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(71) Applicant: **INTERDIGITAL PATENT HOLDINGS, INC.** [US/US]; 200 Bellevue Parkway, Suite 300, Wilmington, Delaware 19809 (US).

(72) Inventors: **HERATH, Prasanna**; 1000 Sherbrooke Street West, 10th Floor, Montreal, Québec H3A 3G4 (CA). **KWAK, Young Woo**; 425 Broadhollow Suite 203, Melville, New York 11747 (US). **LEE, Moon IL**; 425 Broadhollow, Suite 203, Melville, New York 11747 (US). **UR REHMAN, Haseeb**; 1000 Sherbrooke Street West, 10th Floor, Montreal, Québec H3A 3G4 (CA). **STERN-BERKOWITZ, Janet**; 425 Broadhollow Suite

203, Melville, New York 11747 (US). **KHAN BEIGI, Nazli**; 1000 Sherbrooke Street West, 10th Floor, Montreal, Québec H3A 3G4 (CA).

(74) Agent: **NGUYEN, Jamie T.**; 200 Bellevue Parkway, Suite 300, Wilmington, Delaware 19809 (US).

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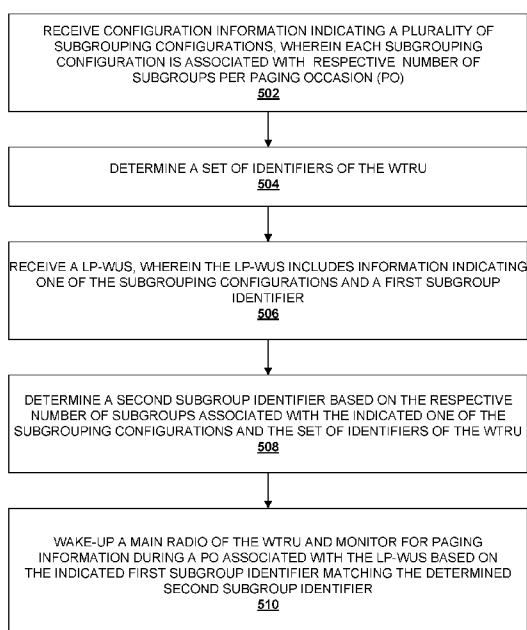


FIG. 5

(57) Abstract: A wireless transmit/receive unit (WTRU) may have a low-power radio and a main radio. The WTRU may receive configuration information indicating plural subgroupings. Each subgrouping may be associated with a respective number of subgroups per paging occasion (PO). The WTRU may determine a set of identifiers of the WTRU. The WTRU may receive, via the low-power radio, a low-power-wake up signal (LP-WUS). The LP-WUS may include information indicating (i) a subgrouping of the plural subgroupings, and (ii) one or more first subgroup identifiers. The WTRU may determine a second subgroup identifier based on the indicated subgrouping and an identifier of the set of identifiers of the WTRU. The WTRU may monitor, using the main radio, for a physical downlink control channel (PDCCH) transmission during a PO associated with the LP-WUS based on the determined second subgroup identifier matching one of the indicated one or more first subgroup identifiers.

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METHODS, ARCHITECTURES, APPARATUSES AND SYSTEMS FOR SUBGROUP BASED WAKE-UP INDICATIONS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 63/617,861 filed 05-Jan-2024, which is incorporated herein by reference.

BACKGROUND

[0002] The present application is related to the fields of communications, software and encoding, including, for example, to methods, architectures, apparatuses, systems directed to the determination of a connection initiating procedure and to the use of subgroup based wake-up indications.

[0003] A study item in 3GPP Release 18 focused on a low power-wake up signal (LP-WUS) in order to support a deep sleep state for a main radio (MR) of a wireless transmit/receive unit (WTRU) while the WTRU is in a radio resource control (RRC) IDLE or INACTIVE state. Support for the WTRU to skip monitoring for a physical downlink control channel (PDCCH) transmission while in a RRC CONNECTED state was also discussed. However, needs exist for the WTRU to determine a connection initiating procedure from among multiple connection initiating procedures and for subgroup based wake-up indications, such as may be supported by the use of a LP-WUS.

