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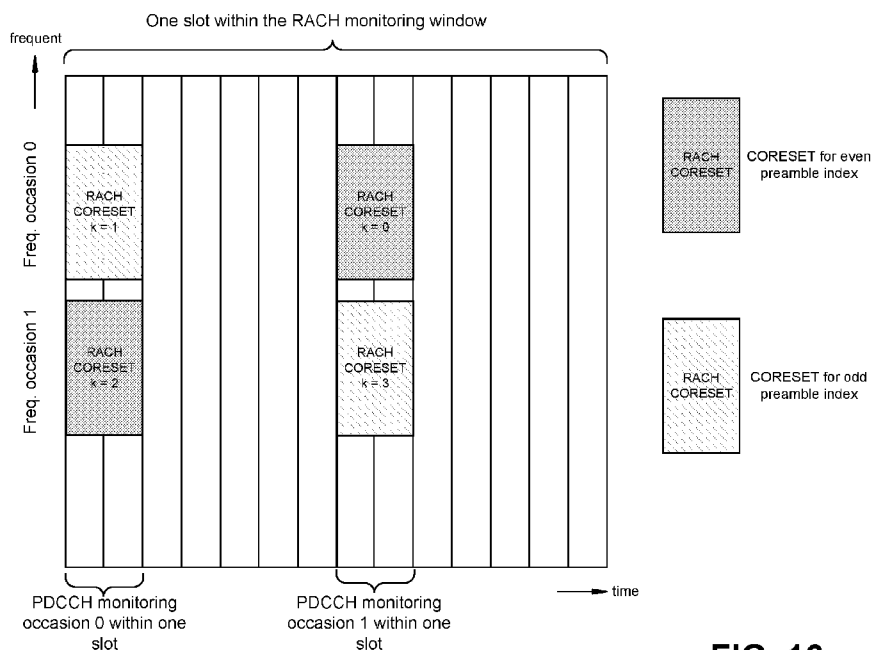
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(54) Title: MULTIPLE MONITORING OCCASIONS AT A RANDOM ACCESS CHANNEL CONTROL RESOURCE SET

**FIG. 16**

(57) **Abstract:** Systems, methods, and instrumentalities are disclosed for configuring multiple random access channel (RACH) control resource set (CORESET) monitoring occasions within a monitoring time period. A WTRU may identify which one of the multiple RACH CORESET monitoring occasions to use based on a preamble index the WTRU selects for a random access operation or based on a synchronization signal block (SSB) index. The preamble index may be configured for the WTRU by a network. The preamble index may be associated with the SSB index. Upon identifying the RACH CORESET monitoring occasion, the WTRU may monitor a physical downlink control channel (PDCCH) at the identified monitoring occasion. A supplementary uplink (SUL) carrier may be implemented and physical random access channel (PRACH) resources may be provided on the SUL carrier.



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MULTIPLE MONITORING OCCASIONS AT A RANDOM ACCESS CHANNEL CONTROL RESOURCE SET

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Provisional U.S. Patent Application No. 62/586,616, filed November 15, 2017, and Provisional U.S. Patent Application No. 62/652,555, filed April 4, 2018, the disclosures of which are incorporated herein by reference in their entireties.

BACKGROUND

[0002] Mobile communications using wireless communication continue to evolve. A fifth generation or Next Gen (NG) wireless systems may be referred to as 5G or New Radio (NR). A previous (legacy) generation of mobile communication may be, for example, fourth generation (4G) long term evolution (LTE).

SUMMARY

[0003] Systems, methods, and instrumentalities are disclosed for providing multiple random access channel (RACH) control resource set (CORESET) monitoring occasions within a monitoring time period. The RACH CORESETs corresponding to the multiple RACH CORESET monitoring occasions may be multiplexed using a time division multiplexing (TDM) technique, a frequency division multiplexing (FDM) technique, or a joint TDM and FDM technique. A wireless transmit/receive unit (WTRU) may identify which one of the multiple RACH CORESET monitoring occasions to use based on a preamble index the WTRU selects for a random access operation or based on a synchronization signal block (SSB) index. The WTRU may determine whether to use the preamble index or the SSB index based on a mapping relationship between the preamble indices and SSB indices configured for the WTRU. For example, if there is a one-to-one relationship between the SSB indices and preamble indices, the WTRU may use either a preamble index or a SSB index to determine the monitoring occasion. If there is a one-to-many relationship between the SSB indices and the preamble indices, the WTRU may use an SSB index to determine the monitoring occasion. If there is a many-to-one relationship between the SSB indices and the preamble indices, the WTRU may use a preamble index to determine the monitoring occasion. Upon identifying the RACH CORESET monitoring occasion, the WTRU may monitor a physical downlink control channel (PDCCH) at

the identified monitoring occasion.

[0004] The WTRU may take into account the total number of the RACH CORESET monitoring occasions configured for the monitoring time period when determining which of the multiple RACH CORESET monitoring occasions to use. For example, the WTRU may divide the preamble index or the SSB index by the number of the RACH CORESET monitoring occasions configured for the monitoring time period and select the RACH CORESET monitoring occasion based on a remainder of the division operation. The monitoring time period described herein may correspond to one slot or multiple slots. The monitoring time period may be inside a random access response (RAR) window.

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.

[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.

[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.

[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.

[0010] FIG. 2 is a diagram illustrating an example of a PRACH format slot.

[0011] FIG. 3 is a diagram illustrating an example of a RACH slot Type.

[0012] FIG. 4 is a diagram illustrating an example of a RACH slot Type.

[0013] FIG. 5 is a diagram illustrating an example of a RACH slot Type.

[0014] FIG. 6 is a diagram illustrating an example of having three synchronization signal (SS) blocks within a slot.

[0015] FIG. 7 is a diagram illustrating an example of having three SS blocks within a slot.

[0016] FIG. 8 is a diagram illustrating an example of having two SS blocks within a slot.

[0017] FIG. 9 is a diagram illustrating an example of having one SS block within a slot.

[0018] FIG. 10 is a diagram illustrating an example of a subframe/slot structure for PRACH transmission.

[0019] FIG. 11 is a diagram illustrating an example of monitoring time division multiplexed (TDMed) control resource sets (CORESETs) based on a preamble index.

[0020] FIG. 12 is a diagram illustrating an example of monitoring frequency division multiplexed

(FDMed) CORESETs based on a preamble index.

[0021] FIG. 13 is a diagram illustrating an example of joint FDMed and TDMed RACH CORESETs.

[0022] FIG. 14 is a diagram illustrating an example of monitoring a TDMed monitoring occasion according to a preamble index.

[0023] FIG. 15 is a diagram illustrating an example of monitoring a FDMed monitoring occasion according to a preamble index.

[0024] FIG. 16 is a diagram illustrating an example of monitoring joint TDMed and FDMed RACH CORESETs within a slot.

[0025] FIG. 17 is a diagram illustrating an example of monitoring joint TDMed and FDMed RACH CORESETs within a slot.

[0026] FIG. 18 is a diagram illustrating an example of monitoring a RACH CORESET based on a mapping relationship between preamble indices and SSB indices.

[0027] FIG. 19 is a diagram illustrating an example of configuring RACH CORESETs for different UL carriers.

[0028] FIG. 20 is a diagram illustrating an example of monitoring RACH CORESETs for different UL carriers.

[0029] FIG. 21 is a diagram illustrating an example of frequency hopping of RACH CORESETs among different RACH occasions.

[0030] FIG. 22 is a diagram illustrating an example of monitoring RACH CORESETs for multiple UL carriers.

[0031] FIG. 23 is a diagram illustrating an example of different linkage among WTRUs.

[0032] FIG. 24 is a diagram illustrating an example of configuring different RACH CORESET frequency offsets for different uplink (UL) bandwidth parts (BWPs) linked to the same downlink (DL) BWP.

[0033] FIG. 25 is a diagram illustrating an example of separating PRACH for channel state information - reference signal (CSI-RS) from PRACH for SSB.

[0034] FIG. 26 is a diagram illustrating an example of having PRACH for CSI-RS as a subset of PRACH for SSB.

[0035] FIG. 27 is a diagram illustrating an example of having different mapping patterns between CSI-RS and RACH occasions.

DETAILED DESCRIPTION

[0036] A detailed description of illustrative embodiments will now be described with reference to the various Figures. Although this description provides a detailed example of possible implementations, it should be noted that the details are intended to be exemplary and in no way limit the scope of the

application.

[0037] FIG. 1A is a diagram of 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 DFT-Spread OFDM (ZT UW DTS-s OFDM), unique word OFDM (UW-OFDM), resource block-filtered OFDM, filter bank multicarrier (FBMC), and the like.

[0038] As shown in FIG. 1A, the communications system 100 may include wireless transmit/receive units (WTRUs) 102a, 102b, 102c, 102d, a RAN 104/113, a CN 106/115, 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” and/or a “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.

[0039] 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 106/115, 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 Node-B, an eNode B, a Home Node B, a Home eNode B, a gNB, a 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.

[0040] The base station 114a may be part of the RAN 104/113, 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, etc. 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.

[0041] 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).

[0042] 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 104/113 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 115/116/117 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 UL Packet Access (HSUPA).

[0043] 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).

[0044] 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 New Radio (NR).

[0045] 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., a eNB and a gNB).

[0046] 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.

[0047] 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 106/115.

[0048] The RAN 104/113 may be in communication with the CN 106/115, 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 106/115 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 104/113 and/or the CN 106/115 may be in direct or indirect communication with other RANs that employ the same RAT as the RAN 104/113 or a different RAT. For example, in addition to being connected to the RAN 104/113, which may be utilizing a NR radio technology, the CN 106/115 may also be in communication with another RAN (not shown) employing a GSM, UMTS, CDMA 2000, WiMAX, E-UTRA, or WiFi radio technology.

[0049] The CN 106/115 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 104/113 or a different RAT.

[0050] 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.

[0051] 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.

[0052] 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) circuits, 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.

[0053] 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.

[0054] 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.

[0055] 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.

[0056] 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).

[0057] 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.

[0058] 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.

[0059] 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, and/or a humidity sensor.

[0060] 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 downlink (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 downlink (e.g., for reception)).

[0061] 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.

[0062] 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.

[0063] 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.

[0064] 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 (or PGW) 166. While each of 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.

[0065] 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.

[0066] 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.

[0067] 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.

[0068] 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.

[0069] 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.

[0070] In representative embodiments, the other network 112 may be a WLAN.

[0071] 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 an 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.

[0072] 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 via signaling. 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.

[0073] 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.

[0074] 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).

[0075] 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, 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).

[0076] 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, the entire available frequency bands may be considered busy even though a majority of the frequency bands remains idle and may be available.

[0077] 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.

[0078] FIG. 1D is a system diagram illustrating the RAN 113 and the CN 115 according to an embodiment. As noted above, the RAN 113 may employ an NR radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 113 may also be in communication with the CN 115.

[0079] The RAN 113 may include gNBs 180a, 180b, 180c, though it will be appreciated that the RAN 113 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).

[0080] 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 varying number of OFDM symbols and/or lasting varying lengths of absolute time).

[0081] 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.

[0082] 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, dual connectivity, 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.

[0083] The CN 115 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 each of the foregoing elements are depicted as part of the CN 115, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.

[0084] The AMF 182a, 182b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 113 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 PDU sessions with different requirements), selecting a particular SMF 183a, 183b, management of the registration area, termination of 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 machine type communication (MTC) access, and/or the like. The AMF 162 may provide a control plane function for switching between the RAN 113 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.

[0085] The SMF 183a, 183b may be connected to an AMF 182a, 182b in the CN 115 via an N11 interface. The SMF 183a, 183b may also be connected to a UPF 184a, 184b in the CN 115 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 WTRU IP address, managing PDU sessions, controlling policy enforcement and QoS, providing downlink data notifications, and the like. A PDU session type may be IP-based, non-IP based, Ethernet-based, and the like.

[0086] The UPF 184a, 184b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 113 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 downlink packets, providing mobility anchoring, and the like.

[0087] The CN 115 may facilitate communications with other networks. For example, the CN 115 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 115 and the PSTN 108. In addition, the CN 115 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 Data Network (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.

[0088] 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.

[0089] 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 may performing testing using over-the-air wireless communications.

[0090] 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.

[0091] Implementations described herein may be used in 5G New Radio (NR) and beam forming. NR may be operable with current and future mobile wireless communications systems. NR may meet requirements set out by ITU-R, NGMN and 3GPP. NR use cases may include, for example, extreme Mobile Broadband (eMBB), massive Machine Type Communications (mMTC), and Ultra High Reliability and Low Latency Communications (URLLC). Different use cases may focus on different requirements, such as, for example, 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.

[0092] As carrier frequency increases, path loss may become a limitation in guaranteeing a sufficient

coverage area. Transmission in mm wave systems may suffer from non-line-of-sight losses, e.g., diffraction loss, penetration loss, oxygen absorption loss, foliage loss, etc. During initial access, the base station and WTRU may need to overcome these high path losses and discover each other. Utilizing dozens or even hundreds of antenna elements to generate a beam formed signal may be an effective way to compensate severe path loss (e.g., by providing significant beam forming gain). Beamforming techniques may include digital, analog, and hybrid beamforming.

[0093] LTE initial synchronization and broadcast channel may be complex. A WTRU may acquire time and frequency synchronization with a cell and may detect the Cell ID of that cell via a cell search procedure. LTE synchronization signals may be transmitted at specific locations in the time domain (e.g., the 0th and 5th subframes of every radio frame). LTE synchronization signals may be used for time and frequency synchronization during initialization. As part of the system acquisition process, a WTRU may synchronize sequentially to the OFDM symbol, slot, subframe, half-frame, and/or radio frame based on the synchronization signals. The synchronization signals may include a Primary Synchronization Signal (PSS) (e.g., to obtain slot, subframe and/or half-frame boundary, as well as physical layer cell identity (PCI) within the cell identity group) and/or a Secondary Synchronization Signal (SSS) (e.g., to obtain the radio frame boundary, as well as enabling the WTRU to determine the cell identity group, which may range from 0 to 167).

[0094] Following a successful synchronization and PCI acquisition, a 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/or PHICH configuration. The LTE synchronization signals and PBCH may be transmitted continuously, e.g., according to the standardized periodicity.

[0095] LTE Random Access (RA) procedure may be provided. An eNB and/or a WTRU may use a random access procedure for at least one of: 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), and 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, and 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/or a maximum number of retransmissions (e.g., preambleTransMax). The PRACH resources (which may include preambles or sets of preambles and/or time/frequency resources 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 detects the preamble, it may respond with a random access response (RAR). If the WTRU 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, $ra\text{-}ResponseWindowSize$), the WTRU may send another preamble at a later time and/or at a higher power (such as, for example, higher than the previous preamble transmission by $powerRampingStep$). The transmission power may be limited by a maximum power, which may be configured 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.

[0096] In an example, 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, which may, for example, be 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). The signaling may include mobility control information and may, for example, indicate or correspond to a handover request. For a contention-free procedure which may be initiated by PDCCH order in subframe n , the PRACH preamble may be transmitted in the first subframe (or the first subframe available for PRACH) $n+k_2$ where k_2 may be ≥ 6 . When initiated by RRC command, there may be delays that may be specified (for example, there may be minimum and/or maximum required or allowed delays). The WTRU may (e.g., may autonomously) initiate a contention-based procedure for reasons which may include, for example, initial access, restoration of UL synchronization, or recovering from radio link failure. For certain events, for example, 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.

[0097] For a contention-free random access (RA) procedure, a network-signaled (e.g., configured by the network) 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., $prach\text{-}configIndex$) which may be provided or signaled (e.g., configured) by the eNB.

[0098] A preamble (e.g., one of the 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 that 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. The terms RA, RACH, and PRACH may be used interchangeably.

[0099] Coverage for PRACH transmission may be an issue when WTRUs are at cell edge or at low SNR regions. PRACH coverage may be enhanced in NR. PRACH may be transmitted with a PRACH preamble format, e.g., to avoid or mitigate inter-symbol interference and/or multi-user interference. PRACH may be transmitted in different RACH slots. PRACH may be transmitted with different patterns of SS blocks (e.g., three SS blocks within one slot, two SS blocks within one slot, one SS block within one slot, etc.).

[0100] Utilization of supplementary uplink (SUL) for PRACH may be provided. SUL handling for PRACH may be implemented. SUL may be used to enhance the uplink coverage in NR. For example, by pairing a SUL carrier on lower frequency with a TDD/FDD carrier on higher frequency, uplink coverage may be enhanced. The coverage of SUL carrier may be better than NR UL carrier in some scenarios, e.g., because the frequency is lower and more UL subframes or slots may be available.

[0101] In examples (e.g., when SUL is configured), two or more UL carriers may be configured for a DL carrier of the same cell. In those examples, one (e.g., only one) PUSCH may be transmitted. A single PUSCH may be transmitted either on SUL or NR UL. A single PUSCH may be transmitted across SUL and NR UL. More than one (e.g., multiple) PUSCH may be transmitted across SUL and NR UL.

[0102] The RACH configuration for the two or more ULs may include a same PRACH configuration index for the ULs or the RACH configuration may include different PRACH configuration indices for the respective ULs, e.g., to support the RACH transmission occasions on those ULs. A carrier index (e.g., SUL carrier index and/or NR UL carrier index) may be carried in a random access response (RAR) or in a RACH message (e.g., RACH message 2). A WTRU may decode NR-PDCCH with RA-RNTI and may decode the corresponding NR-PDSCH for RAR. The WTRU may decode the NR-PDCCH before decoding the corresponding NR-PDSCH. The WTRU may compare the carrier index (e.g., UL carrier index) in RAR and the carrier index (e.g., UL carrier index) that the WTRU selects. If the carrier index in RAR and the carrier index that the WTRU selects match, the WTRU may decide that the decoded RAR is intended for the WTRU; otherwise, the WTRU may discard the received RAR.

[0103] A carrier index may be an index to identify which carrier (e.g., SUL carrier, NR UL carrier, autonomous UL (AUL) carrier, etc.) is to be used to carry communication between a WTRU and a gNB (e.g., from a WTRU to a gNB). A carrier index may be in the form of an explicit indication (e.g., bits of information) or an implicit indication (e.g., which may be derived from other relevant information).

[0104] One or more parameters (e.g., one or more other parameters in addition to a carrier index) may be included in RAR. Examples of these parameters may include a RACH occasion index, a RACH

resource index, an OFDM symbol index, a PRB index, and/or the like. RACH resources may be based on slot, non-slot, a hybrid of slot/non-slot, or multiple non-slots with different durations. A resource index may indicate a time resource, a frequency resource, or a combination of time and frequency resources. A non-slot may be a mini-slot (e.g., smaller (e.g., shorter time period) than a regular slot) or the like. A non-slot may comprise K OFDM symbols (e.g., either consecutive or non-consecutive). For example, K may have a value of 1, 2, 4 or 7. The value of K may be configured in system information, e.g., in NR-PBCH, in remaining minimum system information (RMSI), or in other system information (OSI).

[0105] A carrier index (e.g., SUL carrier index, NR UL carrier index, etc.) may be used to determine an RA-RNTI. RA-RNTI may be a function of a carrier index (e.g., an UL carrier index) and/or one or more other parameters (e.g., different RA-RNTIs may be used for different UL carrier indices). These other parameters may include RACH occasion index, RACH resource index, OFDM symbol index, PRB index, and/or the like. RACH resources may be based on slot, non-slot, a hybrid of slot/non-slot, or multiple non-slots with different durations. A resource index may indicate a time resource, a frequency resource, or a combination of time and frequency resources. A non-slot may be a mini slot or the like. A non-slot may comprise K OFDM symbols. For example, K may have a value of 1, 2, 4 or 7. The value of K may be configured in system information, e.g., in NR-PBCH, in RMSI, or in OSI.

[0106] A carrier index (e.g., SUL carrier index, NR UL carrier index) may be carried in multiple (e.g., two) RARs and used to determine RA-RNTI. A carrier index in RAR may be used to confirm the RA-RNTI determined by carrier index. Double confirmation may be provided and additional protection may be achieved for determining a WTRU's own RAR. For example, when SUL is configured for PRACH, the carrier index for SUL may be included in a RAR to identify the carrier that a WTRU may select after decoding the NR-PDCCH with a corresponding RA-RNTI. Carrier index information may be embedded in the RA-RNTI (e.g., since the RA-RNTI may be a function of the carrier index), making it possible to perform double confirmation. Additional RA-RNTIs may be needed and/or used. Other parameters described herein may be used to determine RA-RNTI. These parameters may be carried in RAR and used to provide double confirmation. Additional protection may be achieved for determining a WTRU's own RAR.

[0107] SUL may be used for contention-based RACH resources, e.g., for one or more of beam management, beam failure indication, beam recovery request, etc. SUL may be used for contention-free or dedicated RACH resources, e.g., for one or more of handover, beam management, beam failure indication, beam recovery request, etc. A WTRU (e.g., a WTRU at the edge of a cell) may select SUL to perform a PRACH transmission, e.g., as the coverage of SUL may be larger. A dedicated preamble may be configured for an SUL RACH occasion, e.g., for handover.

[0108] A gNB may configure SUL (e.g., send configuration information to a WTRU that the WTRU may use for SUL transmission(s)) and assign a dedicated preamble (e.g., preamble index) and/or a carrier

index, e.g., based on one or more of SNR, scenarios, use cases, traffic conditions, service types, etc.

When SUL is configured, the gNB may not configure a dedicated preamble on the primary UL. In examples, when SUL is configured, the gNB may only configure dedicated preamble(s) on the SUL.

[0109] SUL configuration may be based on reference signal received power (RSRP), reference signal received quality (RSRQ), received signal strength indicator (RSSI), and/or the like. For example, if a WTRU's RSRP, RSRQ, and/or RSSI is lower than a respective threshold, a gNB may configure a SUL and may configure dedicated preamble(s) (e.g., which may be selected based on configured preamble indices) for the WTRU to use on the SUL. If the WTRU's RSRP, RSRQ, and/or RSSI is equal to or greater than the respective threshold, the gNB may configure a normal NR UL. The respective threshold may be predetermined or may be configured by the gNB.

[0110] RSRP, RSRQ, and/or RSSI thresholds may be configured by a gNB, e.g., for traffic load balancing between SUL and NR DL carrier. A WTRU may perform initial access based on RACH configuration for an SUL carrier. The configuration information for the SUL carrier may include one or more thresholds (e.g., for RSRP, RSRQ, and/or RSSI). The WTRU may select the SUL carrier for initial access if the RSRP, RSRQ, and/or RSSI measured by the WTRU is lower than the respective configured threshold. The respective RSRP, RSRQ, and/or RSSI thresholds may be indicated in an SS block or in system information such as SS, NR-PBCH, RMSI, OSI or the like. A WTRU may measure RSRP, RSRQ, and/or RSSI on the DL carrier where the WTRU may receive RMSI, SS, and/or NR-PBCH.

[0111] A PRACH preamble format may be associated with SUL. A PRACH preamble format for SUL may be explicitly and/or implicitly configured to support a larger coverage area (e.g., larger than the area covered by the PRACH preamble format used in normal UL). The preamble formats of SUL and normal UL may be different.

