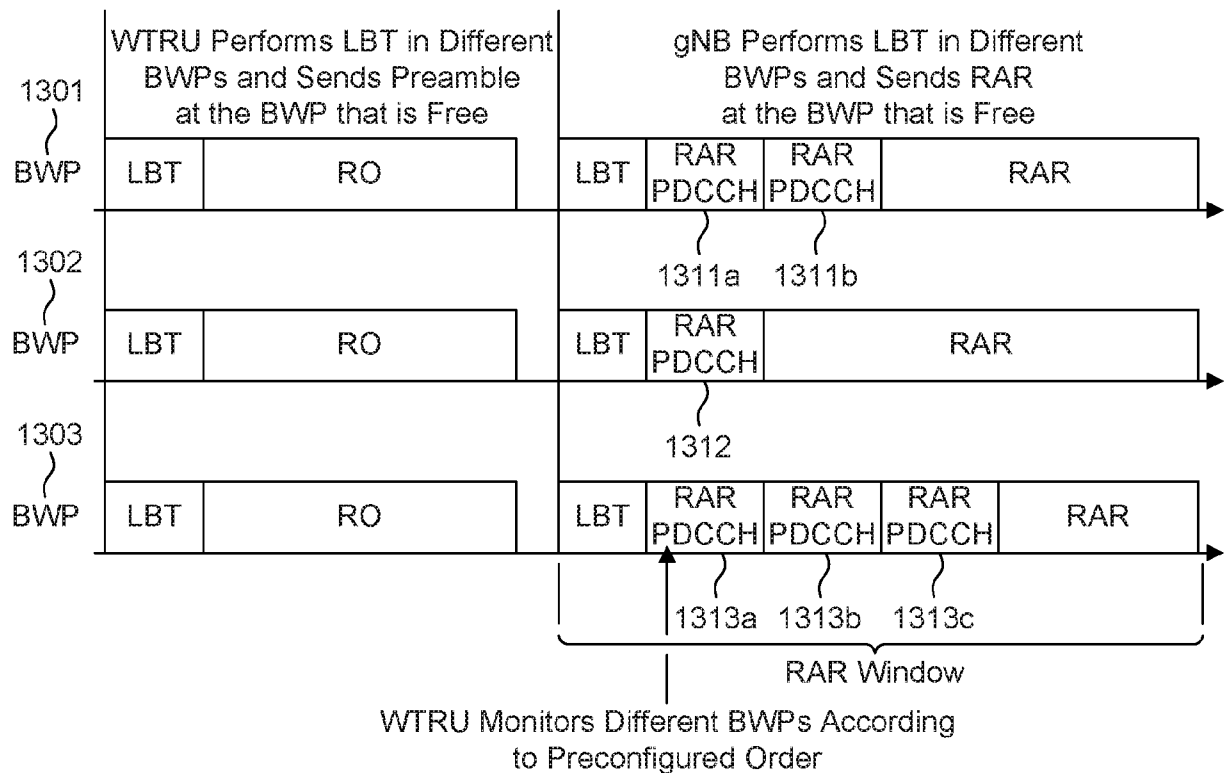


FIG. 13

## INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2019/055400

A. CLASSIFICATION OF SUBJECT MATTER  
INV. H04W74/08  
ADD.

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)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Relevant to claim No. |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X         | INTERDIGITAL: "2-Step RACH Procedure",<br>3GPP DRAFT; R2-1814008 (R15 NRU SI AI<br>11211 2-STEP RACH), 3RD GENERATION<br>PARTNERSHIP PROJECT (3GPP), MOBILE<br>COMPETENCE CENTRE ; 650, ROUTE DES<br>LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX<br>; FRANCE<br><br>vol. RAN WG2, no. Chengdu, China; 20181008<br>- 20181012<br>27 September 2018 (2018-09-27),<br>XP051523471,<br>Retrieved from the Internet:<br>URL: <a href="http://www.3gpp.org/ftp/tsg%5Fran/WG2%5FRL2/TSGR2%5F103bis/Docs/R2%2D1814008%2Ezip">http://www.3gpp.org/ftp/tsg%5Fran/WG2%5FRL2/TSGR2%5F103bis/Docs/R2%2D1814008%2Ezip</a><br>[retrieved on 2018-09-27] | 13-15                 |
| Y         | the whole document<br><br>-/-                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 1-3,5-9,<br>11,12     |



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents :

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Date of the actual completion of the international search