BRIEF SUMMARY

[0004] Briefly stated, in one embodiment, a WTRU may receive configuration information associated with two or more subgroupings. The WTRU may receive and/or determine one or more WTRU IDs. The WTRU may receive a LP-WUS that provides an indication of a subgrouping from the configured subgroupings, one or more subgroup IDs and/or a WTRU ID from among the WTRU IDs. The WTRU may determine a subgroup ID based on the indicated subgrouping and one of its WTRU IDs. If the determined subgroup ID matches one of the subgroup IDs indicated by the LP-WUS, the WTRU may turn on a MR and monitor for a PDCCH in a paging occasion (PO) associated with the received LP-WUS

[0005] In one embodiment, a WTRU may have a low-power radio and a main radio. The WTRU may receive configuration information indicating plural subgroupings. Each subgrouping may be associated with a respective number of subgroups per paging occasion (PO). The WTRU may determine a set of identifiers of the WTRU. The WTRU may receive, via the low-power radio, a

low-power-wake up signal (LP-WUS). The LP-WUS may include information indicating (i) a subgrouping of the plural subgroupings, and (ii) one or more first subgroup identifiers. The WTRU may determine a second subgroup identifier based on the indicated subgrouping and an identifier of the set of identifiers of the WTRU. The WTRU may monitor, using the main radio, for a physical downlink control channel (PDCCH) transmission during a PO associated with the LP-WUS based on the determined second subgroup identifier matching one of the indicated one or more first subgroup identifiers.

[0006] In one embodiment, a WTRU may have a low-power radio and a main radio. The WTRU may receive configuration information indicating a plurality of subgroupings. For example, each subgrouping may be associated with a respective number of subgroups per PO. The WTRU may determine a set of identifiers of the WTRU. The WTRU may receive, via the low-power radio, a LP-WUS. For example, the LP-WUS may include information indicating (i) a subgrouping of the plurality of subgroupings, and (ii) one or more first subgroup identifiers. The WTRU may determine a second subgroup identifier based on the indicated subgrouping and an identifier of the set of identifiers of the WTRU. The WTRU may monitor, using the main radio, for a PDCCH transmission during a PO associated with the LP-WUS based on the determined second subgroup identifier matching one of the indicated one or more first subgroup identifiers.

[0007] In one embodiment, a WTRU may have a low-power radio and a main radio. The WTRU may receive information indicating a plurality of subgroupings. For example, each subgrouping may be associated with a respective number of subgroups per PO. The WTRU may determine a set of identifiers of the WTRU. The WTRU may receive, via the low-power radio, a LP-WUS. For example, the LP-WUS may include information indicating (i) a subgrouping of the plurality of subgroupings, and (ii) one or more first subgroup identifiers. The WTRU may determine a second subgroup identifier based on the indicated subgrouping and an identifier of the set of identifiers of the WTRU. The WTRU may receive, using the main radio, paging information during a PO associated with the LP-WUS based on the determined second subgroup identifier matching one of the indicated one or more first subgroup identifiers.

[0008] In one embodiment, a WTRU may have a low-power radio and a main radio. The WTRU may receive information indicating a plurality of subgroupings. For example, each subgrouping may be associated with a respective number of subgroups per PO. The WTRU may determine a set of identifiers of the WTRU. The WTRU may receive, via the low-power radio, a LP-WUS. For example, the LP-WUS may include information indicating (i) a subgrouping of the plurality of subgroupings, and (ii) one or more first subgroup identifiers. The WTRU may determine a second subgroup identifier based on the indicated subgrouping and an identifier of the set of

identifiers of the WTRU. The WTRU may receive, using the main radio, paging information during a PO associated with the LP-WUS based on the determined second subgroup identifier matching one of the indicated one or more first subgroup identifiers. The WTRU may send, using the main radio, a PRACH transmission based on the paging information.

5 [0009] In one embodiment, a WTRU may have a low-power radio and a main radio. The WTRU may receive information indicating a plurality of subgroupings. For example, each subgrouping may be associated with a respective number of subgroups per PO. The WTRU may determine a set of identifiers of the WTRU. The WTRU may receive, via the low-power radio, a LP-WUS. For example, the LP-WUS may include information indicating (i) a subgrouping of the plurality
10 of subgroupings, and (ii) one or more first subgroup identifiers. The WTRU may determine a second subgroup identifier based on the indicated subgrouping and an identifier of the set of identifiers of the WTRU. The WTRU may receive, using the main radio, paging information during a PO associated with the LP-WUS based on the determined second subgroup identifier matching one of the indicated one or more first subgroup identifiers. The WTRU may receive,
15 using the main radio, a MIB and/or a SIB based on the paging information.