[0112] Example short sequence PRACH preamble formats are shown in the following Table 1.

TABLE 1

Preamble format		# of Sequence	TCP	TSEQ	TGP	Path profile (Ts)	Path profile (us)	Maximum Cell radius (meter)	Use case
A	0	1	144	2048	0	48	1.56	469	TA is already known or Very small cell
	1	2	288	4096	0	96	3.13	938	Small cell
	2	4	576	8192	0	144	4.69	2,109	Normal cell
	3	6	864	12288	0	144	4.69	3,516	Normal cell
B	1	2	216	4096	72	96	3.13	469	Small cell
	2	4	360	8192	216	144	4.69	1,055	Normal cell
	3	6	504	12288	360	144	4.69	1,758	Normal cell

	4	12	936	24576	792	144	4.69	3,867	Normal cell
C	0	1	1240	2048	1096	144	4.69	5300	Normal cell
	2	4	2048	8192	2916	144	4.69	9200	Normal cell

The preamble formats of SUL may be a subset of the preamble formats for normal UL. For example, the normal UL may use all the PRACH formats in Table 1 above, while SUL may use certain PRACH formats in Table 1 (e.g., a subset of the PRACH formats in Table 1). For example, SUL may use a subset of PRACH format A, B, or C in TABLE 1 (e.g., where A, B and C are PRACH preamble formats).

[0113] Certain restrictions may be added to one or more SUL preamble formats. A restriction set for preamble formats for SUL may be used. Preamble formats that support larger coverage areas may be included in the restriction set. A gNB may configure the preamble formats of SUL within the restriction set. The restriction set may be configured or otherwise provided, for example, based on the preamble formats configured to NR UL. The restriction set size of a preamble format on SUL may be K, which can be indicated by $\log_2(K)$ bits.

[0114] A restriction set can be determined and/or provided as follows. As stated above, a restriction set may be based on NR UL preamble formats. If a long preamble format is configured for NR UL, then long preamble formats (e.g., only long preamble formats) may be configured to SUL. Examples of preamble format restriction sets (e.g., when long preamble formats are configured) may be as the following:

Restriction set is {1, 2, 3}

Restriction set is {2, 3}

Restriction set is {3}

[0115] If a short preamble format is configured for NR UL, then examples of preamble format restriction sets may resemble the following:

Restriction sets are {A1/B1 A2/B2, A3/B3, C0, C2, 0, 1, 2}

Restriction sets are {A2/B2, A3/B3, B4, C0, 0, 1, 2, 3}

Restriction sets are {A3/B3, B4, C0, C2, 0, 1, 2, 3}

Restriction sets are {B4, C0, C2, 0, 1, 2, 3}

Restriction sets are {C0, C2, 0, 1, 2, 3}

Restriction sets are {C2, 0, 1, 2, 3}

[0116] A subcarrier spacing (SCS) restriction set may be used for SUL, NR UL, or both. The SCS of RACH on SUL may be the same as or different from that on NR UL.

[0117] The PRACH configuration periodicity of multiple (e.g., two) ULs may be configured with different values. For SUL, one or more of the following may or may not be used: SS block, PDCCH monitoring, DL/UL switch point, dynamic slot format indicator (SFI), and/or semi-static DL/UL scheduling.

RACH occasions (ROs) and/or the periodicities of PRACH configuration on multiple (e.g., two) ULs may be configured differently. For example, one or more of the following may be implemented. Different PRACH preamble formats may be used on multiple (e.g., two) ULs (e.g., SUL may support fewer RACH occasions (ROs) within one slot). On SUL (e.g., if there is no PDCCH monitoring), PRACH may start from the 1st OFDM symbol within a slot (e.g., SUL may support more ROs within one slot). On SUL (e.g., if there is no SS block transmitting), there may be more resources for PRACH than on normal NR UL (e.g., SUL may support more ROs within one slot).

[0118] Mechanisms for supporting SUL frequency may be provided. In examples, SUL may be the only UL resource for a carrier. In examples, SUL may be used as a complimentary access link (e.g., for random access) in addition to NR TDD and NR FDD UL. A WTRU may select PRACH resources in NR TDD and/or FDD uplink frequency. A WTRU may select PRACH resources in the SUL frequency. The SUL frequency may be a shared frequency (e.g., shared with LTE UL). A WTRU may support simultaneous transmission on an NR UL frequency and an SUL frequency.

[0119] The carrier frequency of SUL may be lower than an NR unpaired carrier. There may be more available UL slots (e.g., subframes) on SUL than on an NR unpaired carrier. The UL coverage area of SUL may be larger than that of NR unpaired carrier.

[0120] A WTRU may be allowed to transmit on UL carriers in different frequency ranges. The WTRU may have the capability to transmit on one of the carriers at a given time. For example, an SRS carrier may be switched with predetermined frequency ranges (e.g., for LTE-NR UL sharing). This may be applied to the NR standalone (SA) operations or NR non-standalone (NSA) operations of a WTRU.

[0121] A hybrid format based PRACH transmission may be implemented. One PRACH format may be configured for a cell. In examples (e.g., alternately), a hybrid PRACH format may be configured for a cell. For PRACH formats based on short sequence length, format A and format B may be considered as a package for the PRACH configuration. Mixed format A and B or format C may be configured. Hybrid format A/B may be configured, the last PRACH resource within a RACH slot may use the PRACH preamble format B with a guard period and the other PRACH resources within the RACH slot may use format A without guard period. This may reduce inter-symbol interference (ISI) from the same or other WTRUs. PRACH preamble format B4 within a RACH slot may be used in the case of a single PRACH occasion within a RACH slot. Other mixed PRACH preamble formats may be provided.

[0122] A PRACH format may be configured of PRACH format A0, A1, A2, and/or A3, mixed within a RACH slot. A PRACH format may be configured of PRACH format A0, A1, A2, and/or A3 mixed with PRACH format B0, B1, B2, and/or B3 within a RACH slot. Different PRACH preamble formats may be used. For example, PRACH preamble format A0 may be used for a very small cell (e.g., when the timing advance (TA) may be already known).

[0123] Preamble format A may not have guard time, and may interfere the uplink data receiving in the following symbol. If no uplink data is transmitting in the following symbol, PRACH format A may be used. The first two symbols may be reserved for DL control such as PDCCH monitoring. FIG. 2 is an example of a PRACH format slot. The PRACH preamble format A may be used at the end of the RACH slot in FIG. 2, since there is no uplink data in the following symbol (e.g., the first symbol of the next slot which may be reserved for PDCCH).

[0124] A WTRU may receive an indication of whether the DL control or control resource set (CORESET) is present in the first OFDM symbol of a slot, e.g., the next slot. PRACH preamble format A may be configured or used in the last RACH resource of a slot, e.g., if the DL control or CORESET is not present or configured in the first OFDM symbol of the slot (e.g., next slot). Otherwise, PRACH preamble format B may be configured or used in the last RACH resource of a slot.

[0125] Preamble format B may exhibit performance degradation (e.g., as compared with preamble format A), for example due to the guard time and may need a different FFT block from the PUSCH reception. The coverage of preamble format B may be smaller than preamble format A (e.g., due to the guard time). The more the preamble formats are supported, the more the signaling overhead for indicating the preamble formats may be required, which may be carried in RMSI.

[0126] A PRACH preamble format A1~A3 may be supported within one slot (e.g., when there is no uplink transmission following the last RACH resource or RO of a slot). A hybrid PRACH preamble format may be [A A A A ... A A] or [A A A A ... A B]. A WTRU may select (e.g., or be configured to use) PRACH preamble format combination [A A A A ... A A] if uplink transmission following the last RACH resource (or RO of a slot) is not configured or present. A WTRU may select (e.g., or be configured to use) PRACH preamble format combination [A A A A ... A B] if uplink transmission following the last RACH resource (or RO of a slot) is configured or present. A hybrid PRACH preamble format may also be [A A A A ... B B] within one slot.

[0127] When [A A A A ... A A] or [A A A A ... A B] are used, A may be a single PRACH format chosen from one (e.g., only one) of the PRACH formats A0, A1, A2 or A3. A may be a mixed or hybrid PRACH format chosen from any of A0, A1, A2 or A3. Combinations of A0, A1, A2 or A3 may be provided. B may be a single PRACH format chosen from one (e.g., only one) of the PRACH formats B1, B2, B3 or B4. B may be a mixed or hybrid PRACH format chosen from any of B1, B2, B3 or B4. Combinations of B1, B2, B3, or B4 may be provided.

[0128] RACH slot types may be provided for PRACH resources. Multiple types of RACH slots may be introduced. RACH slot types may be defined based on whether a SS block is present or absent. For example, two types of RACH slots may be defined: (i) RACH slot Type 1: in RACH slot Type 1, one or more (e.g., all) OFDM symbols may be available for PRACH resources; and (ii) RACH slot Type 2: in RACH slot

Type 2, there may be some symbols that are unavailable for PRACH resource. A pattern of SS blocks within a slot may be predefined. The types of RACH slots may be based on the SCS of SS block and PRACH (e.g., RACH message 1 or preamble).

[0129] FIG. 3 is an example of a RACH slot (e.g., a type 2 slot). If the SCS of SS blocks is the same as the SCS of RACH, and one or more (e.g., all) SS blocks (SSB) are transmitted, the pattern of an SSB slot may be as depicted in FIG. 3. The last 4 symbols at the end of the slot may be used as PRACH.

[0130] FIG. 4 shows more examples of RACH slots (e.g., type 2 slots). If the SCS of SS blocks is the same as the SCS of RACH, and one or more (e.g., fewer than all) SSBs are transmitted, the pattern of an SSB slot may be as depicted in FIG. 4. The starting symbol index of PRACH may be the 7th OFDM symbol (e.g., as in the upper example of FIG. 4) or the 11th OFDM symbol (e.g., as in the lower example of FIG. 4).

[0131] FIG. 5 is an example of a RACH slot (e.g., a type 2 slot). The SCS of SS blocks may be twice the SCS of RACH. If one or more (e.g., all) SS blocks are transmitted, then the pattern of SSB slot may be as depicted in FIG. 5. The 6th – 8th OFDM symbols may be used as PRACH, and/or the 13th and 14th OFDM symbols may be used as PRACH.

[0132] FIG. 6 shows examples of including three SS blocks (e.g., shown as shaded blocks) within one slot. FIG. 7 shows examples of including three SS blocks (e.g., shown as shaded blocks) within one slot. FIG. 8 shows examples of including two SS blocks (e.g., shown as shaded blocks) within one slot. FIG. 9 shows examples of including one SS block (e.g., shown as shaded blocks) within one slot.

[0133] A similar approach to the above may be applied to a RACH mini-slot (e.g., a RACH non-slot) with different durations and/or number of OFDM symbols.

[0134] A RACH configuration may map RACH resources onto one or more slots, for example irrespective of the time locations of actually transmitted SS/PBCH blocks for FDD and/or TDD. An actually transmitted SS/PBCH block may overlap with a RACH resource within a RACH configuration period. In such overlap, predefined rules may be used to indicate which RACH resource(s) may still be valid. These rules may be sent via RRC signaling, may be predefined, and/or may be fixed. DL/UL switching points may be considered. Potential impact due to semi-static or dynamic DL/UL configuration may be considered. For dynamic DL/UL configuration, dynamic slot format indication (SFI) may be used.

[0135] The impact of the time location of the SS/PBCH block to the RACH configuration table design may be reduced or minimized. Since an SS/PBCH block location may be fixed, RACH may be designed to avoid collisions. This may be achieved by one or more of the following: (i) smart design of a configuration table; (ii) intelligent rules (e.g., which may be predefined or signaled); and/or (iii) using a dynamic indication such as an SFI.

[0136] The slot duration for PRACH resource mapping for short preamble formats (e.g., L=139) may

be based on the numerology of RACH Msg1, e.g., based on SCS. The slot duration for PRACH resource mapping for long preamble formats (e.g., L=839) may be based on 15kHz SCS.

[0137] RACH configurations (e.g., NR-RACH configurations) may be specified using a table, for example, a table indexed by PRACH config index. PRACH transmission occasions may be time multiplexed or frequency multiplexed. Time multiplexed and/or frequency multiplexed PRACH transmission occasions may use the same PRACH Config Index. A WTRU may be indicated (e.g., by a 1-bit indicator) which multiplexing scheme is used (e.g., time multiplexed or frequency multiplexed PRACH transmission occasions). Subcarrier spacing (SCS) and/or PRACH preamble formats may be included in the table. The number of bits used for the RACH configuration may be reduced (e.g., minimized). For example, N bits may be used for RACH configuration and N may be six, eight, ten, or other suitable values.

[0138] A pattern given by a PRACH Config Index may repeat (e.g., in every RACH configuration period). The density and duration for RACH occasions (e.g., within each RACH configuration period) may be indicated (e.g., configured). For example, a RACH occasion may occur in every slot or non-slot (e.g., a mini-slot). A RACH configuration period may be 10ms, 20ms, 40ms, 80ms, or 160ms. The same values may be used for low and high frequency ranges (e.g., above and below 6GHz). Different values may be used for low and high frequency ranges (e.g., above and below 6GHz).

[0139] A PRACH configuration may include a PRACH configuration table and/or a PRACH formula indicator. The PRACH formula indicator may indicate one or more of the following: (i) numerology (e.g., subcarrier spacing); (ii) PRACH preamble format; (iii) long sequence or short sequence; and/or (iv) configuration period. The PRACH configuration table may include numerology (e.g., subcarrier spacing) and/or PRACH preamble format (e.g., which may be determined according to a configured PRACH preamble index).

[0140] Other variants of the above may be used. For example, to configure PRACH transmission occasions, a table may be used which may specify the subframe numbers used for RACH. Multiple rules may be used to configure the PRACH occasions and/or period. An example PRACH configuration table is given in Table 2 below.

TABLE 2

NR-RACH Configuration Index	Preamble Format	System frame number	Subframe number	NR-RACH Configuration Index	Preamble Format	System frame number	Subframe number
0	[0]	[Even]	[4]	28	[2]	[Any]	[2]
1	[0]	[Even]	[9]	29	[2]	[Any]	[6]
2	[0]	[Even]	[7]	30	[2]	[Any]	[2,6]
3	[0]	[Any]	[4]	31	[3]	[Even]	[4]
4	[0]	[Any]	[9]	32	[3]	[Even]	[9]

5	[0]	[Any]	[7]	33	[3]	[Even]	[7]
6	[0]	[Any]	[4, 9]	34	[3]	[Any]	[4]
7	[0]	[Any]	[3, 8]	35	[3]	[Any]	[9]
8	[0]	[Any]	[2, 7]	36	[3]	[Any]	[7]
9	[0]	[Any]	[4, 9, 7]	37	[3]	[Any]	[4, 9]
10	[0]	[Any]	[2, 3, 8]	38	[3]	[Any]	[3, 8]
11	[0]	[Any]	[2,3,4,7,8,9]	39	[3]	[Any]	[2, 7]
12	[0]	[Any]	2~9	40	[3]	[Any]	[4, 9, 7]
13	[1]	[Even]	[8]	41	[3]	[Any]	[2, 3, 8]
14	[1]	[Even]	[7]	42	[3]	[Any]	[2,3,4,7,8,9]
15	[1]	[Even]	[3]	43	[3]	[Any]	2~9
16	[1]	[Any]	[8]	0	[A/B]	[Even]	[4]
17	[1]	[Any]	[7]	1	[A/B]	[Even]	[6]
18	[1]	[Any]	[3]	2	[A/B]	[Even]	[8]
19	[1]	[Any]	[3, 8]	3	[A/B]	[Any]	[4]
20	[1]	[Any]	[2, 7]	4	[A/B]	[Any]	[6]
21	[1]	[Any]	[1, 6]	5	[A/B]	[Any]	[8]
22	[1]	[Any]	[1, 3, 8]	6	[A/B]	[Any]	[4, 7]
23	[1]	[Any]	[2, 5, 8]	7	[A/B]	[Any]	[5, 8]
24	[1]	[Any]	[1,3,5,7]	8	[A/B]	[Any]	[6, 9]
25	[2]	[Even]	[2]	9	[A/B]	[Any]	[4, 6, 8]
26	[2]	[Even]	[6]	10	[A/B]	[Any]	[5, 7, 9]
27	[2]	[Even]	[2,6]	11	[A/B]	[Any]	[4,5,6,7,8,9]
				Others - Reserved			

For a given PRACH density, there may be multiple slots, non-slots, or subframe allocations. For example, three different slot, non-slot, or subframe allocations may be used corresponding to a given PRACH density. Some subframe allocation may overlap with SS blocks. For example, subframe#7 or slot #7 may overlap with an SS block when there are 8 SS blocks with SCS = 15khz and the period of SS block = 5ms.

[0141] A PRACH configuration may use one bit to indicate whether a long or short sequence should be used. A PRACH configuration may use 6 bits to indicate an NR-RACH configuration Index. A PRACH configuration may use 7 bits to indicate a frequency offset. A PRACH configuration may use 3 bits to indicate a frequency index. A PRACH configuration may use 1 bit to indicate whether SCS is 15khz or

30kHz (e.g., when a long sequence is used). A PRACH configuration may use 1 bit to indicate whether SCS is 15kHz or 30kHz for below 6GHz scenarios (e.g., when a short sequence is used) and may use 1 bit to indicate whether SCS is 60kHz or 120kHz for above 6GHz scenarios (e.g., when a short sequence is used).

[0142] In examples (e.g., when a short sequence is used), 4 bits may be used to indicate up to 16 PRACH preamble formats (for example, A0, B4, C0, C2, A1~A3, mixed format A/B (1~3), etc.). RACH SCS of 60kHz with preamble format A1 may have coverage of approximately 234m. RACH SCS of 120kHz with preamble format A2 may have similar coverage (e.g., 263m). The two configurations may be associated with each other. FIG. 10 is an example of a subframe/slot structure for PRACH transmission.

[0143] One or more RACH CORESETs may be monitored (e.g., for a random access response). A remaining minimum system information (RMSI) CORESET configuration may indicate that multiple monitoring occasions may exist within a slot, and/or that a PDCCH monitoring occasion for RMSI may be among the multiple monitoring occasions of the slot (e.g., according to an SSB index). A monitoring occasion as referenced herein may be associated with a point or duration in time (e.g., in the time domain), and/or with a segment in frequency (e.g., in the frequency domain). A PDCCH monitoring occasion and a RACH CORESET monitoring occasion may be used interchangeably herein.

[0144] A number of (e.g., one or more) RACH CORESETs may be implemented within a time duration (e.g., such as a slot or multiple slots). Such a time duration may be pre-defined, configured, or indicated. It should be noted that although a slot is used in some of the examples described herein, those examples may still be valid if the slot is replaced with a time duration or time period comprising multiple slots. A WTRU may monitor a CORESET (e.g., only one CORESET) according to a preamble index (e.g., the preamble index that the WTRU selected for RACH Msg1) and/or one or more other parameters.

[0145] Multiple RACH CORESETs within a slot may employ one or more of TDM multiplexing, FDM multiplexing, and/or joint TDM and FDM multiplexing. A WTRU may monitor one or multiple RACH CORESETs according to a preamble index (e.g., the PRACH preamble index that the WTRU selected in Msg1) and/or other parameters. Using such a technique, diversity and/or interference mitigation may be achieved, e.g., for licensed bands or unlicensed bands. A WTRU may monitor one or multiple RACH CORESETs according to one or more of the following: PRACH preamble index, PRACH resource index, and/or SS block index (e.g., such as a combination of PRACH preamble index and resource index that the WTRU selected in Msg1).

[0146] RACH CORESETs within a slot may be TDMed. A RACH CORESET configuration may indicate that there are more than one monitoring occasion (e.g., in time and/or frequency domain) within a slot, and a WTRU may monitor one (e.g., only one) of the monitoring occasions. The WTRU may decide which CORESET to monitor according to the preamble index with which the PDCCH and/or a RAR are

associated. For example, where there are two PDCCH monitoring occasions (e.g., in time and/or frequency domain) within a slot, the WTRU may monitor the first PDCCH monitoring occasion if the preamble index of Msg1 is even, and may monitor the second PDCCH monitoring occasion if the preamble index of Msg1 is odd. A WTRU may decide which CORESET to monitor based on a modulo operation. For example, when there is a total of v TDMed RACH PDCCH monitoring occasions within a slot, indexed by $0, 1, 2, \dots, v-1$, respectively, a WTRU using a preamble of index i (e.g., in Msg 1) may monitor PDCCH occasion j , where j satisfies $\text{mod}(i, v) = j$. To illustrate, where there are four PDCCH monitoring occasions within a slot, the WTRU may monitor the first PDCCH occasion if the preamble index of Msg1 divided by four results in a remainder 0. The WTRU may monitor the second PDCCH occasion if the preamble index of Msg1 divided by four results in a remainder of 1. The WTRU may monitor the third PDCCH occasion if the preamble index of Msg1 divided by four results in a remainder 2, and the WTRU may monitor the fourth PDCCH occasion if the preamble index of Msg1 divided by four results in a remainder of 3.

[0147] FIG. 11 is an example of determining a monitoring occasion (e.g., a PDCCH monitoring occasion) for a TDMed CORESET based on a preamble index. One or more of the following may be performed by a WTRU. The WTRU may be configured (e.g., via higher layer signalling or downlink control information) with v TDMed RACH PDCCH monitoring occasions within a slot. The monitoring occasions may be indexed by $0, 1, 2, \dots, v-1$, respectively. The WTRU may select an SSB index l . The WTRU may determine (e.g., randomly determine, (e.g., when there is a multiple-to-one relationship between the preamble indices and an SSB index)) a preamble index i within a preamble subset (e.g., the preamble index may uniquely identify a preamble within the preamble subset). The WTRU may send the preamble associated with the preamble index. The preamble (e.g., or preamble subset) may be associated with the selected SSB index l , e.g., via a type of preamble index to SSB index association.

[0148] The WTRU may determine (e.g., calculate) the PDCCH occasion to monitor (e.g., using $j = \text{mod}(i, v)$). The WTRU may monitor the TDMed PDCCH occasion j in a (e.g., every) slot within a RAR window. The WTRU may detect a corresponding RAR within the RAR window, and the WTRU may send Msg3 using UL resources indicated in the RAR.

[0149] If the WTRU does not detect a corresponding RAR within the RAR window, the WTRU may determine the preamble index i within the preamble subset and may repeat one or more of the operations described herein (e.g., determining a preamble index i within the preamble subset, sending the preamble, etc.).

[0150] RACH CORESETs may be FDM multiplexed for one or more (e.g., each) RACH PDCCH monitoring occasions. A WTRU may monitor a (e.g., only one) FDMed CORESET, e.g., according to the preamble index of Msg1. FIG. 12 is an example of determining a monitoring occasion (e.g., a PDCCH

monitoring occasion) for a FDMed CORESET based on a preamble index. For example, where two FDMed CORESETs are configured for a monitoring occasion (e.g., in the time domain), a WTRU may monitor one FDMed CORESET (e.g., using one FDMed RACH PDCCH monitoring occasion in the frequency domain) if the preamble index of Msg1 is odd, and may monitor the other FDMed CORESET (e.g., using another RACH PDCCH monitoring occasion in the frequency domain) if the preamble index of Msg1 is even. A WTRU may decide which CORESET to monitor based on a modulo operation. For example, there may be a total of λ FDMed RACH CORESETs for a (e.g., each) RACH monitoring occasion. The CORESETs may be indexed by 0, 1, 2, ..., $\lambda-1$, respectively. The WTRU may send a preamble of index i and may monitor the FDMed RACH CORESET j with j satisfying $\text{mod}(i, \lambda) = j$.