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## INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2019/055400

| C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                       |
|------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Category*                                            | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Relevant to claim No. |
| A                                                    | -----                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 4,10                  |
| X                                                    | <p>QUALCOMM INCORPORATED: "Report of Email Discussion [103#55][NR-U] 2-step RACH Model and Initial Information Contents (Qualcomm)",<br/>3GPP DRAFT;<br/>R2-1813690 REPORT EMAIL DISCUSSION NRU_2ST EP, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE</p> <p>,<br/>vol. RAN WG2, no. Chengdu, China; 20181008 - 20181012<br/>30 September 2018 (2018-09-30),<br/>XP051523185,<br/>Retrieved from the Internet:<br/>URL:<a href="http://www.3gpp.org/ftp/tsg%5Fran/WG2%5FRL2/TSGR2%5F103bis/Docs/R2%2D1813690%2Ezip">http://www.3gpp.org/ftp/tsg%5Fran/WG2%5FRL2/TSGR2%5F103bis/Docs/R2%2D1813690%2Ezip</a><br/>[retrieved on 2018-09-30]</p> | 13-15                 |
| Y                                                    | the whole document                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 1-3,5-9,<br>11,12     |
| A                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 4,10                  |
| Y                                                    | <p>-----</p> <p>NOKIA ET AL: "On Initial Access and Mobility for NR-U",<br/>3GPP DRAFT; R1-1810624 INITIAL ACCESS AND MOBILITY, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE</p> <p>,<br/>vol. RAN WG1, no. Chengdu, China; 20181008 - 20181012<br/>28 September 2018 (2018-09-28),<br/>XP051518030,<br/>Retrieved from the Internet:<br/>URL:<a href="http://www.3gpp.org/ftp/tsg%5Fran/WG1%5FRL1/TSGR1%5F94b/Docs/R1%2D1810624%2Ezip">http://www.3gpp.org/ftp/tsg%5Fran/WG1%5FRL1/TSGR1%5F94b/Docs/R1%2D1810624%2Ezip</a><br/>[retrieved on 2018-09-28]</p>                                                                               | 1-3,5-9,<br>11,12     |
| A                                                    | the whole document                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 4,10,<br>13-15        |
|                                                      | -----<br>-/--                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                       |

## INTERNATIONAL SEARCH REPORT

International application No

PCT/US2019/055400

| C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                       |
|------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Category*                                            | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Relevant to claim No. |
| A                                                    | <p>INTEL CORPORATION: "Enhancements to initial access and mobility for NR-unlicensed",<br/>3GPP DRAFT; R1-1808686-INTEL-ENHANCEMENTS TO INITIAL ACCESS AND MOBILITY FOR NR-UNLICENSED, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPH</p> <p>,<br/>vol. RAN WG1, no. Gothenburg, Sweden;<br/>20180820 - 20180824<br/>11 August 2018 (2018-08-11), XP051516061,<br/>Retrieved from the Internet:<br/>URL:<a href="http://www.3gpp.org/ftp/tsg%5Fran/WG1%5FRL1/TSGR1%5F94/Docs/R1%2D1808686%2Ezip">http://www.3gpp.org/ftp/tsg%5Fran/WG1%5FRL1/TSGR1%5F94/Docs/R1%2D1808686%2Ezip</a><br/>[retrieved on 2018-08-11]<br/>the whole document</p> <p>-----</p> | 1-15                  |
| A                                                    | <p>MEDIATEK INC: "2-step CBRA procedure",<br/>3GPP DRAFT; R2-1812342 2-STEP CBRA PROCEDURE, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE</p> <p>,<br/>vol. RAN WG2, no. Gothenburg, Sweden;<br/>20180820 - 20180824<br/>9 August 2018 (2018-08-09), XP051521949,<br/>Retrieved from the Internet:<br/>URL:<a href="http://www.3gpp.org/ftp/tsg%5Fran/WG2%5FRL2/TSGR2%5F103/Docs/R2%2D1812342%2Ezip">http://www.3gpp.org/ftp/tsg%5Fran/WG2%5FRL2/TSGR2%5F103/Docs/R2%2D1812342%2Ezip</a><br/>[retrieved on 2018-08-09]<br/>the whole document</p> <p>-----</p>                                                                | 1-15                  |
| A                                                    | <p>"3rd Generation Partnership Project;<br/>Technical Specification Group Radio Access Network; NR; Medium Access Control (MAC) protocol specification (Release 15)",<br/>3GPP STANDARD; TECHNICAL SPECIFICATION; 3GPP TS 38.321, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE,<br/>vol. RAN WG2, no. V15.3.0,<br/>25 September 2018 (2018-09-25), pages 1-76, XP051487371,<br/>[retrieved on 2018-09-25]<br/>section 1 "Scope"<br/>section 5.1 "Random Access procedure"<br/>section 5.4.3 "Multiplexing and assembly"</p> <p>-----</p>                                                                                     | 1-15                  |