[0010] In one embodiment, a WTRU may have a low-power radio and a main radio. The WTRU may receive information indicating a plurality of subgroupings. For example, each subgrouping may be associated with a respective number of subgroups per PO. The WTRU may determine a set of identifiers of the WTRU. The WTRU may receive, via the low-power radio, a LP-WUS.
20 For example, the LP-WUS may include information indicating (i) a subgrouping of the plurality of subgroupings, and (ii) one or more first subgroup identifiers. The WTRU may determine a second subgroup identifier based on the indicated subgrouping and an identifier of the set of identifiers of the WTRU. The WTRU may receive, using the main radio, paging information during a PO associated with the LP-WUS based on the determined second subgroup identifier
25 matching one of the indicated one or more first subgroup identifiers. The WTRU may receive, using the main radio, a ETWS message based on the paging information.

[0011] In one embodiment, a WTRU may have a low-power radio and a main radio. The WTRU may receive information indicating a plurality of subgroupings. For example, each subgrouping may be associated with a respective number of subgroups per PO. The WTRU may determine a set of identifiers of the WTRU. The WTRU may receive, via the low-power radio, a LP-WUS.
30 For example, the LP-WUS may include information indicating (i) a subgrouping of the plurality of subgroupings, and (ii) one or more first subgroup identifiers. The WTRU may determine a second subgroup identifier based on the indicated subgrouping and an identifier of the set of identifiers of the WTRU. The WTRU may receive, using the main radio, paging information

during a PO associated with the LP-WUS based on the determined second subgroup identifier matching one of the indicated one or more first subgroup identifiers. The WTRU may receive, using the main radio, a CMAS message based on the paging information.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The following detailed description will be better understood when read in conjunction with the appended drawings, in which there are shown examples of one or more of the multiple embodiments of the present disclosure. It should be understood, however, that the embodiments described herein are not limited to the precise arrangements and instrumentalities shown in the drawings. In the drawings:

[0013] FIG. 1A is a system diagram illustrating an example communications system, according to one or more embodiments of the present disclosure;

[0014] FIG. 1B is a system diagram illustrating an example wireless transmit/receive unit (WTRU) that may be used within the communications system illustrated in FIG. 1A, according to one or more embodiments of the present disclosure;

[0015] FIG. 1C is a system diagram illustrating an example radio access network (RAN) and an example core network (CN) that may be used within the communications system illustrated in FIG. 1A, according to one or more embodiments of the present disclosure;

[0016] FIG. 1D is a system diagram illustrating a further example RAN and a further example CN that may be used within the communications system illustrated in FIG. 1A, according to one or more embodiments of the present disclosure;

[0017] FIG. 2 is a system diagram illustrating an example receiver architecture of a low-power wake-up radio receiver and a main radio receiver, according to one or more embodiments of the present disclosure;

[0018] FIG. 3 is a timing diagram illustrating examples of LP-WUSs and different wake-up procedures, according to one or more embodiments of the present disclosure;

[0019] FIG. 4 is a procedural diagram illustrating an example of performing a wake-up procedure by a WTRU configured with a plurality of wake-up procedures, according to one or more embodiments of the present disclosure;

[0020] FIG. 5 is a procedural diagram illustrating an example of determining to perform a wake-up procedure by a WTRU configured with a plurality of subgrouping configurations, according to one or more embodiments of the present disclosure.

[0021] present disclosure;

[0022] FIG. 6 is a procedural diagram illustrating an example of a subgroup-based wake-up procedure, according to one or more embodiments of the present disclosure;

[0023] FIG. 7 is a procedural diagram illustrating another example of a subgroup-based wake-up procedure, according to one or more embodiments of the present disclosure;

5 [0024] FIG. 8 is a procedural diagram illustrating an example of a first subgroup-based wake-up procedure, according to one or more embodiments of the present disclosure;

[0025] FIG. 9 is a procedural diagram illustrating an example of a second subgroup-based wake-up procedure, according to one or more embodiments of the present disclosure;

10 [0026] FIG. 10 is a procedural diagram illustrating an example of a third subgroup-based wake-up procedure, according to one or more embodiments of the present disclosure; and

[0027] FIG. 11 is a procedural diagram illustrating an example of a fourth subgroup-based wake-up procedure, according to one or more embodiments of the present disclosure.