[0151] A WTRU may perform one or more of the following. The WTRU may be configured with a total of λ FDMed RACH PDCCH monitoring occasions within a slot, indexed by 0, 1, 2, ..., $\lambda-1$, respectively. The WTRU may select an SSB index l . The WTRU may determine (e.g., randomly when there is a multiple-to-one relationship between the preamble indices and an SSB index) a preamble index i within the preamble subset (e.g., the preamble index may uniquely identify a preamble within the preamble subset). The WTRU may send the preamble associated with the preamble index. The preamble or preamble subset may be associated with the selected SSB index l , e.g., via a type of preamble index to SSB index association.

[0152] The WTRU may calculate the value of the monitoring occasion, e.g., using $j = \text{mod}(i, \lambda)$. The WTRU may monitor the FDMed PDCCH occasion j in a (e.g., every) slot within a RAR window. The WTRU may detect a corresponding RAR within the RAR window, and the WTRU may send Msg3 in UL resources indicated in the RAR. If the WTRU does not detect a corresponding RAR within the RAR window, the WTRU may determine a preamble index i within a preamble subset and may repeat one or more of the operations described herein.

[0153] RACH CORESETs may be joint TDM and FDM multiplexed within a slot. A WTRU may monitor a RACH CORESET according to the preamble index of Msg1 and/or one or more other parameters. FIG. 13 is an example of determining a monitoring occasion for joint FDM and TDM multiplexed RACH CORESETs. In the example, there may be two TDMed PDCCH monitoring occasions within a slot and there may be two FDMed CORESETs for each of the monitoring occasions. A WTRU may monitor one of the FDMed CORESETs at the first monitoring occasion within the slot according to the preamble index of Msg1, and may monitor another one of the FDMed CORESETs at the second monitoring occasion within the slot according to the preamble index of Msg1. The WTRU may monitor different FDMed CORESETs at different monitoring occasions within the slot. A frequency location of the RACH CORESET that the WTRU monitors may depend on the preamble index and/or the RACH monitoring occasion. For example, the WTRU may monitor one CORESET if the preamble index of Msg1 is odd, and

may monitor another CORESET if the preamble index of Msg1 is even. Using this configuration/technique, the WTRU may obtain frequency diversity gains for RACH messages such as the RACH messages received in an unlicensed band.

[0154] A WTRU may perform one or more of the following for joint FDMed and TDMed RACH CORESETs. The WTRU may determine a preamble index i within a preamble subset and send the preamble associated with the preamble index. The preamble or preamble subset may be associated with a selected SSB index l , e.g., via a type of preamble index to SSB index association. The WTRU may determine (e.g., calculate the time and/or frequency domain index value for) the monitoring occasion, e.g., using $j = \text{mod}(i + k, \lambda)$, wherein j may represent the frequency domain index associated with the monitoring occasion, k may represent the time domain index associated with the monitoring occasion, i may represent the preamble index chosen by the WTRU, and λ may represent the number of FDMed RACH CORESETs. The WTRU may monitor the determined joint FDMed and TDMed PDCCH occasion (e.g., the determined RACH CORESET with a frequency domain index of j (e.g., as calculated above) and a time domain index of k in one or more slots (e.g., every slot) of a RAR window. The WTRU may detect a corresponding RAR within the RAR window, and the WTRU may send Msg3 in UL resources indicated in the RAR. If the WTRU does not detect a corresponding RAR within the RAR window, the WTRU may determine the preamble index i within the preamble subset and repeat one or more of the operations described herein.

[0155] A WTRU may employ joint FDM and TDM multiplexing CORESETs. A WTRU may monitor one or more of the FDMed CORESETs according to a preamble index and monitor one or more of the TDMed CORESETs according to an SSB index. The SSB index may be associated to Msg1. The WTRU may monitor the RACH CORESET with frequency index $\text{mod}(i, \lambda)$ at a first monitoring occasion if the preamble index is even. The WTRU may monitor the RACH CORESET with frequency index $\text{mod}(i, \lambda)$ at a second monitoring occasion if the preamble index is odd. The WTRU may monitor one or more of the TDMed CORESETs according to a preamble index and monitor one or more of the FDMed CORESETs according to an SSB index. The SSB index may be associated to Msg1.

[0156] FIG. 14 is an example of a WTRU monitoring a TDMed monitoring occasion according to a preamble index (e.g., a preamble index associated with Msg 1). As shown, there may be two PDCCH monitoring occasions (e.g., in the time domain) within a slot (e.g., of a RACH monitoring window). A WTRU may be configured to use a first PDCCH monitoring occasion if the preamble index is even and use a second PDCCH monitoring occasion if the preamble index is odd.

[0157] FIG. 15 is an example of a WTRU monitoring a FDMed monitoring occasion according to a preamble index (e.g., a preamble index associated with Msg 1). As shown, there may be two RACH CORESET monitoring occasions (e.g., in the frequency domain) within a slot (e.g., of a RACH monitoring

window). A WTRU may be configured to monitor a first RACH CORESET if the preamble index is even and monitor a second RACH CORESET if the preamble index is odd.

[0158] FIG. 16 is an example of a WTRU monitoring joint TDMed and FDMed RACH CORESETs within a slot (e.g., inside a RACH monitoring window). As shown, there may be two TDMed PDCCH monitoring occasions within the slot and there may be two FDMed CORESETs for each of the monitoring occasions, resulting in a total of four CORESETs in the slot. The WTRU may determine which CORESET to monitor, e.g., by performing one or more of the following. The WTRU may assign an index k to each of the four CORESETs, for example, based on the respective locations of the CORESETs in the time-frequency domain. For example, the four CORESETs may be assigned an index of 0, 1, 2, and 3, respectively, as shown in FIG. 16. A first pair of diagonally opposite CORESETs (e.g., based on the locations of the CORESETs in the time-frequency grid) may be assigned even-numbered indices (e.g., 0 and 2) while a second pair of diagonally opposite CORESETs may be assigned odd-numbered indices (e.g., 1 and 3). Other ways for assigning indices to the CORESETs may also be applied (e.g., as shown in FIG. 17).

[0159] The WTRU may decide which CORESET among multiple CORESETs (e.g., four CORESETs as shown in FIG. 16) should be monitored based on a modulo operation. For example, among the four CORESETs shown in FIG. 16, the WTRU may choose to monitor the CORESET associated with index $k = \text{mod}(i, K)$, where i may represent a selected preamble index for Msg1 and K may represent the total number of CORESETs in the slot (e.g., $K = 4$, as shown in the example of FIG. 16). To illustrate, if there are four CORESETs monitoring occasions in a slot, as shown in FIG. 16, the WTRU may decide to monitor the CORESET with index 0 (e.g., $k = 0$) if the selected preamble index i divided by K results in a remainder of 0. The WTRU may decide to monitor the CORESET with index 1 (e.g., $k = 1$) if the selected preamble index i divided by K results in a remainder of 1. The WTRU may decide to monitor the CORESET with index 2 (e.g., $k = 2$) if the selected preamble index i divided by K results in a remainder of 2. The WTRU may decide to monitor the CORESET with index 3 (e.g., $k = 3$) if the selected preamble index i divided by K results in a remainder of 3.

[0160] FIG. 17 is an example of a WTRU monitoring joint TDMed and FDMed RACH CORESETs within a slot (e.g., inside a RACH monitoring window). The CORESETs are assigned indices (e.g., in a different order as that shown in FIG. 16). The WTRU may decide which CORESET among the multiple CORESETs (e.g., four CORESETs) the WTRU should monitor based on a modulo operation (e.g., in a similar manner as illustrated by the example of FIG. 16). It should be noted that because the CORESET indices are assigned in a different order than that in FIG. 16, the specific CORESET selected by the WTRU based on a preamble index may be different than the CORESET selected in the example of FIG. 16. For example, based on a preamble index of 1, a WTRU in the example of FIG. 17 may select the CORESET at

PDCCH monitoring occasion 0 and frequency occasion 1 for monitoring. Based on the same preamble index of 1, a WTRU in the example of FIG. 16 may select the CORESET at PDCCH monitoring occasion 0 and frequency occasion 0 for monitoring.

[0161] As described herein (e.g., the parameter *CBRApreamble-per-SSB-per-RO*, which may indicate the number of preambles corresponding an SSB in a RACH occasion), a WTRU may receive a configuration that indicates the relationship (e.g., an association) between one or more preambles and one or more SSBs. The WTRU may determine which CORESET among a plurality of CORESETs that the WTRU should monitor based on the configured relationship. FIG. 18 shows an example of a WTRU determining which CORESET to monitor based on the relationship (e.g., an association) between preambles and SSBs. As shown, the WTRU may receive configuration information relating to SSBs and/or a RACH procedure to be performed by the WTRU. For example, the configuration information may indicate one or more PRACH preamble indices for the WTRU. The configuration information may indicate one or more PRACH resource indices for the WTRU. The configuration information may indicate one or more SSB indices for the WTRU. The configuration information may indicate or the WTRU may determine based on the configuration information a relationship between the one or more SSBs preambles and the one or more PRACH preambles. Such a relationship may be a one-to-one relationship (e.g., one SSB corresponds to one specific PRACH preamble), a many-to-one relationship (e.g., multiple SSBs correspond to one PRACH preamble), or a one-to-many relationship (e.g., one SSB corresponds to multiple PRACH preambles).

[0162] The WTRU may be further configured with multiple CORESET monitoring occasions, as described herein. The WTRU may select a CORESET monitoring occasion among the multiple configured occasions based on the relationship between the SSBs and PRACH preambles. For example, if the relationship is a one-to-one relationship (e.g., one SSB corresponds to one PRACH preamble), the WTRU may select the CORESET monitoring occasion based on either a preamble index or an SSB index (e.g., by performing a modulo operation on the selected preamble index or SSB index, as described herein). If the relationship is a one-to-many relationship (e.g., one SSB corresponds to multiple PRACH preambles), the WTRU may select the CORESET monitoring occasion based on an SSB index (e.g., by performing a modulo operation on the selected SSB index, as described herein). If the relationship is a many-to-one relationship (e.g., multiple SSBs correspond to one PRACH preamble), the WTRU may select the CORESET monitoring occasion based on a preamble index (e.g., by performing a modulo operation on the selected preamble index, as described herein).

[0163] Monitoring of one or more SUL RACH CORESETs may be implemented. SUL carriers may be configured, e.g., in addition to a NR UL carrier. For example, there may be multiple UL carriers (e.g., NR UL carrier, SUL carriers, etc.) in NR. A WTRU may choose one of the UL carriers to send a preamble

according to preconfigured criterions. A WTRU which sends preambles (e.g., on UL or SUL) may monitor a RACH CORESET on an NR DL carrier. The RACH CORESETs for different UL carrier indexes may be FDM multiplexed on an NR DL carrier. Each FDMed CORESET may be for one (or a subset) of UL carriers. FIG. 19 is an example of RACH CORESET monitoring for different UL carriers.

[0164] FDMed RACH CORESETs for multiple UL carriers may be implemented, where a WTRU may monitor one of the FDMed RACH CORESETs according to the SUL carrier index or UL carrier index. FIG. 20 is an example of WTRU monitoring a RACH CORESET when different UL carriers are configured. There may be U UL carriers, indexed by $0, 1, \dots, U-1$. A WTRU may be configured with multiple (e.g., U , which may correspond to one per UL carrier) RACH CORESETs (e.g., FDMed) for a (e.g., each) RACH PDCCH monitoring occasion (e.g., a RACH PDCCH monitoring occasion in the time domain). The WTRU may be configured with a RAR window. The WTRU may select UL carrier index u (e.g., u may be equal to $0, 1, \dots, U-1$) for RACH according to preconfigured UL carrier selection criterions. The WTRU may send the preamble on UL carrier u . The WTRU may monitor the RACH CORESET with UL carrier index u in a (e.g., every) RACH PDCCH occasion within the RAR window.

[0165] The WTRU may detect an RAR within the RAR window, and may send the Msg3 in UL resources indicated in the RAR. If the WTRU does not detect an RAR within the RAR window, the WTRU may select a UL carrier index u for RACH according to preconfigured UL carrier selection criterions. The WTRU may send the preamble on UL carrier u and repeat the one or more of the operations described herein.

[0166] In examples, the RACH CORESET of a (e.g., one) UL carrier may be frequency hopping among different monitoring occasions (e.g., CORESET or PDCCH monitoring occasions), for example, in order to obtain frequency diversity gain. FIG. 21 is an example of frequency hopping of RACH CORESET among different RACH occasions. In the example, a WTRU may be configured with three UL carriers with indexed as $0, 1$, and 2 , respectively. The WTRU may choose UL carrier 1 for RACH, and may monitor RACH CORESET with frequency index 1 at monitoring occasion 0 , monitor RACH CORESET with frequency index 2 at monitoring occasion 1 , and monitor RACH CORESET with frequency index 0 at monitoring occasion 2 .

[0167] FIG. 22 is an example of a WTRU implementing RACH CORESET frequency hopping among different RACH occasions for UL carriers. As shown, if the WTRU chooses UL carrier index u for RACH, at RACH monitoring occasion index k , the WTRU may monitor RACH CORESET with frequency index $\text{mod}(u + k, U)$, where U may be the total number of UL carriers for RACH.

[0168] FDMed RACH CORESETs for multiple UL carriers may be implemented. A WTRU may monitor a RACH CORESET (e.g., one of the FDMed RACH CORESETs) according to the UL carrier index and monitoring index. For example, there may be U UL carriers, indexed by $0, 1, \dots, U - 1$. A WTRU

may be configured with U FDMed RACH CORESETs for a (e.g., each) RACH PDCCH monitoring occasion. The WTRU may be configured with a RAR window. The WTRU may select a UL carrier index u for RACH according to preconfigured UL carrier selection criterions. The WTRU may send a preamble on UL carrier u .

[0169] At RACH monitoring occasion index k within the RAR window, the WTRU may monitor the RACH CORESET with frequency index of $\text{mod}(u + k, U)$. The WTRU may detect the RAR within the RAR window, and may send the Msg3 in the UL resources indicated in RAR. If the WTRU does not detect an RAR within the RAR window, the WTRU may select a UL carrier index u for RACH according to preconfigured UL carrier selection criterions. The WTRU may send a preamble on UL carrier u and repeat one or more of the operations described herein.

[0170] A gNB may configure whether RACH CORESETs are frequency hopping among different monitoring occasions. A WTRU may receive the configuration and perform one or more of the operations described herein according to the configuration.

[0171] A leftover RACH occasion may be used for contention free random access (CFRA). RACH resources (e.g., RACH occasions or RACH preambles) configuration for contention based random access (CBRA) may be included in RMSI. RACH occasions may be configured by *PRACH-configuration-index*, which may indicate the slot index for a PRACH preamble transmission. The association between SSBs and CBRA resources may be given (e.g., indicated) by one or more of the following parameters: *SSB-per-RO* (e.g., which may indicate the number of SSBs in a RACH occasion (RO)), and/or *CBRApreamble-per-SSB-per-RO* (e.g., which may indicate the number of preambles corresponding an SSB in a RACH occasion). The actually transmitted SSBs and RACH occasions (ROs) may be associated (e.g., cyclically) within one mapping period. If there are leftover ROs, SSBs may or may not be mapped to the leftover ROs.

[0172] In examples, the leftover ROs (e.g., which may not be used for SSB mapping in CBRA) may be used as dedicated RACH occasions for CFRA. The leftover ROs may be used for CSI-RS mapping. The leftover ROs may be indicated in PDCCH order for PDCCH ordered RACH.

[0173] A gNB may trigger a PDCCH ordered RACH (e.g., if the gNB requests UL synchronization re-establishment or a UL timing adjustment). The gNB may indicate a preamble index and a leftover RO index in PDCCH order to a WTRU. The WTRU may send the preamble at the RO indicated in the PDCCH order, and the gNB may perform the time estimation based on the received preamble.

[0174] Leftover ROs may be indicated from index 0. There may be 64 leftover ROs (e.g., at most). A six-bit parameter, *RO_index*, may be used in PDCCH order to indicate a leftover RO. This leftover RO may be used for a WTRU CFRA preamble transmission. In PDCCH order, a 1-bit indicator or parameter, *leftover_RO*, may be used to indicate whether the RACH occasion is a dedicated RO or a regular RO.

[0175] Leftover ROs may be used for CSI-RS mapping. A mapping indication or instruction may follow the CSI-RS based RACH. A leftover RACH occasion may be used for CFRA. In examples, there may be one or more leftover RACH occasions after CBRA mapping. A WTRU may detect a PDCCH order. In the PDCCH order, if the value of parameter *leftover_RO* is 1, a parameter (e.g., a 6-bit *RO_index*) may indicate which leftover RO should be used for PDCCH ordered RACH. If the value of parameter *leftover_RO* is 0, a combination of parameters (e.g., a 6-bit *SSB_index* and a 3-bit *RO_index*) may indicate which RO should be used for PDCCH ordered RACH. A preamble index may be indicated in the PDCCH order.

[0176] The WTRU may generate a Msg1 preamble using the preamble index in PDCCH order, and may send the preamble at the RO that to be used for PDCCH ordered RACH (e.g., according to whether a leftover RO is used). A gNB may receive the WTRU's preamble and may perform UL timing estimation for the WTRU. The timing adjustment command may be sent (e.g., in an RAR).

[0177] RACH with multiple bandwidth parts (BWP) may be implemented. For a (e.g., each) carrier, a (e.g., each) WTRU may be configured with a number of bandwidth parts (BWP) such as up to 4 UL/DL bandwidth parts (BWP). For TDD and/or CBRA, PRACH configuration/resources on UL BWPs may be linked with DL BWPs. A WTRU may (e.g., only) monitor RAR on DL BWPs that are linked to the used UL PRACH resources. The linkage between DL BWP and UL BWP among WTRUs may be different.

[0178] FIG. 23 is an example of different linkage among WTRUs. BWP linkage of a first WTRU (e.g., WTRU 1) may be different from another WTRU (e.g., WTRU 2). The numbering of BWP for each WTRU may be internal (e.g., decided by the WTRU). For example, UL BWP 1 of WTRU 1 may be different from UL BWP 1 of WTRU 2. For example, DL BWP 1 of WTRU 1 may be different from the DL BWP 1 of WTRU 2. From the system's view, DL BWP 1 of WTRU 1 may employ the same BWP with DL BWP 2 of WTRU 2, and they may not be the same as the system DL BWP 3.

[0179] WTRU 1 in FIG. 23 may send Msg1 on UL BWP 1. WTRU 2 in FIG. 23 may send Msg1 with the same preamble index at the same RACH occasion and using the same frequency id as WTRU 1, but on UL BWP 2. According to the RA-RNTI definition, RA-RNTI may be determined according to $RA-RNTI = 1 + s_id + 14 * t_id + 14 * X * f_id + 14 * X * Y * ul_carrier_id$, where *s_id* may be the starting symbol index, *t_id* may be the slot index, *f_id* may be the frequency id and *ul_carrier_id* may be the UL carrier ID. The RA-RNTI of the respective preambles for WTRU 1 and WTRU 3 (e.g., two preambles for WTRU 1 and WTRU 2) may be the same.

[0180] The gNB may transmit RAR in the linked DL BWP 1 of WTRU 1 (e.g., as shown in FIG. 23) and transmit RAR in the linked DL BWP 2 for WTRU 2 (e.g., FIG. 23). As the DL BWP 1 of WTRU 1 and the DL BWP 2 of WTRU 2 may be the same DL BWP from gNB's perspective, the gNB may send two RARs on the same DL BWP with the same RA-RNTI and with the same preamble index inside the RAR. In

this example, WTRU 1 and WTRU 2 may not be able to differentiate which RAR is for WTRU 1 and which is for WTRU 2. The gNB may differentiate the two RARs for two WTRUs.

[0181] RA-RNTI may be a function of UL BWP index. UL BWP index may be a system index which may be consistent for multiple (e.g., all) WTRUs. When the gNB assigns the UL BWP to a WTRU, the system BWP index may be indicated to the WTRU. When receiving an RAR, the WTRU may use the system BWP to calculate the RA-RNTI and receive the PDCCH based on the RA-RNTI (e.g., use the RA-RNTI to accept the PDCCH).

[0182] An system UL BWP index may be carried in an RAR, and a WTRU may use the decoded BWP information to decide whether the RAR is intended for the WTRU. After decoding the RAR, the WTRU may check the system UL BWP index inside the RAR. The WTRU may decide that the RAR is intended for it if the system UL BWP index is consistent with the UL BWP of Msg1. Otherwise, the WTRU may withdraw the RAR.

[0183] FDMed RACH CORESETs may be used for different UL BWPs linked to the same DL BWP. When the gNB sends the RACH configuration for UL BWP to a WTRU, the frequency offset of the RACH CORESET may be configured for that UL BWP. After sending the preamble, the WTRU may monitor the RACH CORESET at the frequency location of frequency offset on the linked DL BWP.

[0184] FIG. 24 is an example of different RACH CORESET frequency offsets for different UL BWPs linked to the same DL BWP. For system UL BWP 1 (e.g., UL BWP 1 of WTRU 2 as shown in FIG. 24), the gNB may configure frequency offset 1 for RACH CORESET, while for system UL BWP 2 (e.g., UL BWP 1 of WTRU 1 as shown in FIG. 24), the gNB may configure a different frequency offset, frequency offset 2, for RACH CORESET. After sending preamble on UL BWP 1, WTRU 1 may monitor the RACH CORESET with frequency offset 2 for receiving RAR with RA-RNTI. If the RAR contains the correct preamble index, WTRU 1 may decide that the RAR is intended for it. Similarly, after sending preamble on UL BWP 1, WTRU 2 may monitor the RACH CORESET with frequency offset 1 for receiving RAR with RA-RNTI. If the RAR contains the correct preamble index, WTRU 2 may decide that the RAR is for it. The RAR for WTRU 1 and that for WTRU 2 may be differentiated on different FDMed RACH CORESETs.

[0185] Channel state information - reference signal (CSI-RS) based RACH may be implemented. PRACH information may be employed for CSI-RS mapping. The RACH occasion for CSI-RS may be the associated RO with the SSB (e.g., which may be QCLed with the CSI-RS). In IDLE mode (e.g., RRC IDLE mode), CSI-RS may not have an associated SSB for inter-frequency case. In IDLE mode (e.g., RRC IDLE mode), there may not be QCLed SSB for CSI-RS, and the associated RO may not be derived (e.g., according to QCLed SSB).

[0186] RACH may be based on CSI-RS. In an example, a WTRU needing to report a CSI-RS may perform RACH based on the selected CSI-RS. The RACH occasions for performing RACH based on CSI-

RS may be the same as the RACH occasions used in initial access (e.g., that may be configured by parameter *PRACH-configuration-index* in RMSI). In RRC IDLE mode, PRACH for CSI-RS may be configured and the number of CSI-RS may be very large (e.g., up to 96). PRACH for CSI-RS may be configured in RMSI. RMSI may be payload limited.

[0187] RACH occasions for CSI-RS mapping (CSI-RS RO) may be configured to be separately FDMed or TDMed from the RACH occasions for SSB mapping (SSB RO). FIG. 25 is an example of separating PRACH for CSI-RS from PRACH for SSB. In the example, pattern 1-1 may be implemented in which CSI-RS RO may be FDMed with SSB RO. CSI-RS RO and SSB RO may be separated. The RACH occasions for CSI-RS mapping may not be used for SSB mapping, and *vice versa*. Pattern 1-2 may be implemented in which CSI-RS RO may be TDMed with SSB RO. CSI-RS RO and SSB RO may be separate. The RACH occasions for CSI-RS mapping may not be used for SSB mapping, and *vice versa*.

[0188] For the FDMed CSI-RS RO and SSB RO, the time domain configurations for CSI-RS RO may be the same with that for SSB RO. The frequency domain configuration *prach-CSI-FDM* may be configured separately in the RACH configuration for CSI-RS. For the TDMed CSI-RS RO and SSB RO, the time domain configuration for CSI-RS RO may be configured separately with a different *PRACH-configuration-index*; or the time domain configuration may be configured as a partition factor α of the PRACH that may be configured by *PRACH-configuration-index* in RMSI. Parameter α may be the number of PRACH slots, which may mean that within one PRACH configuration period configured with *PRACH-configuration-index*, the number of PRACH slots that are for CSI-RS mapping may be the first (e.g., or last) α PRACH slots, and the remaining slots may be used for SSB mapping. Parameter α may be fractional, which may mean that within one PRACH configuration period configured with *PRACH-configuration-index*, the number of PRACH slots for CSI-RS mapping may be $\lfloor \alpha N_{prach} \rfloor$, where N_{prach} may be the total number of PRACH slots configured by *PRACH-configuration-index*. The remaining slots may be used for SSB mapping.

[0189] FIG. 26 is an example showing that PRACH for CSI-RS may be a subset of PRACH for SSB. In the example, a pattern (e.g., pattern 2, which may be different than pattern 1-1 and 1-2 of FIG. 25) may be implemented. In the pattern, RACH occasions for CSI-RS mapping may be the same as or a subset of RACH occasions for SSB mapping, where the RACH occasions for CSI-RS mapping may also be used for SSB mapping.

[0190] The PRACH for CSI-RS may be configured as a subset of the PRACH for SSB mapping, with one or more of the following parameters: *T_offset*, *F_offset*, *Window_length*, *Window_height*, and *CSI_RS_PRACH_gap*. One or more parameters may be fixed for some scenarios. For example, $\{T_offset, F_offset, Window_length, Window_height, CSI_RS_PRACH_gap\}$ may be configured as $\{0, 0, length\}$ of

the mapping period, $\text{prach_FDM}, 0\}$, which may mean that all the PRACH for SS may be used for CSI-RS (e.g., at the same time).

[0191] CSI-RS mapping (e.g., for a WTRU) may be implemented. A WTRU may be configured with a parameter (e.g., a 1-bit parameter *CSI_RS_RO_Pattern*) that may indicate which pattern described herein (e.g., pattern 1-1 of FIG. 25, pattern 1-2 of FIG. 25, and/or pattern 2 of FIG. 26) may be used for CSI-RS RO configuration. In an example where pattern 1-1 and/or pattern 1-2 of FIG. 25 is indicated, a parameter (e.g., a 1-bit parameter *CSI_RS_RO_SS_RO_Multiplexing*) may indicate which multiplexing (e.g., TDM or FDM) scheme may be used between CSI-RS RO and SSB RO. If TDM is configured, a parameter α (e.g., 2 bits) with value equal to one of $\{1,2,4,8\}$ may be configured. Parameter α may indicate the number of CSI-RS RO within a (e.g., each) PRACH configuration period. The WTRU may perform the mapping between CSI-RS and the CSI-RS RO obtained according to one or more mapping rules for CSI-RS (e.g., mapping rules between PRACH and CSI-RS, as described herein). If FDM is configured, a parameter (e.g., a 2-bit parameter *prach-CSI-FDM*) with value equal to one of $\{1,2,4,8\}$ may be configured. Such a parameter (e.g., *prach-CSI-FDM*) may indicate the number of FDMed CSI-RS RO. The WTRU may perform the mapping between CSI-RS and the CSI-RS RO obtained according to the mapping rule for CSI-RS.

[0192] In an example where pattern 2 of FIG. 26 is indicated, T_{offset} , F_{offset} , $Window_length$, $Window_height$, and *CSI_RS_PRACH_gap* may be configured to indicate the location of CSI RO. The WTRU may perform the mapping between CSI-RS and the CSI-RS RO obtained according to the mapping rule for CSI-RS.

[0193] Mapping (e.g., mapping rules) between PRACH and CSI-RS may be implemented. FIG. 27 is an example of different mapping patterns between CSI-RS and RACH occasions. The mapping between CSI-RS and RACH occasions may be configured as one of the following mapping patterns: one-to-one mapping, one-to-many mapping, many-to-one mapping, and many-to-many mapping. In one-to-one mapping, there may be only one CSI-RS mapped to one RACH occasion. In one-to-many mapping, one CSI-RS may be mapped to many RACH occasions. In many-to-one mapping, many CSI-RSs may be mapped to one RACH occasion. In many-to-many mapping, many CSI-RS may be mapped to many RACH occasions. One or more of the following parameters may be used for the CSI-RS and PRACH mapping pattern configuration: number of CSI-RS associated with one RACH occasion, $N_{RO}^{CSI_RS}$, and number of RACH occasions that is associated with one CSI-RS, $N_{CSI_RS}^{RO}$.

[0194] The parameters $N_{RO}^{CSI_RS}$ and $N_{CSI_RS}^{RO}$ may be configured for different mapping patterns. For example, for one-to-one mapping, the following may be true $N_{RO}^{CSI_RS} = N_{CSI_RS}^{RO} = 1$. For one-to-many mapping, the following may be true $N_{RO}^{CSI_RS} = 1$ and $N_{CSI_RS}^{RO} > 1$. For many-to-one mapping, the following may be true $N_{RO}^{CSI_RS} > 1$ and $N_{CSI_RS}^{RO} = 1$. For many-to-many mapping, the following may be true $N_{RO}^{CSI_RS} > 1$ and $N_{CSI_RS}^{RO} > 1$.

[0195] The parameter N_{RO}^{CSI-RS} may be SSB-per-RO, and together with $N_{CSI-RS}^{RO}=1$, it may represent one-to-one mapping, many-to-one mapping, and/or one-to-many mapping, while together with $N_{CSI-RS}^{RO}>1$, it may represent many-to-many mapping.

[0196] The CSI-RS may be cell-specific CSI-RS or WTRU-specific CSI-RS. The CSI-RS may be cyclically mapped to RACH occasions in the ascending order (e.g., or descending order) of CSI-RS index. A 1-bit parameter, *CSI-RS_index_order*, may be used to indicate the ascending (e.g., or descending order) of CSI-RS index.

[0197] A mapping order between CSI-RS and RACH occasion may be based on priority order or nature order. For example, the following mapping rules may be employed: first in increasing preamble indices within a single CSI-RS RACH occasion; then in increasing number of frequency multiplexed CSI-RS RACH occasions; then in increasing number of time-domain CSI-RS RACH occasions within a CSI-RS RACH slot; and then in increasing number of CSI-RS RACH slots.

[0198] A mapping order between CSI-RS and RACH occasion may be employed: e.g., first in increasing preamble indices within a single CSI-RS RACH occasion; then in increasing number of time-domain CSI-RS RACH occasions within a CSI-RS RACH slot; then in increasing number of frequency multiplexed CSI-RS RACH occasions; and then in increasing number of CSI-RS RACH slots.

[0199] A WTRU may be configured with a parameter, e.g., *CSI-RS_mapping_order*, that indicates which mapping order may be configured.

[0200] CSI-RS and RO may be associated. As described herein, a WTRU may be configured by RO for CSI-RS. A WTRU may receive one or more parameters such as *CSI-RS_index_order* and *CSI-RS_mapping_order* in RACH configuration for CSI-RS. If the *CSI-RS_index_order* is 0, then the WTRU index CSI-RS may be in ascending order (e.g., CSI-RS0, CSI-RS1, ..., CSI-RSX may be indexed as 0, 1, 2, ..., X, respectively). If the *CSI-RS_index_order* is 1, then the WTRU index CSI-RS may be in descending order (e.g., CSI-RSX, CSI-RSX-1, ..., CSI-RS1, CSI-RS0 may be indexed as 0, 1, 2, ..., X, respectively).

[0201] If the *CSI-RS_mapping_order* is 0, the WTRU mapping CSI-RS index may be given as described herein to RACH occasions in the following order: first in increasing preamble indices within a single CSI-RS RACH occasion; then in increasing number of frequency multiplexed CSI-RS RACH occasions; then in increasing number of time-domain CSI-RS RACH occasions within a CSI-RS RACH slot; and then in increasing number of CSI-RS RACH slots.

[0202] If the *CSI-RS_mapping_order* is 1, the WTRU mapping CSI-RS index may be given as described herein to RACH occasions in the following order: first in increasing preamble indices within a single CSI-RS RACH occasion; then in increasing number of time-domain CSI-RS RACH occasions within

a CSI-RS RACH slot; then in increasing number of frequency multiplexed CSI-RS RACH occasions; and then in increasing number of CSI-RS RACH slots.

[0203] Other orders or combinations for preamble indices, frequency multiplexed CSI-RS RACH occasions, time-domain CSI-RS RACH occasions, CSI-RS RACH slots, etc. may be employed for *CSI-RS_mapping_order* being 0 or 1 (or other values). PRACH mapping for CSI-RS may be completed and the WTRU may perform CSI-RS based RACH.

[0204] The proposed implementations and techniques described herein may be used for NR licensed spectrum. The proposed implementations and techniques described herein may be used for NR unlicensed spectrum. The processes and/or methods described above may be implemented in a computer program, software, and/or firmware incorporated in a computer-readable medium for execution by a computer and/or processor. Examples of computer-readable media include, but are not limited to, electronic signals (transmitted over wired and/or wireless connections) and/or 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, but not limited to, internal hard disks and removable disks, magneto-optical media, and/or optical media such as CD-ROM disks, and/or digital versatile disks (DVDs). A processor in association with software may be used to implement a radio frequency transceiver for use in a WTRU, terminal, base station, RNC, and/or any host computer.

CLAIMS

1. A wireless transmit/receive unit (WTRU), comprising:
a processor configured to:
 - receive a configuration indicating a preamble index associated with a random access operation of the WTRU, the preamble index further associated with a synchronization signal block (SSB) index related to the random access operation;
 - determine that multiple random access channel (RACH) control resource set (CORESET) monitoring occasions are configured for a monitoring time period;
 - identify, based on at least one of the preamble index or the SSB index, one RACH CORESET monitoring occasion among the multiple RACH CORESET monitoring occasions configured for the monitoring time period; and
 - monitor a physical downlink control channel (PDCCH) at the identified RACH CORESET monitoring occasion.
2. The WTRU of claim 1, wherein the processor is configured to identify the one RACH CORESET monitoring occasion among the multiple RACH CORESET monitoring occasions based further on a number of the RACH CORESET monitoring occasions configured for the monitoring time period.
3. The WTRU of claim 2, wherein, to identify the one RACH CORESET monitoring occasion among the multiple RACH CORESET monitoring occasions, the processor is configured to divide the preamble index or the SSB index by the number of the RACH CORESET monitoring occasions configured for the monitoring time period and determine the one RACH CORESET monitoring occasion based on a remainder of the division.
4. The WTRU of claim 1, wherein the RACH CORESETs corresponding to the multiple RACH CORESET monitoring occasions are multiplexed using a time division multiplexing (TDM) technique or a frequency division multiplexing (FDM) technique.
5. The WTRU of claim 1, wherein the RACH CORESETs corresponding to the multiple RACH CORESET monitoring occasions are multiplexed jointly using a time division multiplexing (TDM) technique and a frequency division multiplexing (FDM) technique.

6. The WTRU of claim 1, wherein the processor is configured to receive an indication of a mapping relationship between preamble indices and SSB indices.
7. The WTRU of claim 6, wherein the processor is configured to identify the one RACH CORESET monitoring occasion based on the preamble index if the mapping relationship indicates that the preamble index is mapped to multiple SSB indices, the processor further configured to identify the one RACH CORESET monitoring occasion based on either the preamble index or the SSB index if the mapping relationship indicates that the preamble index is mapped to only the SSB index, the processor further configured to identify the one RACH CORESET monitoring occasion based on the SSB index if the mapping relationship indicates that the SSB index is mapped to multiple preamble indices.
8. The WTRU of claim 1, wherein the monitoring time period corresponds to one slot or multiple slots.
9. The WTRU of claim 1, wherein the monitoring time period is within a random access response window.
10. The WTRU of claim 9, wherein the processor is further configured to monitor the PDCCH at the identified RACH CORESET monitoring occasion for a random access response from a network entity.
11. A method implemented in a wireless transmit/receive unit (WTRU), the method comprising:
 - receiving a configuration indicating a preamble index associated with a random access operation of the WTRU, the preamble index further associated with a synchronization signal block (SSB) index related to the random access operation;
 - determining that multiple random access channel (RACH) control resource set (CORESET) monitoring occasions are configured for a monitoring time period;
 - identifying, based on at least one of the preamble index or the SSB index, one RACH CORESET monitoring occasion among the multiple RACH CORESET monitoring occasions configured for the monitoring time period; and
 - monitoring a physical downlink control channel (PDCCH) at the identified RACH CORESET monitoring occasion.
12. The method of claim 11, wherein the identifying of the one RACH CORESET monitoring occasion among the multiple RACH CORESET monitoring occasions is based further on a number of the RACH CORESET monitoring occasions configured for the monitoring time period.

13. The method of claim 12, wherein the identifying of the one RACH CORESET monitoring occasion among the multiple RACH CORESET monitoring occasions comprises dividing the preamble index or the SSB index by the number of the RACH CORESET monitoring occasions configured for the monitoring time period and determining the one RACH CORESET monitoring occasion based on a remainder of the division.
14. The method of claim 11, wherein the RACH CORESETs corresponding to the multiple RACH CORESET monitoring occasions are multiplexed using a time division multiplexing (TDM) technique or a frequency division multiplexing (FDM) technique.
15. The method of claim 11, wherein the RACH CORESETs corresponding to the multiple RACH CORESET monitoring occasions are multiplexed jointly using a time division multiplexing (TDM) technique and a frequency division multiplexing (FDM) technique.
16. The method of claim 11, further comprising receiving an indication of a mapping relationship between preamble indices and SSB indices.
17. The method of claim 16, wherein the identifying of the one RACH CORESET monitoring occasion among the multiple RACH CORESET monitoring occasions configured for the monitoring time period comprises:
 - identifying the one RACH CORESET monitoring occasion based on the preamble index on a condition that the mapping relationship indicates that the preamble index is mapped to multiple SSB indices;
 - identifying the one RACH CORESET monitoring occasion based on either the preamble index or the SSB index on a condition that the mapping relationship indicates that the preamble index is mapped to only the SSB index; or
 - identifying the one RACH CORESET monitoring occasion based on the SSB index on a condition that the mapping relationship indicates that the SSB index is mapped to multiple preamble indices.
18. The method of claim 11, wherein the monitoring time period corresponds to one slot or multiple slots.
19. The method of claim 11, wherein the monitoring time period is within a random access response window.

20. The method of claim 19, further comprising monitoring the PDCCH at the identified RACH CORESET monitoring occasion for a random access response from a network entity.

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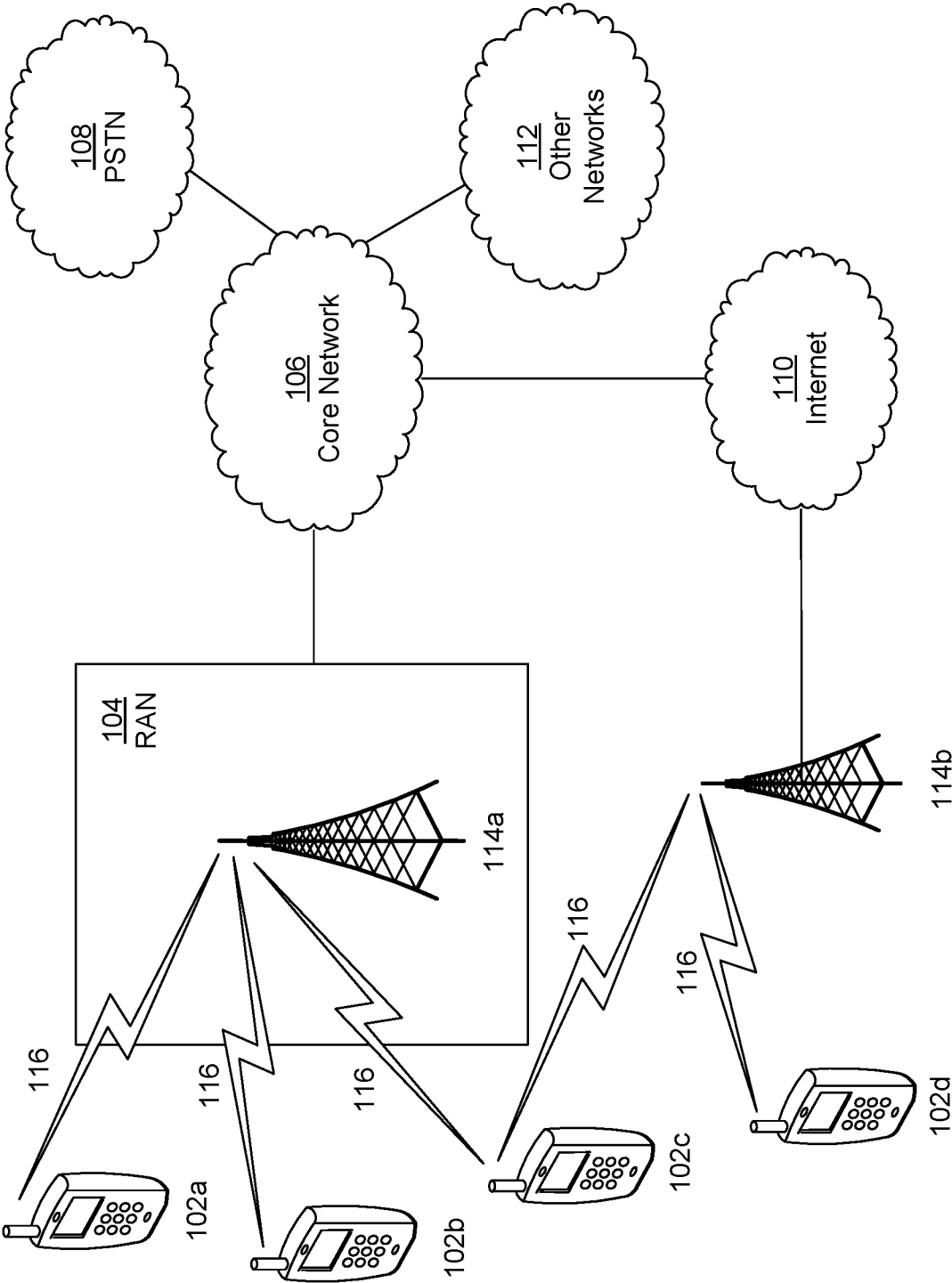
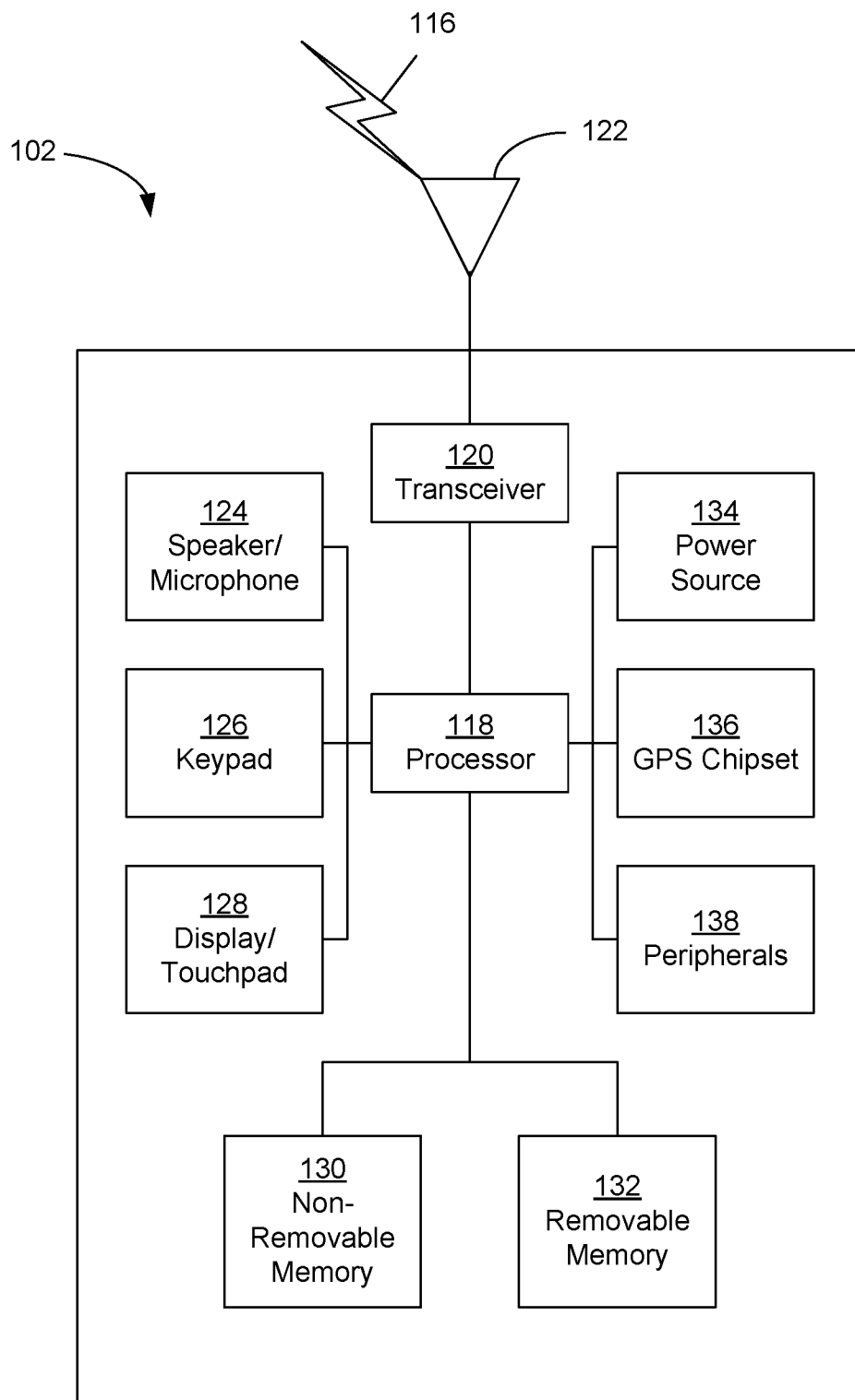


FIG. 1A

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**FIG. 1B**

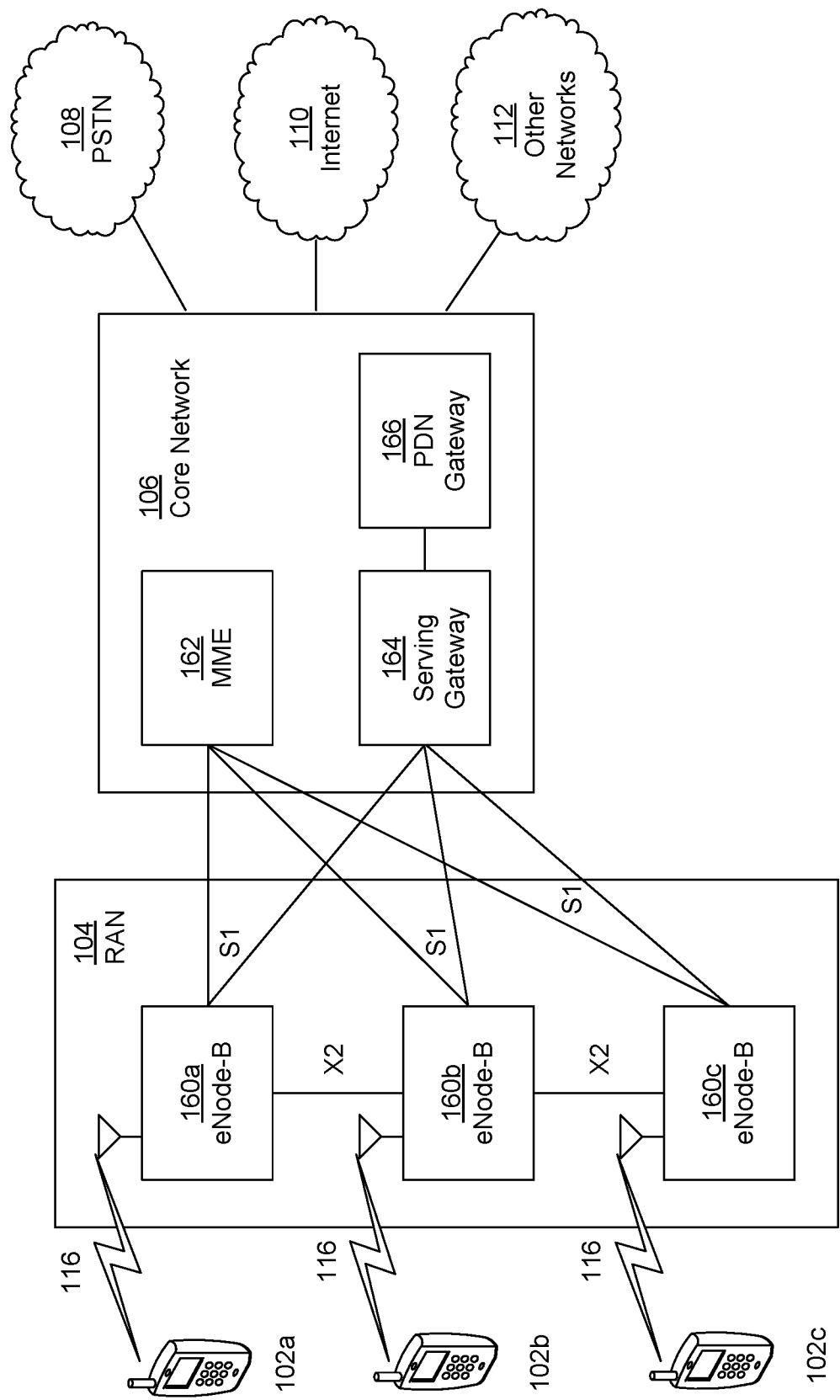


FIG. 1C

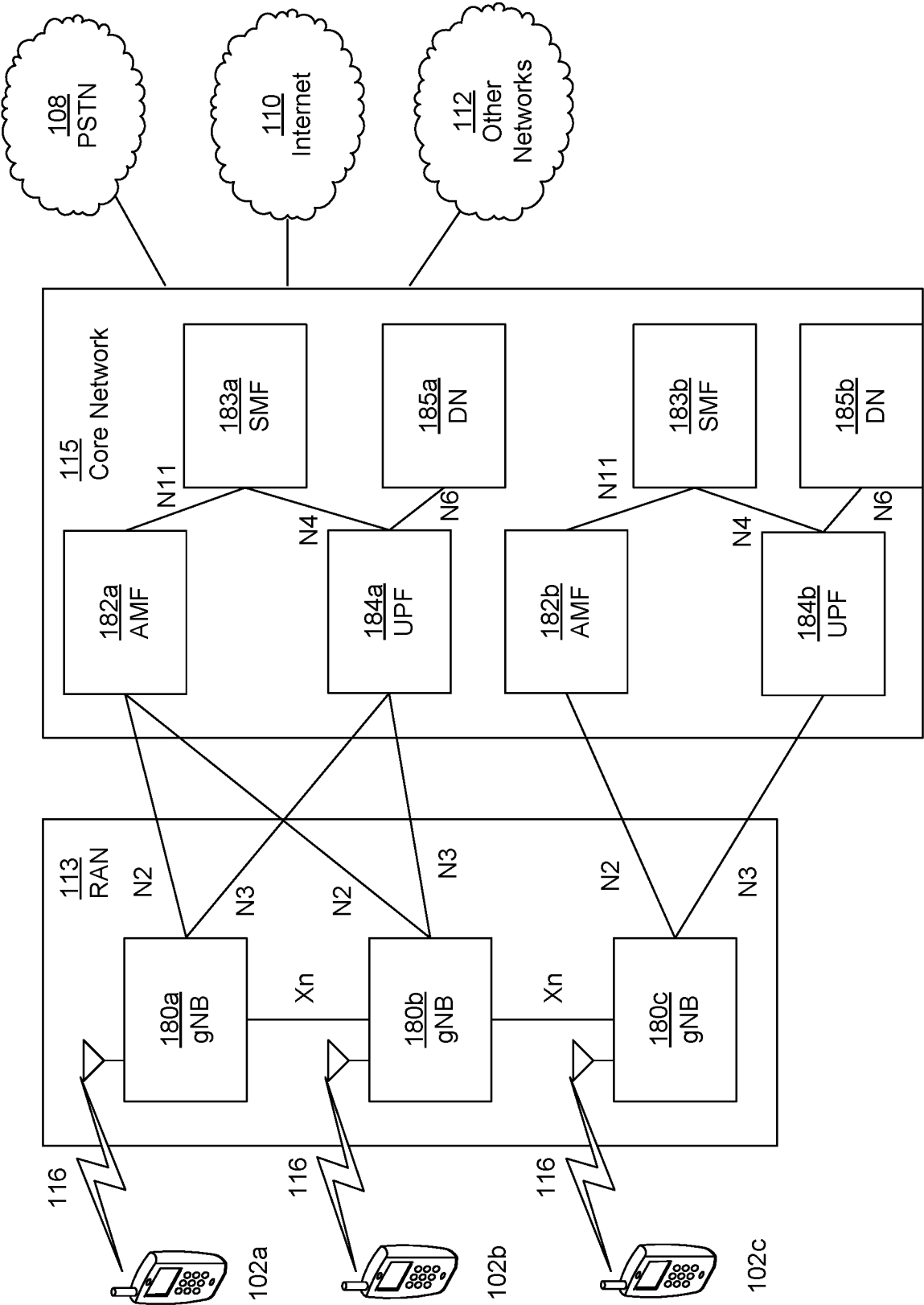


FIG. 1D

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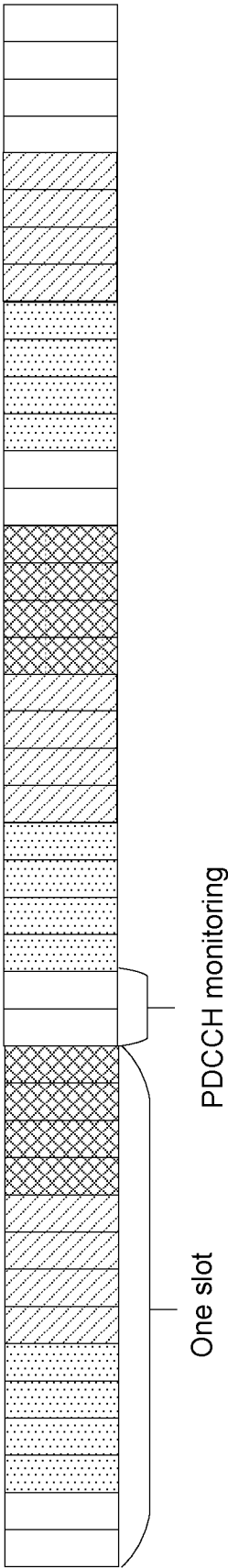


FIG. 2

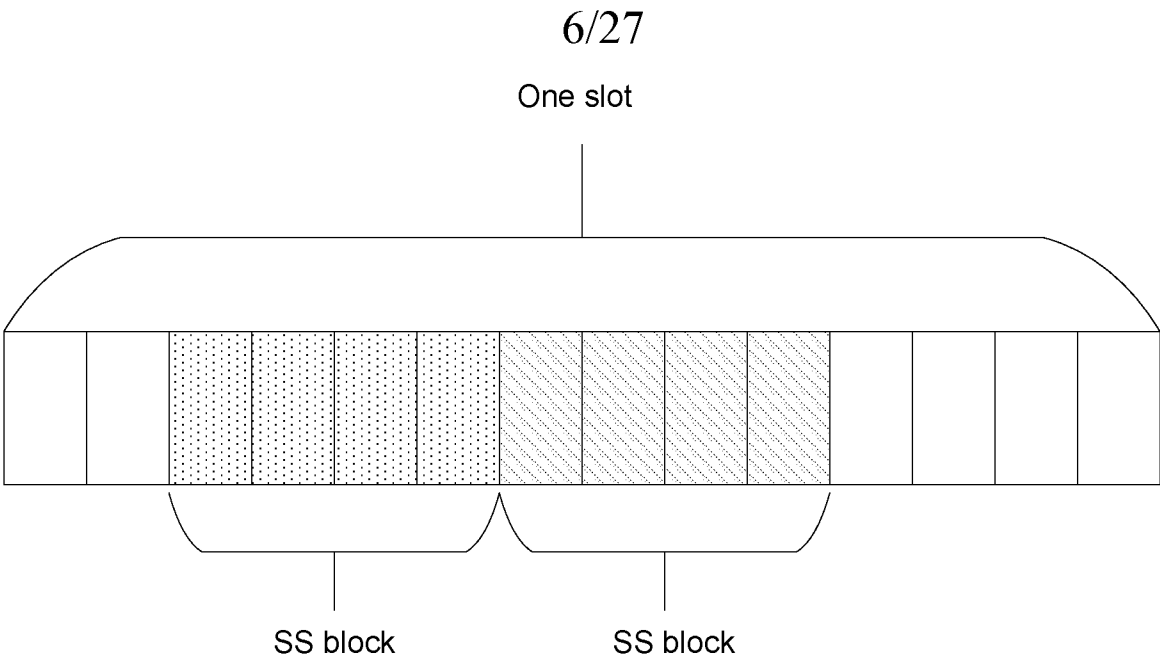


FIG. 3

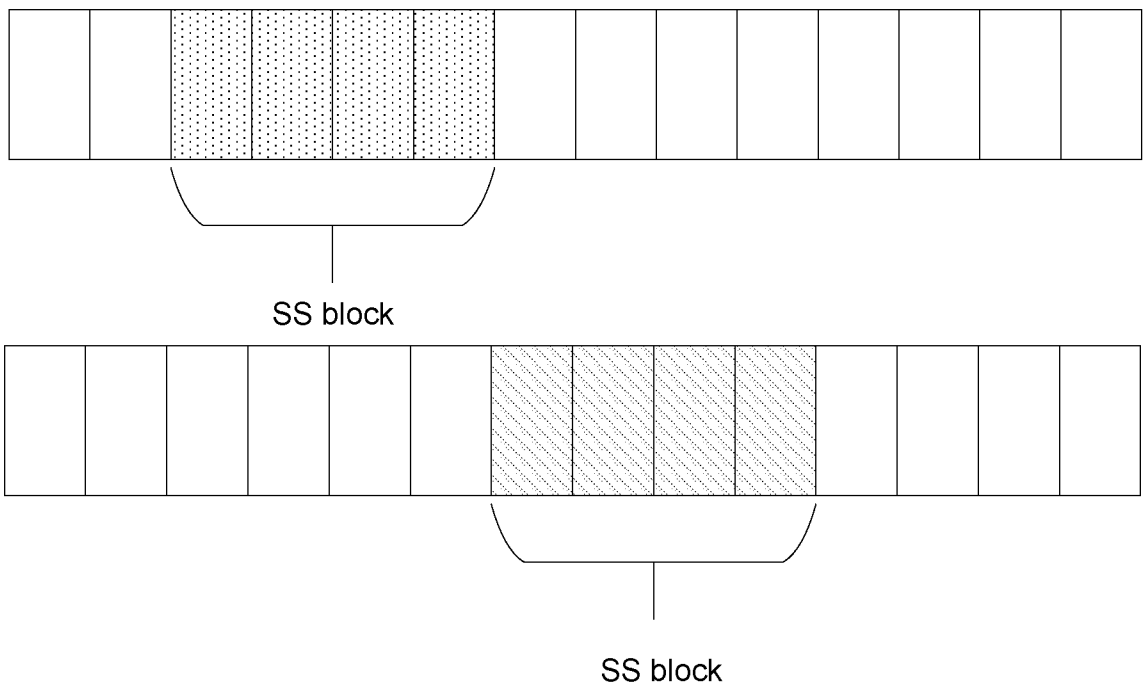


FIG. 4

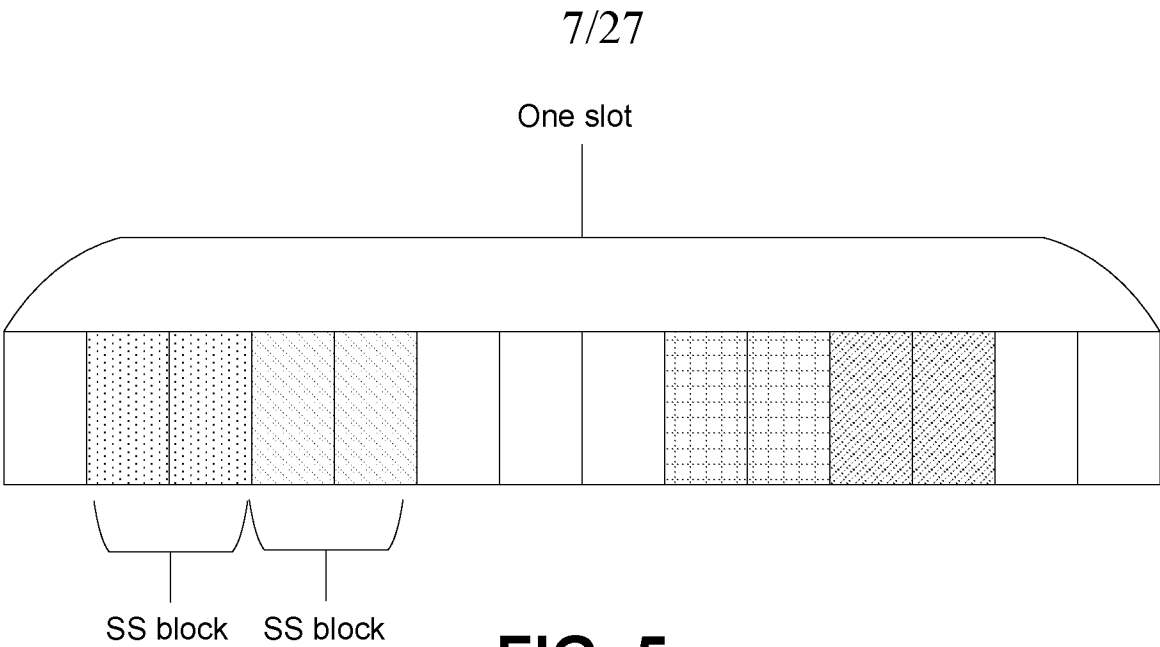


FIG. 5

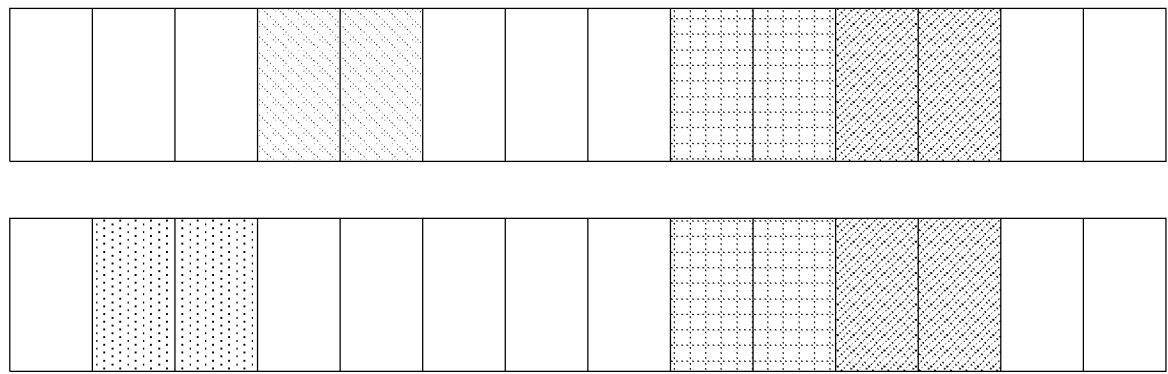


FIG. 6

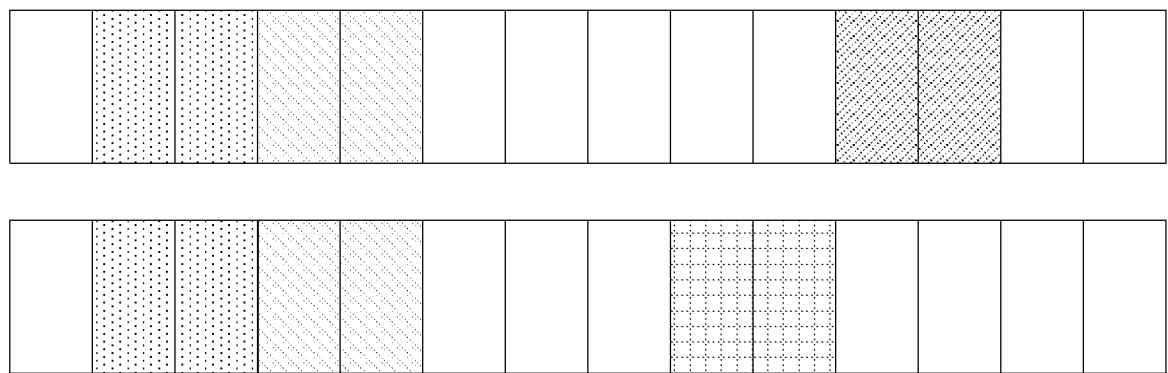


FIG. 7

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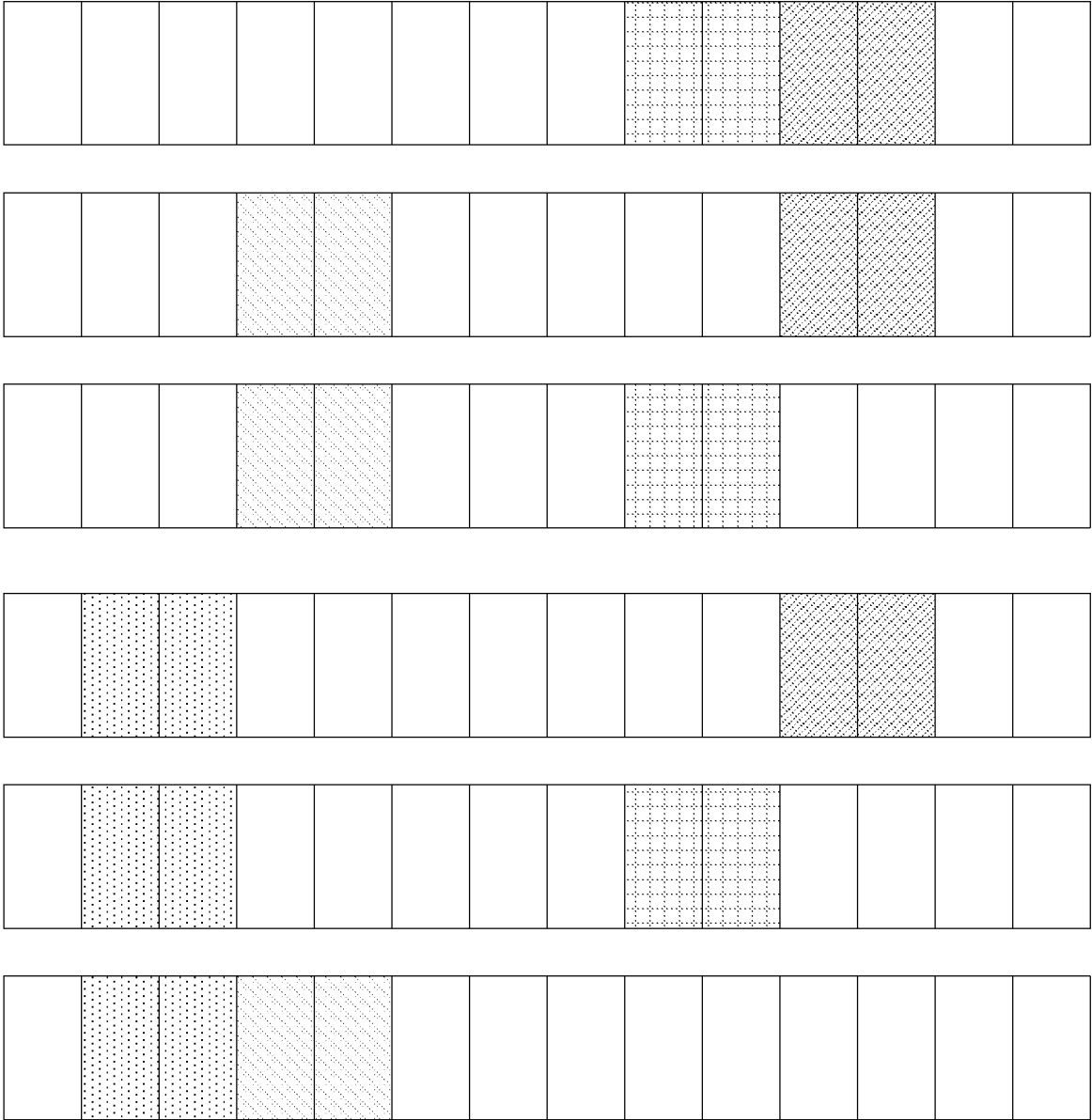


FIG. 8

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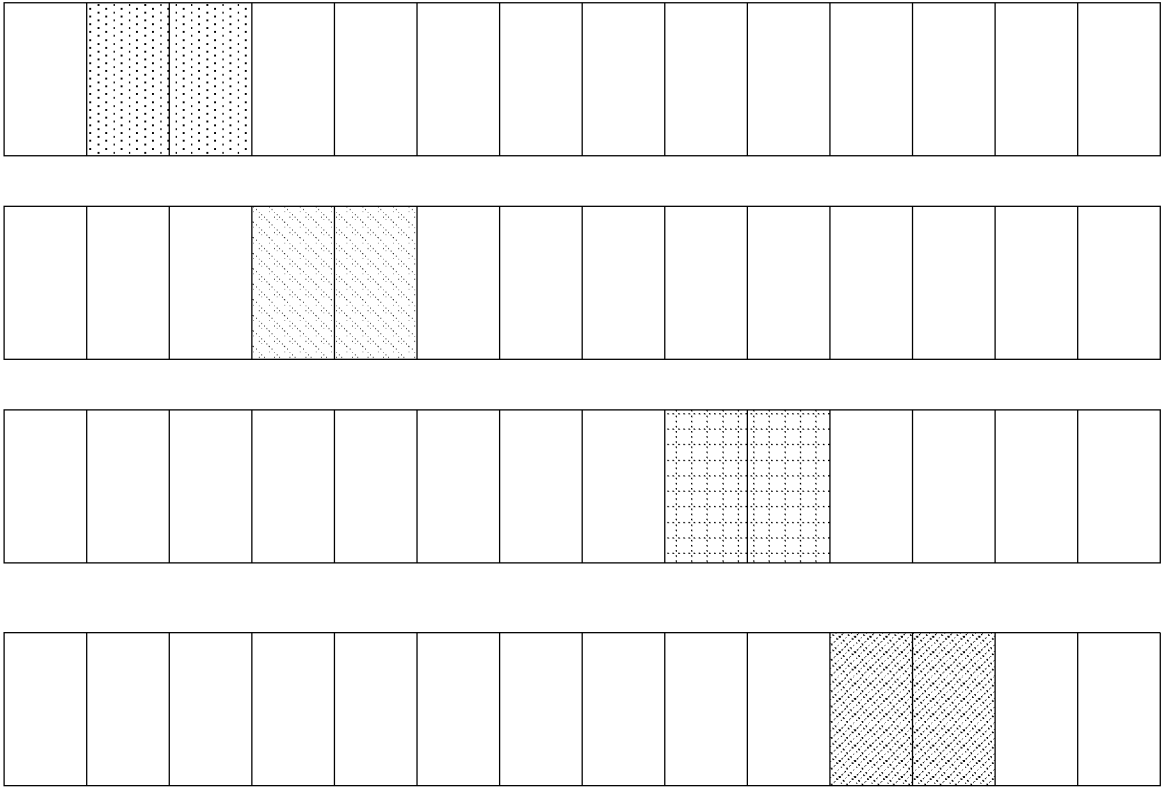


FIG. 9

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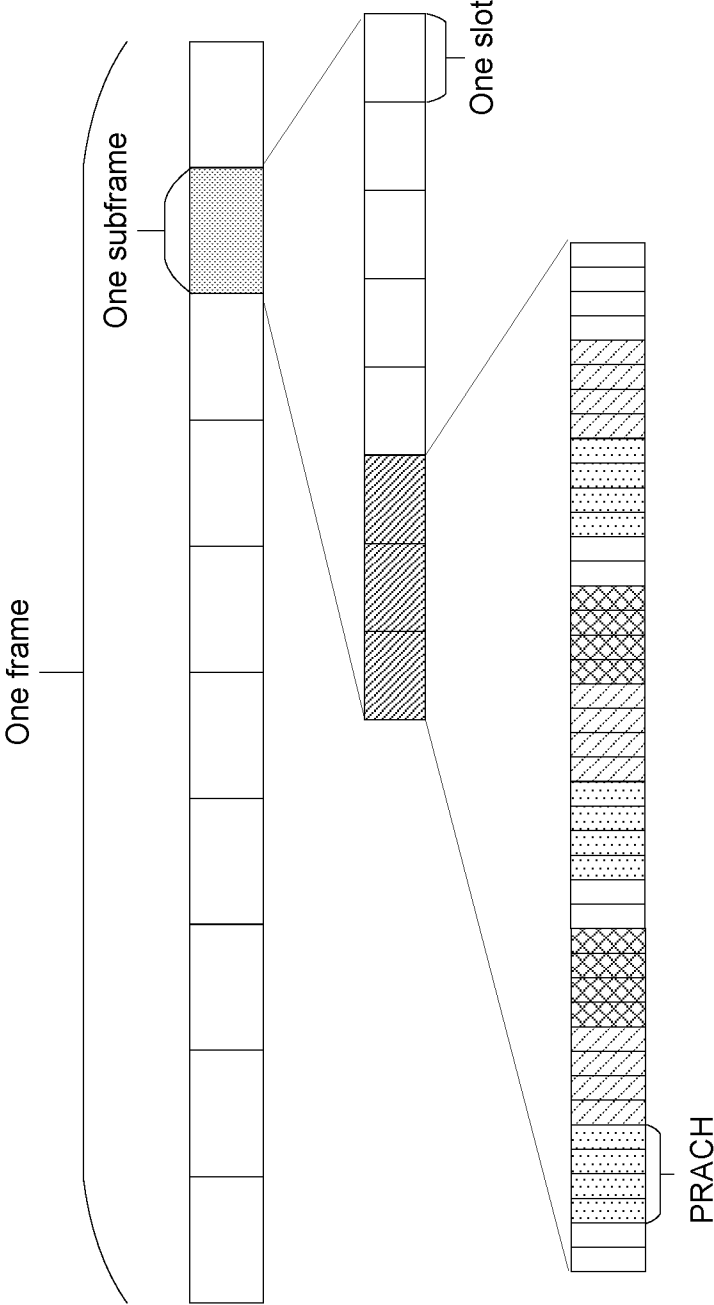


FIG. 10

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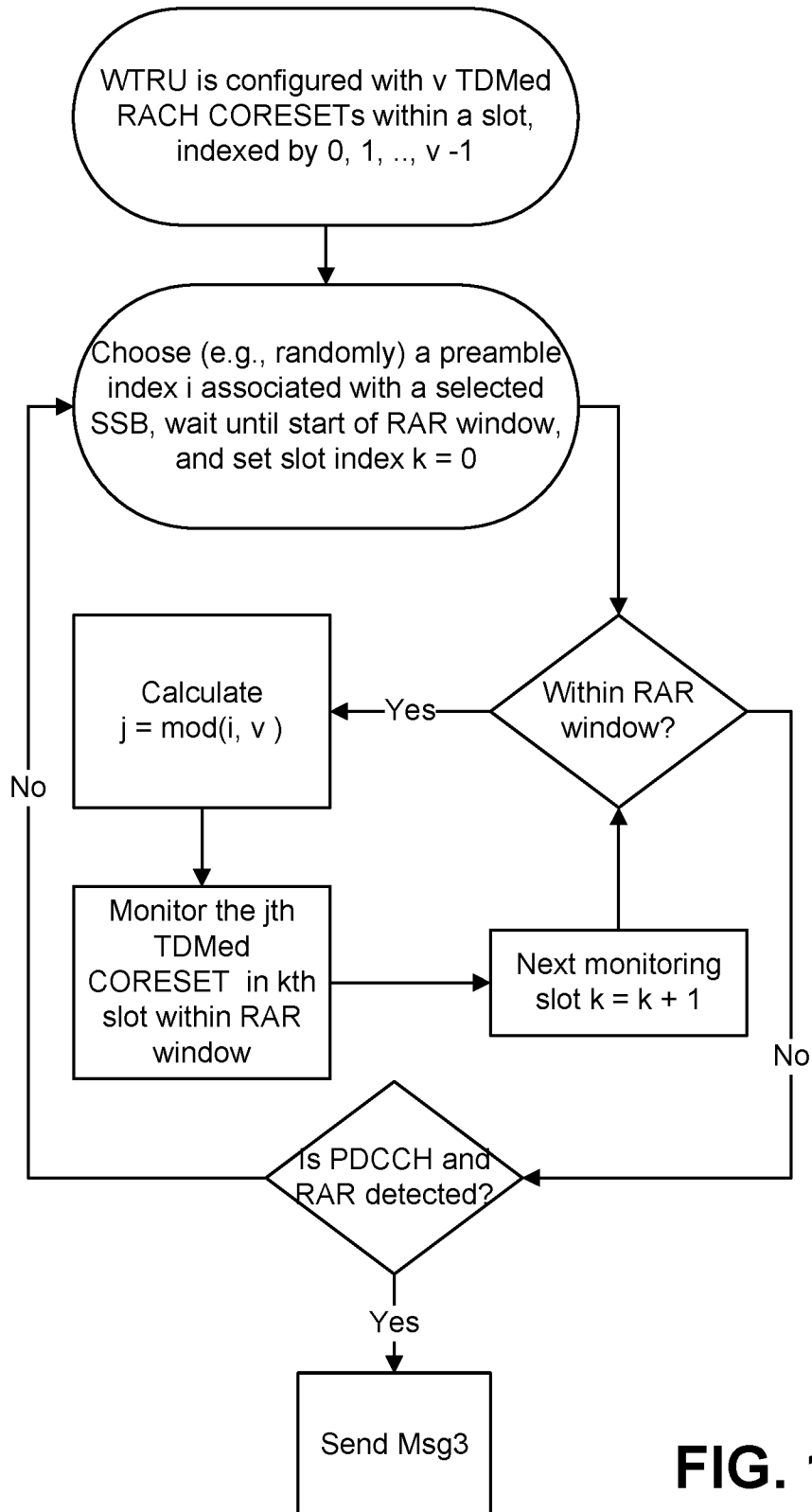


FIG. 11

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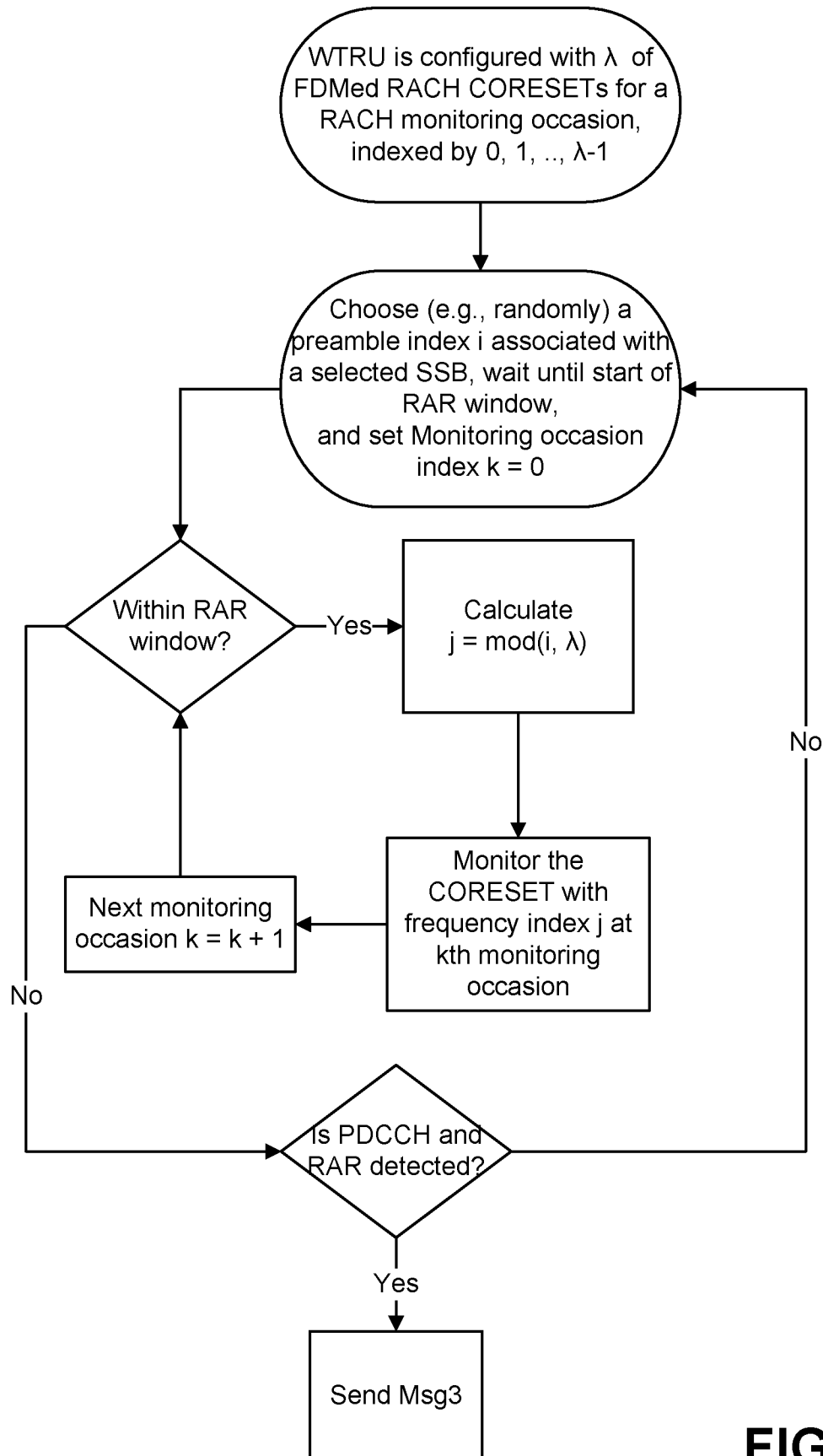


FIG. 12

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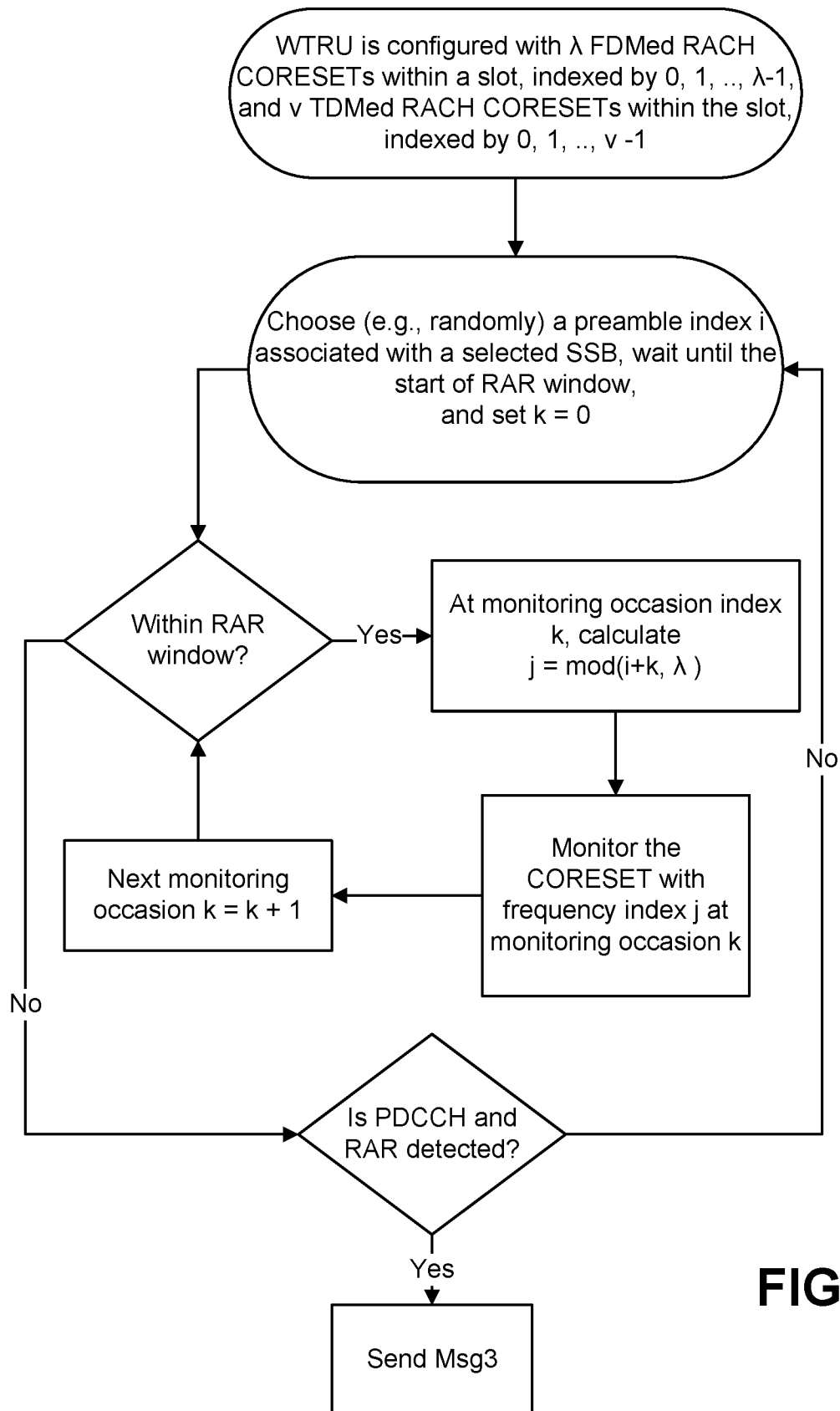
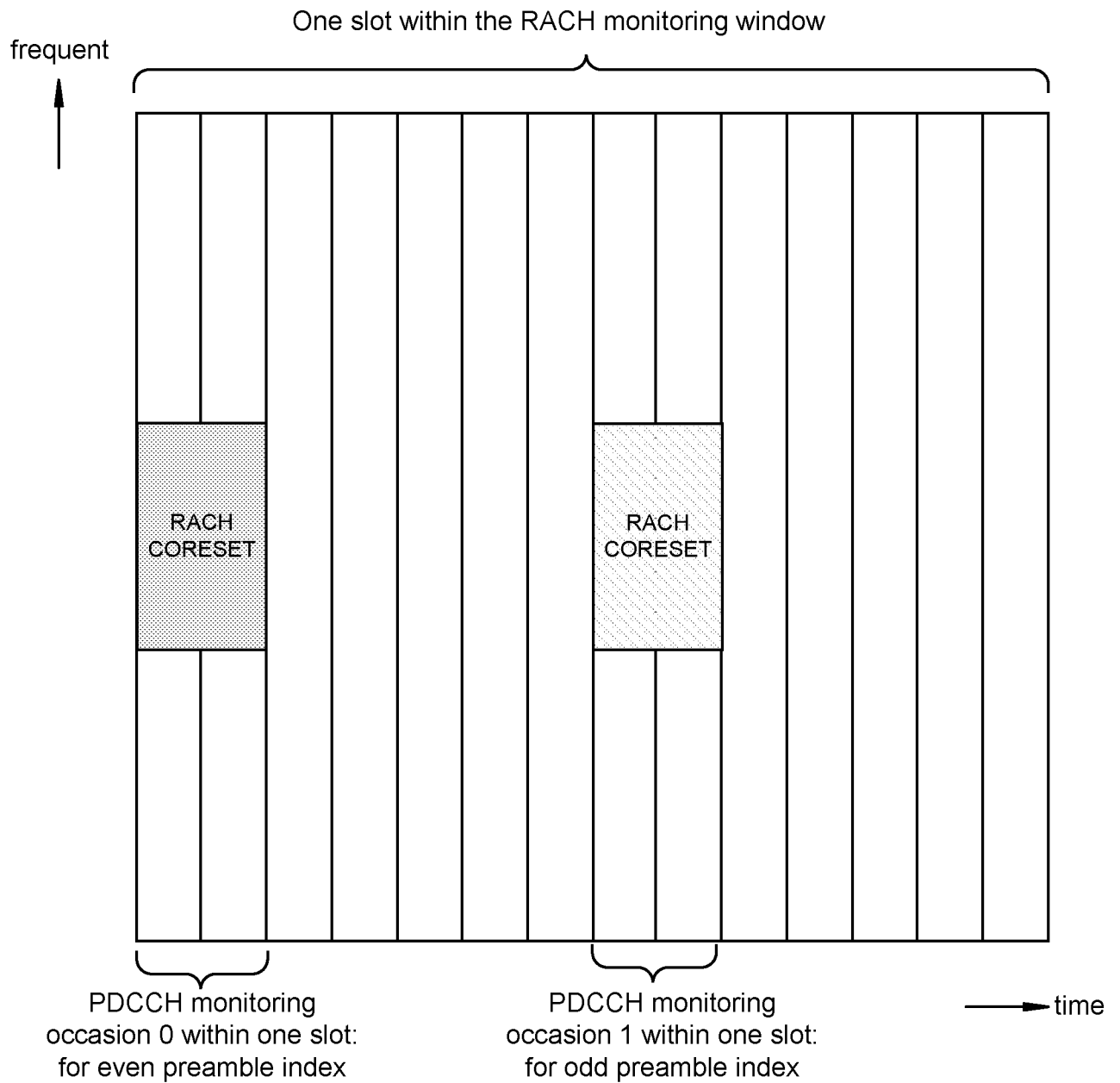


FIG. 13

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**FIG. 14**

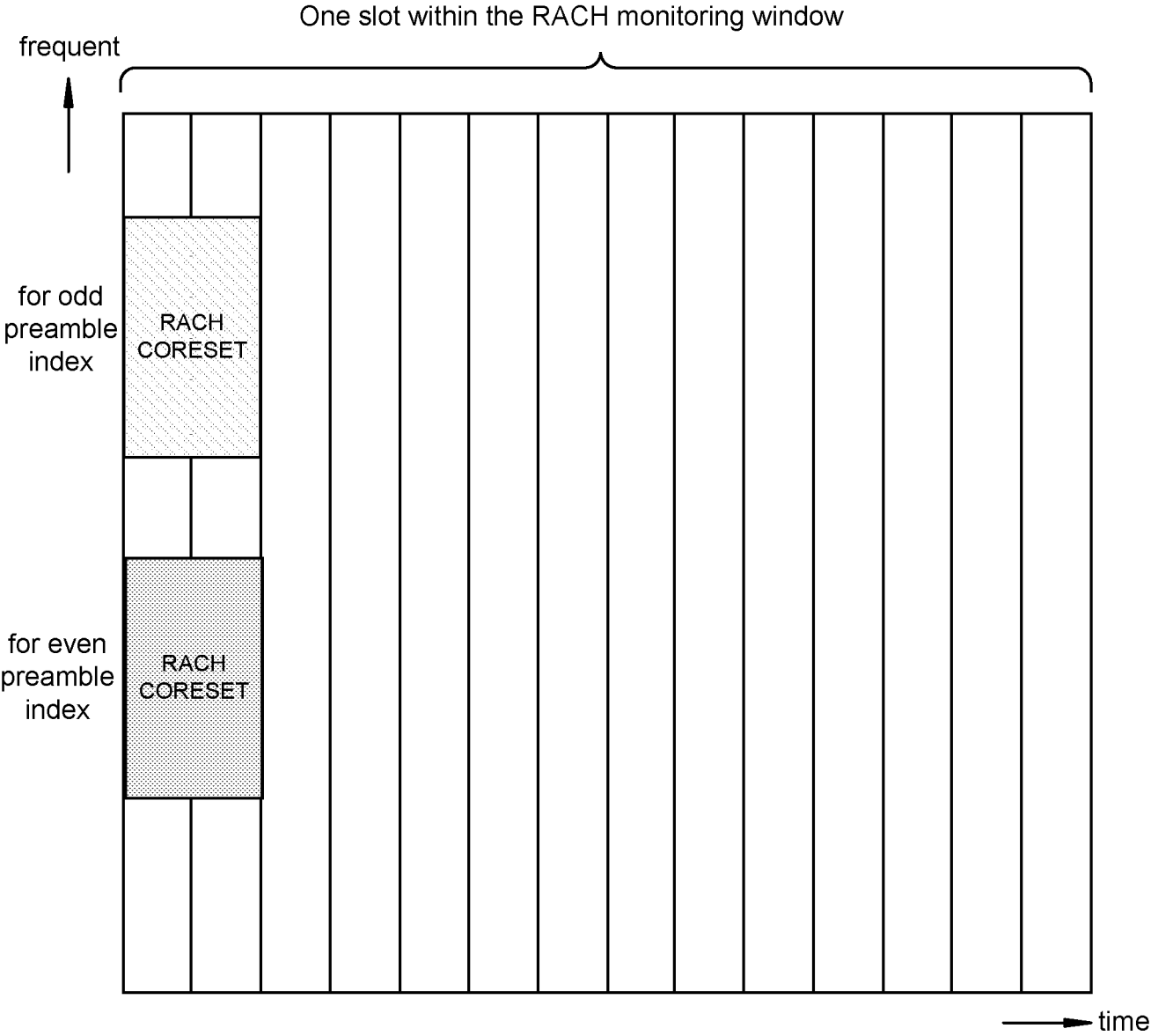


FIG. 15

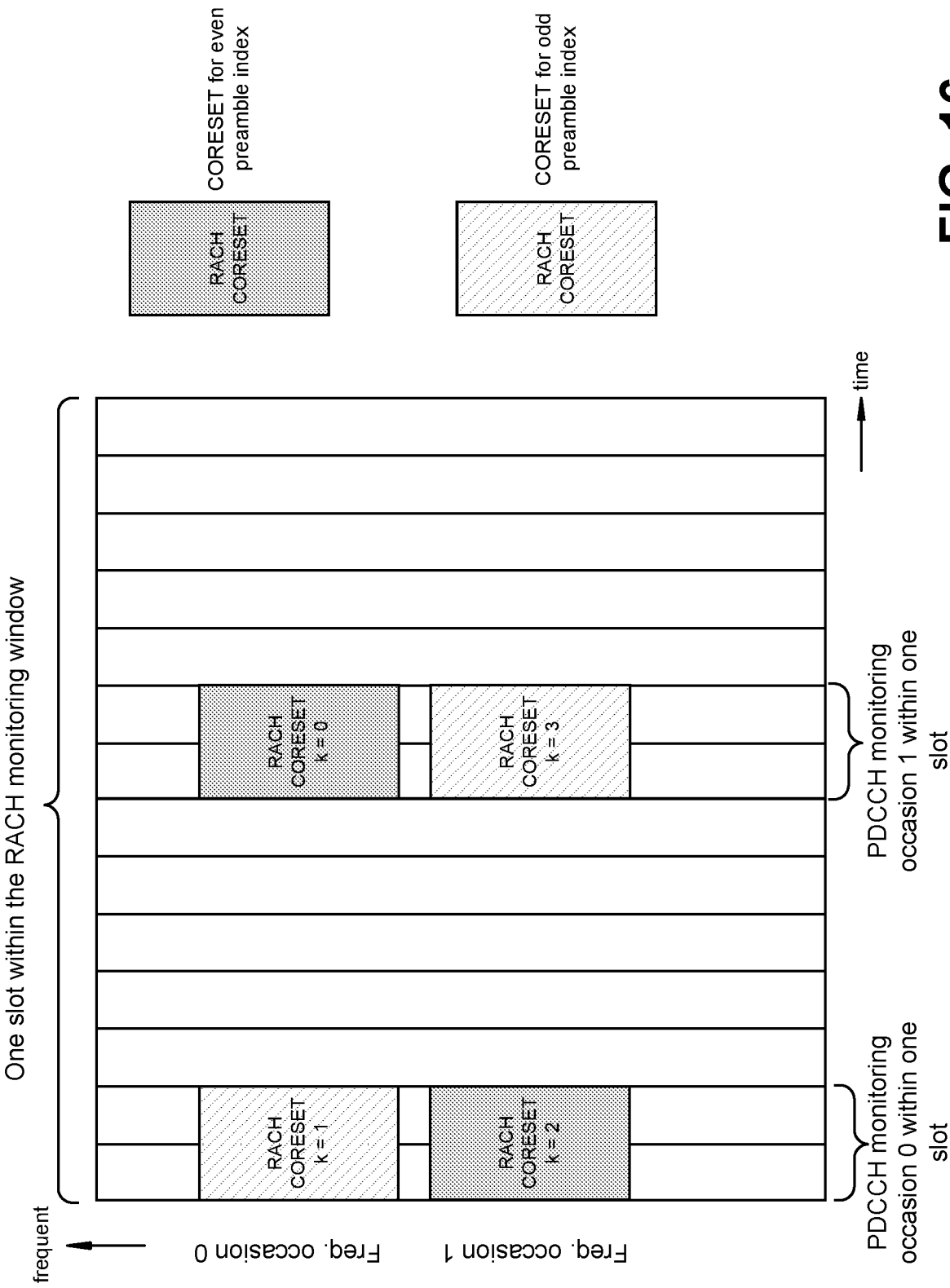


FIG. 16

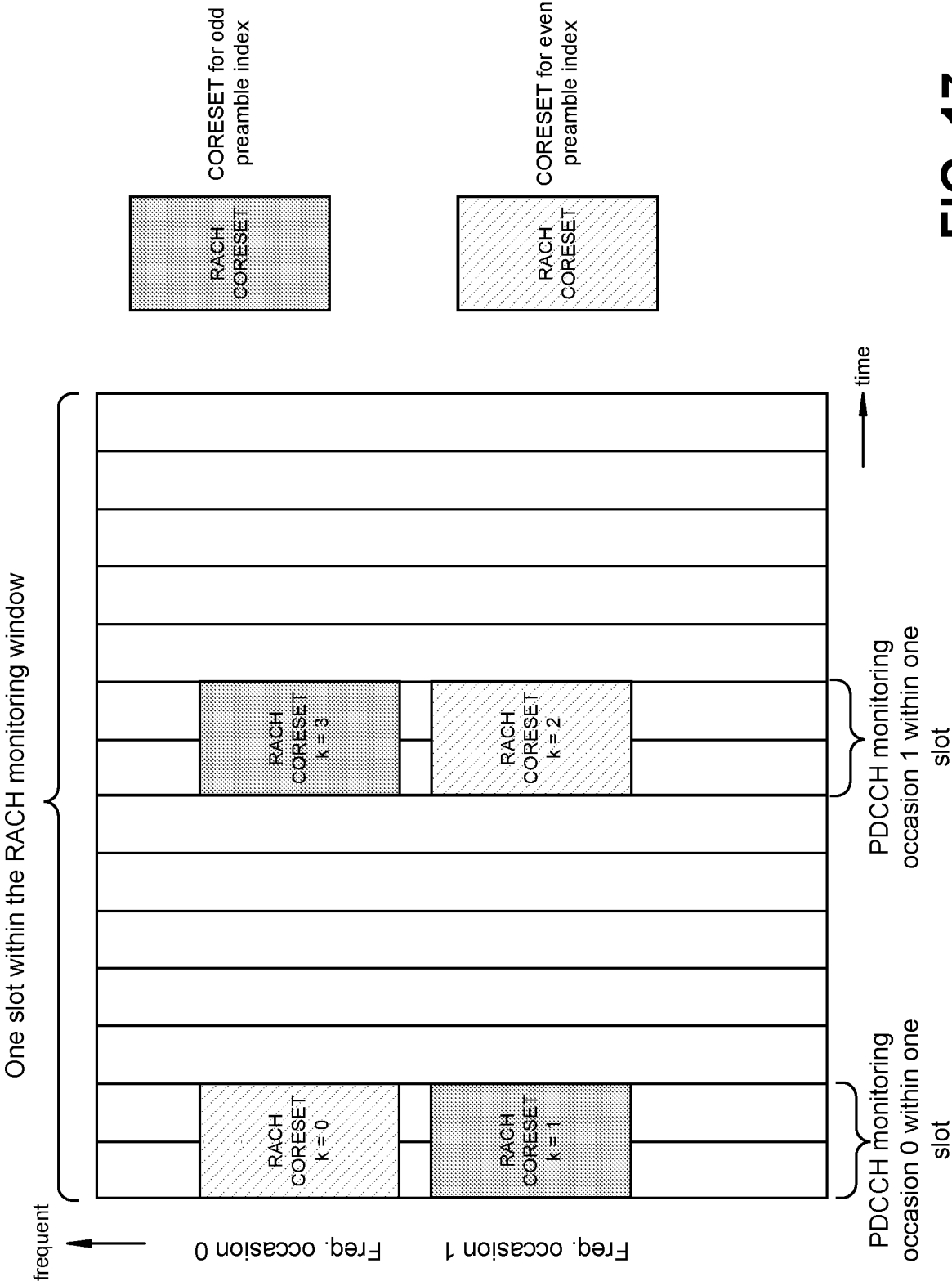


FIG. 17

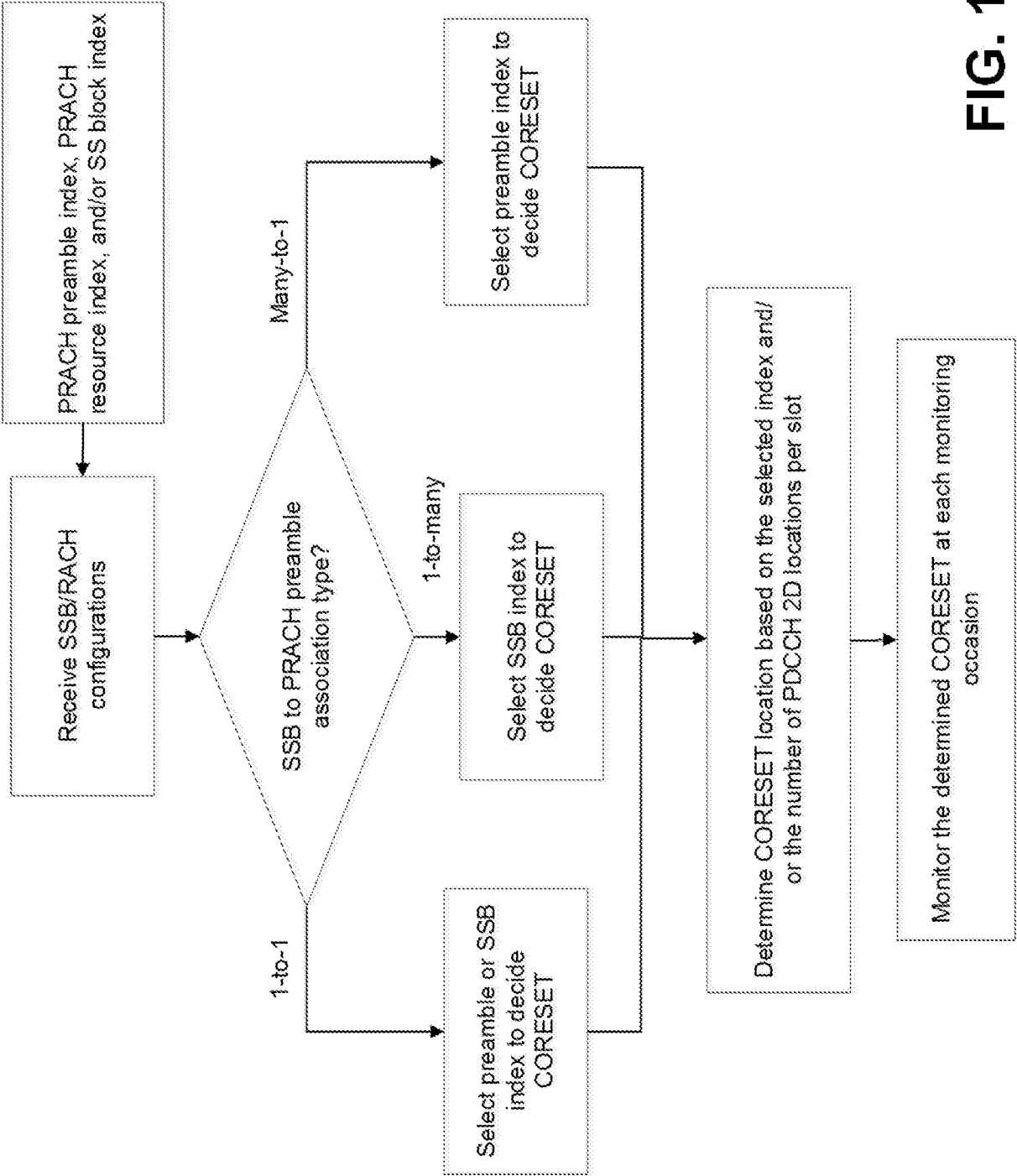


FIG. 18

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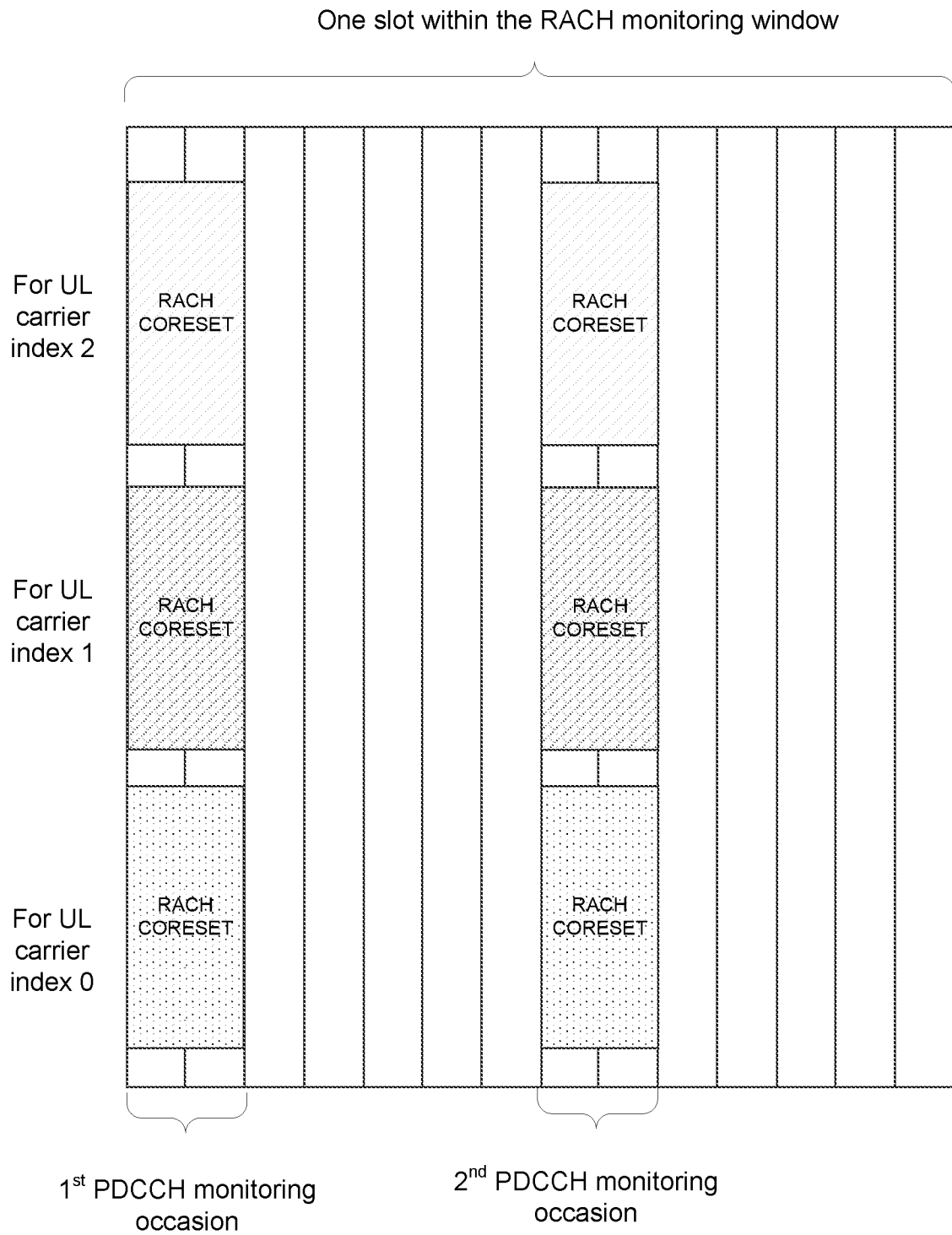
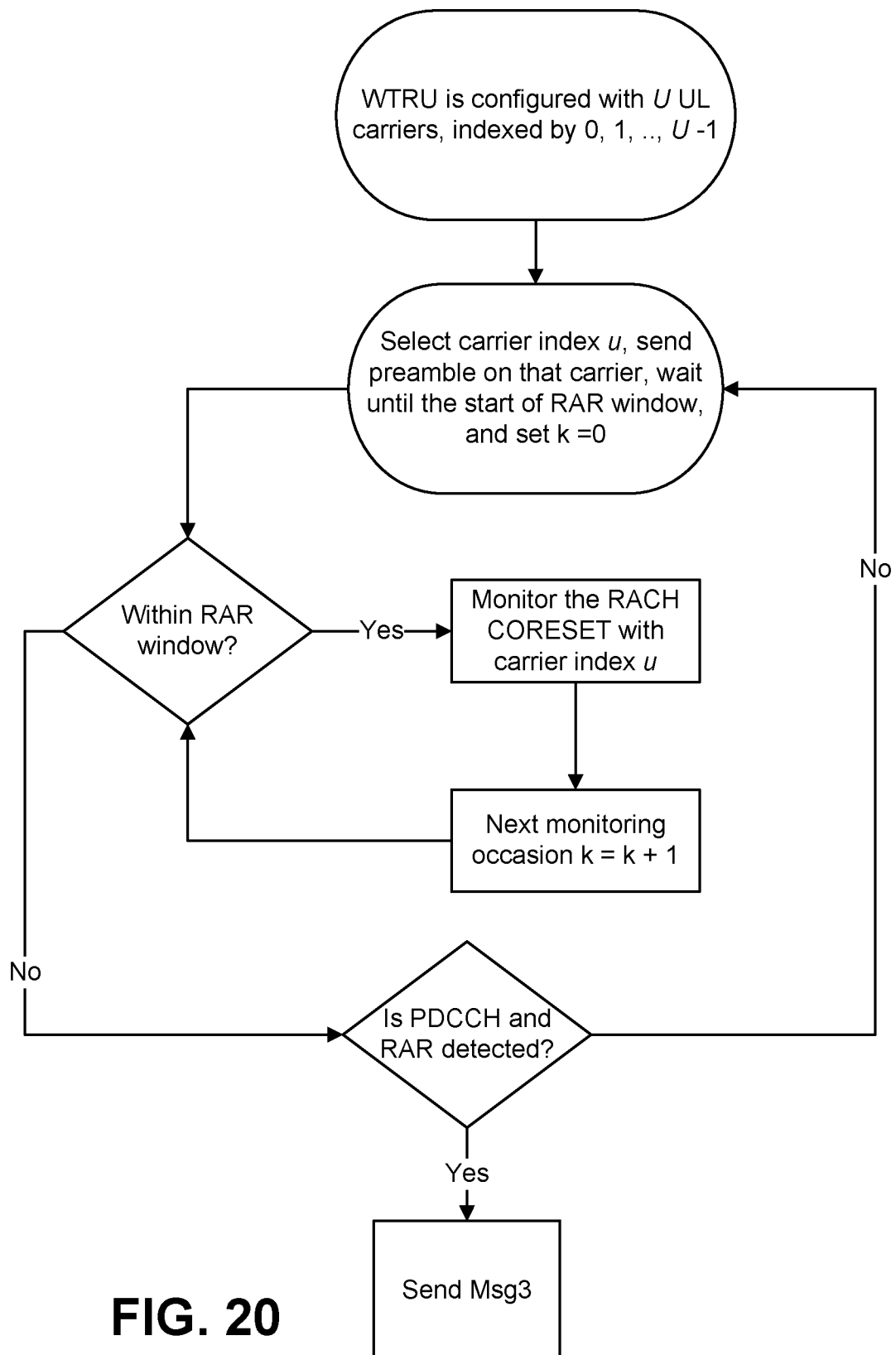


FIG. 19

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**FIG. 20**

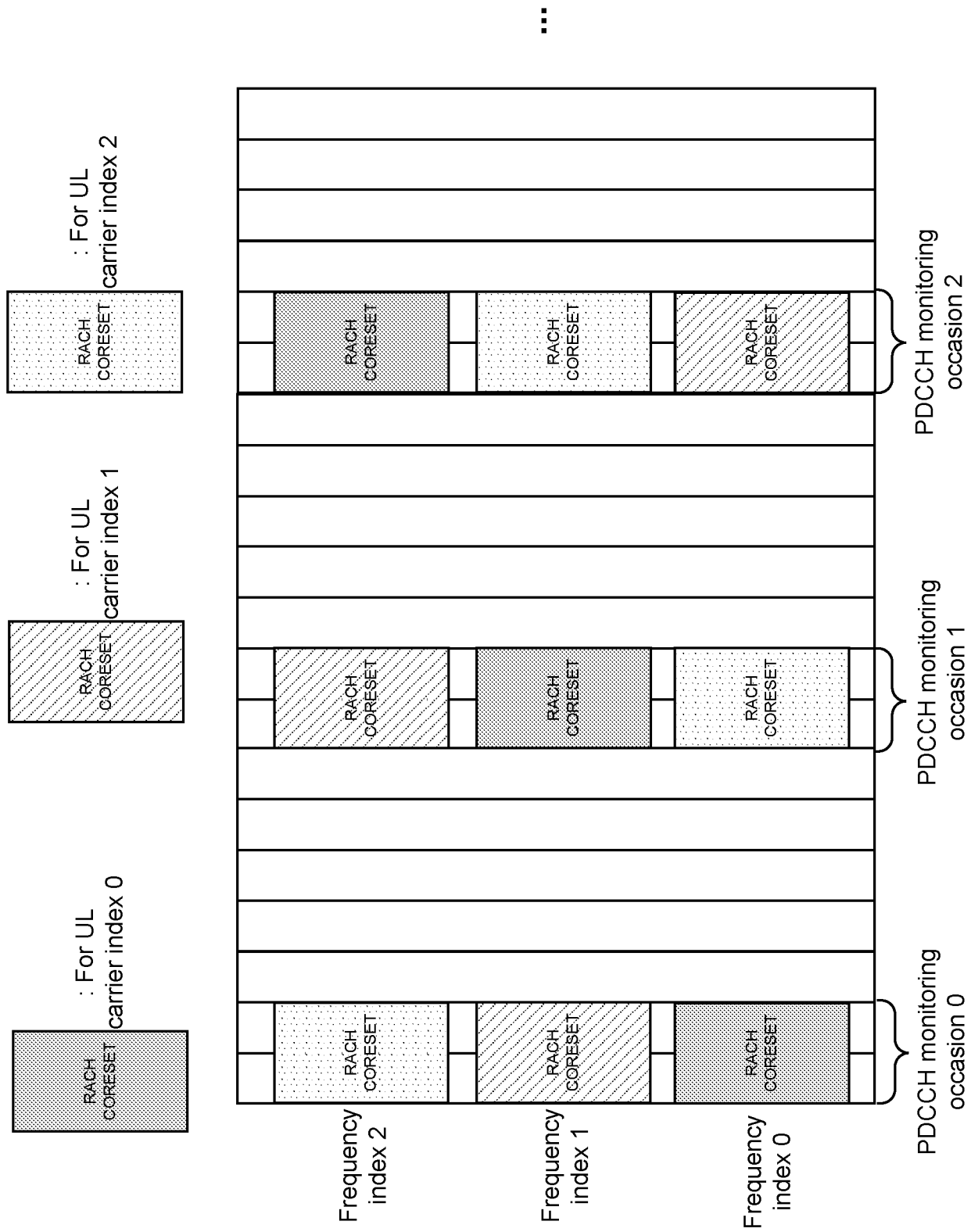


FIG. 21

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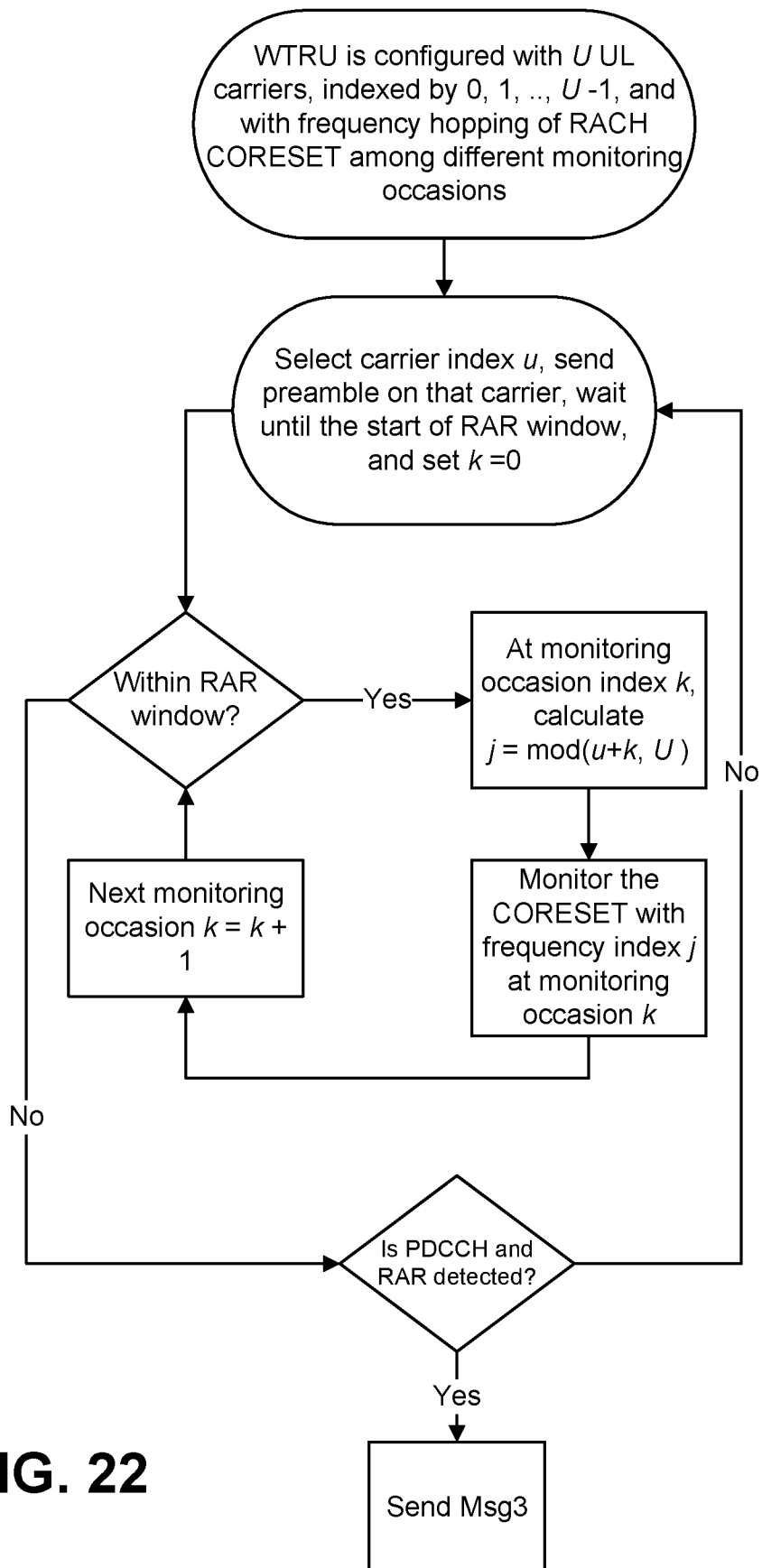


FIG. 22

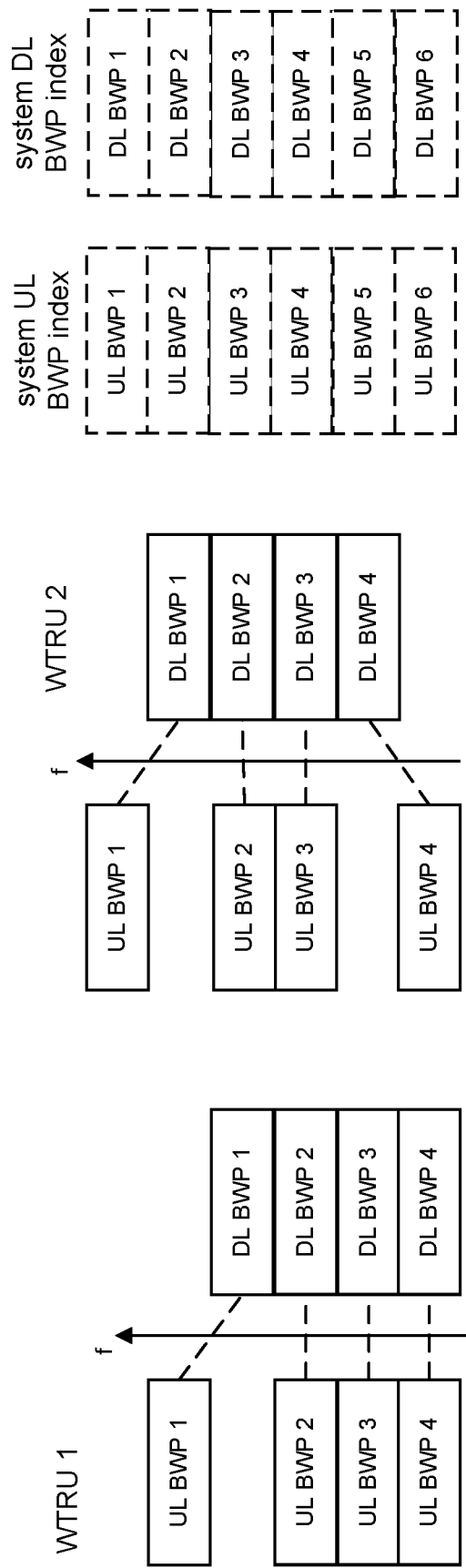
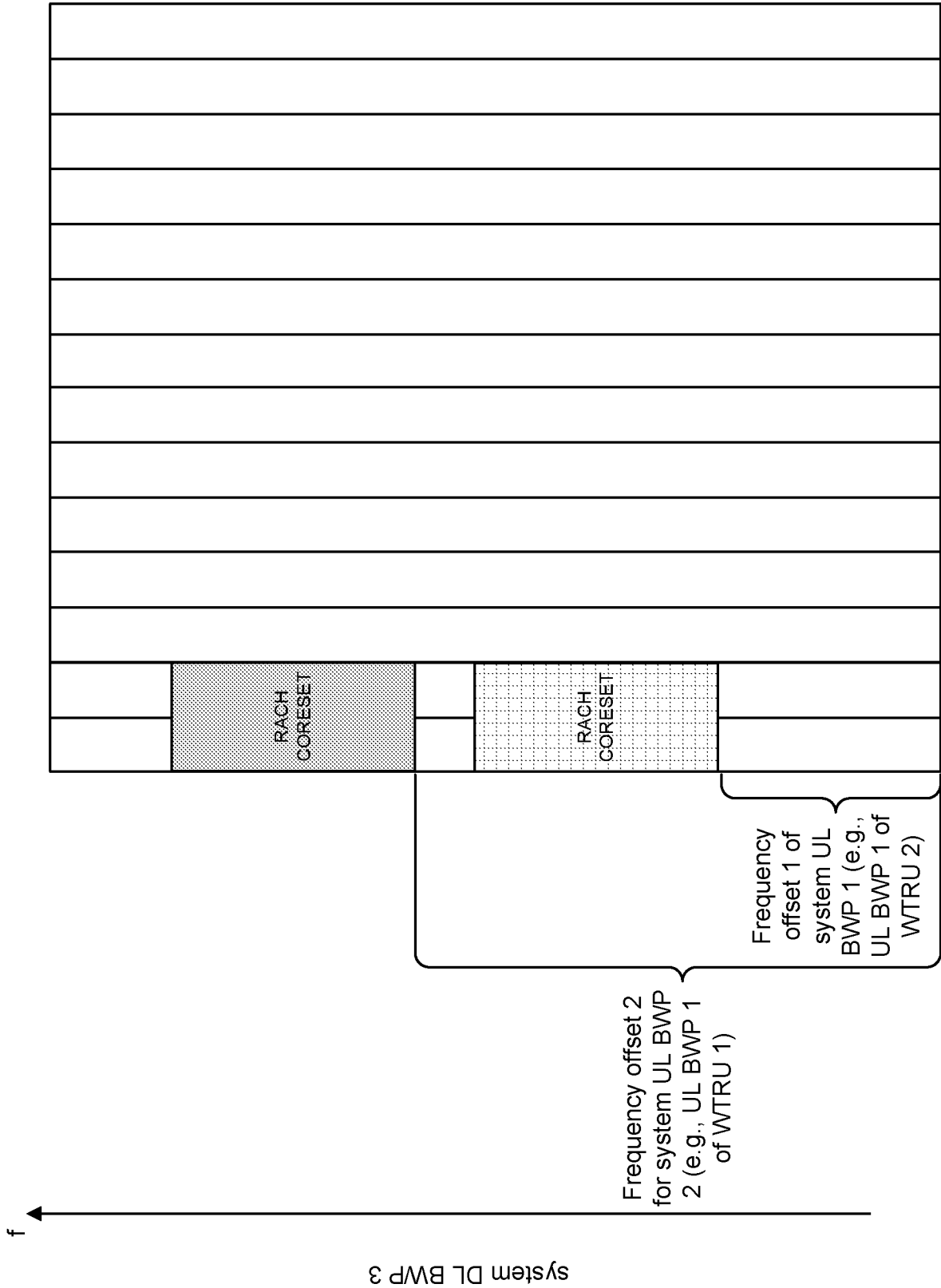


FIG. 23

FIG. 24



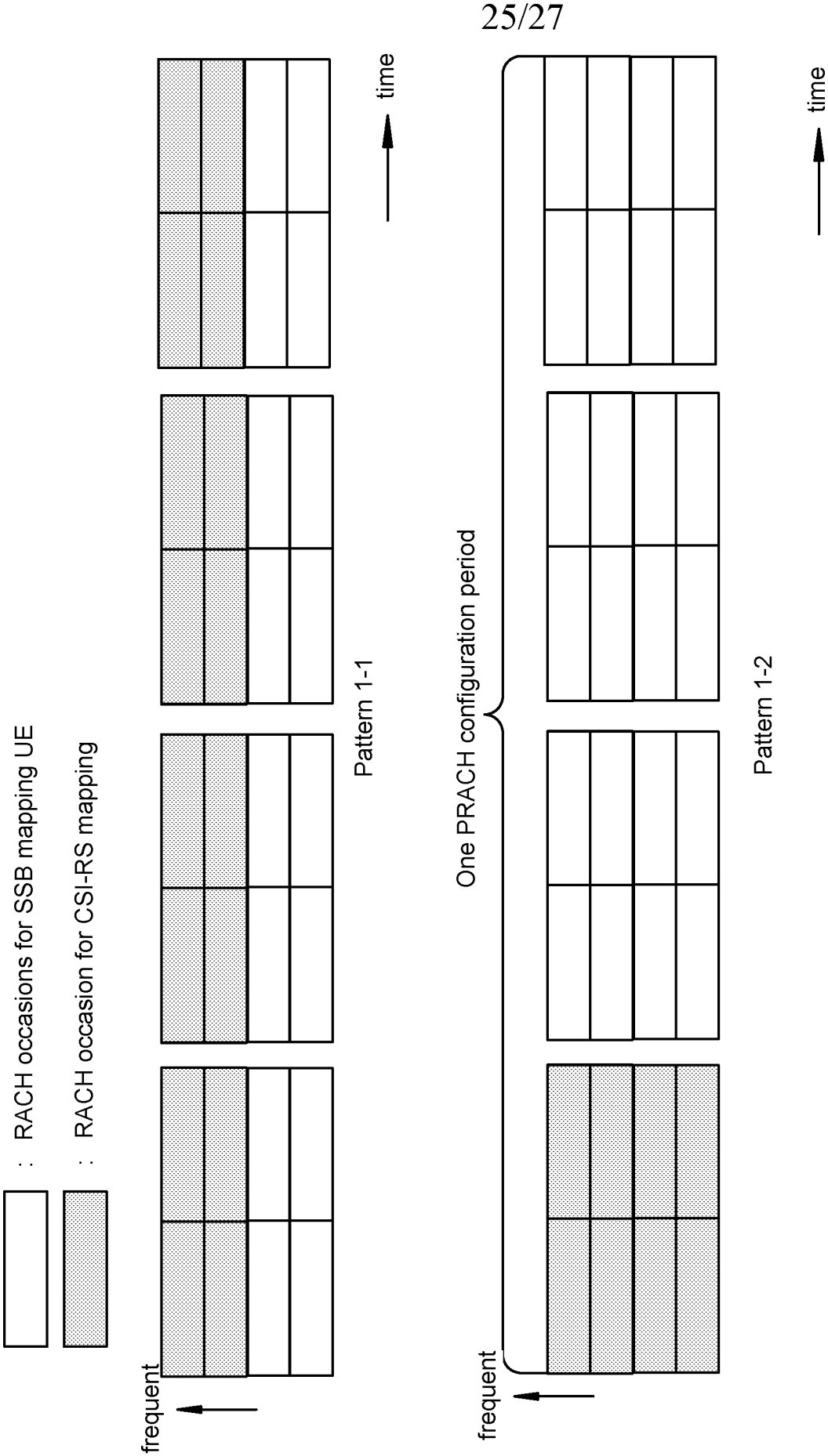


FIG. 25

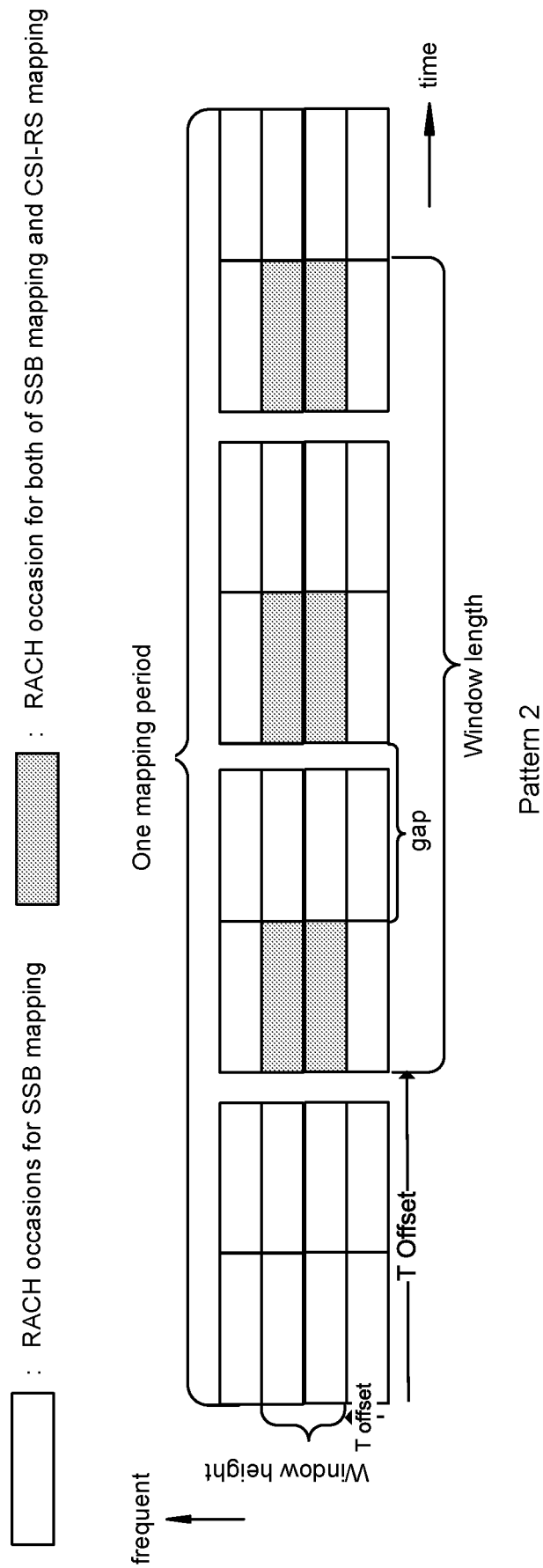


FIG. 26

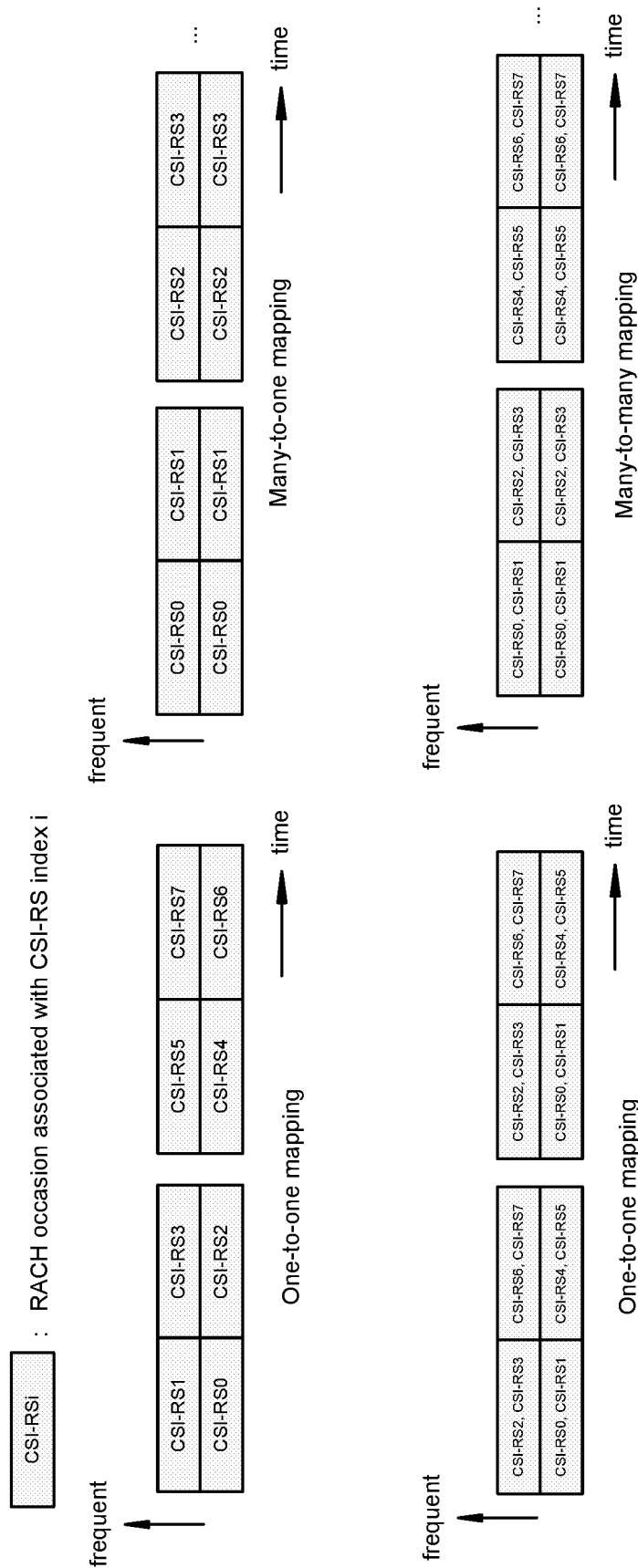


FIG. 27

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2018/060907

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W74/00
ADD. H04W74/08 H04L5/00

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W H04L

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

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

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	MEDIATEK INC: "RAR design supporting multiple preamble transmission", 3GPP DRAFT; R2-1708049 RAR DESIGN SUPPORTING MULTIPLE PREAMBLE TRANSMISSION, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CE	1-5, 9-15,19, 20
Y	vol. RAN WG2, no. Berlin, Germany; 20170821 - 20170825 20 August 2017 (2017-08-20), XP051317959, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN2/Docs/ [retrieved on 2017-08-20] clause 1 "Introduction" clause 2.1 "RAR window" clause 2.2 "RA-RNTI" ----- -/-	6-8, 16-18



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

30 January 2019

Date of mailing of the international search report

11/02/2019

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Andrés Muñoz, E

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2018/060907

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	MEDIATEK INC: "On 4-step RACH procedure", 3GPP DRAFT; R1-1710824 ON 4-STEP RACH PROCEDURE, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Qingdao, P.R. China; 20170627 - 20170630 26 June 2017 (2017-06-26), XP051300028, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN1/Docs/ [retrieved on 2017-06-26]	6-8, 16-18
A	clause 3 "Msg2: RAR reception" clause 4 "RACH resource association with CSI-RS" -----	1-5, 9-15,19, 20
A	ZTE ET AL: "Remaining details of RACH procedure", 3GPP DRAFT; R1-1717036, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Prague, Czech Republic; 20171009 - 20171013 8 October 2017 (2017-10-08), XP051340228, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN1/Docs/ [retrieved on 2017-10-08] clause 4 "RA-RNTI" clause 7 "Msg_2 Reception" -----	1-20