DETAILED DESCRIPTION

15 [0028] In describing the various embodiments of the present disclosure, certain terminology is used herein for convenience only and should not be considered as limiting such embodiments. In the drawings, the same reference numerals are employed for designating the same elements throughout the several figures and the present description.

[0029] In the following detailed description, numerous specific details are set forth to provide a
20 thorough understanding of embodiments and/or examples disclosed herein. However, it will be understood that such embodiments and examples may be practiced without some or all of the specific details set forth herein. In other instances, well-known methods, procedures, components and circuits have not been described in detail, so as not to obscure the following description. Further, embodiments and examples not specifically described herein may be practiced in lieu of,
25 or in combination with, the embodiments and other examples described, disclosed or otherwise provided explicitly, implicitly and/or inherently (collectively "provided") herein. Although various embodiments are described and/or claimed herein in which an apparatus, system, device, etc. and/or any element thereof carries out an operation, process, algorithm, function, etc. and/or any portion thereof, it is to be understood that any embodiments described and/or claimed herein
30 assume that any apparatus, system, device, etc. and/or any element thereof is configured to carry out any operation, process, algorithm, function, etc. and/or any portion thereof.

[0030] Example Communications System

[0031] The methods, apparatuses and systems provided herein are well-suited for communications involving both wired and wireless networks. An overview of various types of

wireless devices and infrastructure is provided with respect to FIGs. 1A-1D, where various elements of the network may utilize, perform, be arranged in accordance with and/or be adapted and/or configured for the methods, apparatuses and systems provided herein.

[0032] FIG. 1A is a system diagram illustrating an example communications system 100 in which one or more disclosed embodiments may be implemented. The communications system 100 may be a multiple access system that provides content, such as voice, data, video, messaging, broadcast, etc., to multiple wireless users. The communications system 100 may enable multiple wireless users to access such content through the sharing of system resources, including wireless bandwidth. For example, the communications systems 100 may employ one or more channel access methods, such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), single-carrier FDMA (SC-FDMA), zero-tail (ZT) unique-word (UW) discrete Fourier transform (DFT) spread OFDM (ZT UW DTS-s OFDM), unique word OFDM (UW-OFDM), resource block-filtered OFDM, filter bank multicarrier (FBMC), and the like.

[0033] As shown in FIG. 1A, the communications system 100 may include wireless transmit/receive units (WTRUs) 102a, 102b, 102c, 102d, a radio access network (RAN) 104/113, a core network (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 (or be) 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.

[0034] 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, e.g., to facilitate

access to one or more communication networks, such as the CN 106/115, the Internet 110, and/or the networks 112. By way of example, the base stations 114a, 114b may be any of a base transceiver station (BTS), a Node-B (NB), an eNode-B (eNB), a Home Node-B (HNB), a Home eNode-B (HeNB), a gNode-B (gNB), a NR Node-B (NR NB), 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.

[0035] 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 an 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 or any sector of the cell. For example, beamforming may be used to transmit and/or receive signals in desired spatial directions.

[0036] 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).

[0037] 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 116 using wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet Access (HSPA) and/or Evolved HSPA (HSPA+). HSPA may include High-Speed Downlink Packet Access (HSDPA) and/or High-Speed Uplink Packet Access (HSUPA).

[0038] 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).

5 [0039] 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).

[0040] 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
10 102a, 102b, 102c may implement LTE radio access and NR radio access together, for instance using dual connectivity (DC) principles. Thus, the air interface utilized by WTRUs 102a, 102b, 102c may be characterized by multiple types of radio access technologies and/or transmissions sent to/from multiple types of base stations (e.g., an eNB and a gNB).

[0041] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may
15 implement radio technologies such as IEEE 802.11 (i.e., Wireless Fidelity (Wi-Fi)), 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.

20 [0042] 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 an embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology
25 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 an 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 any of a small cell, picocell or femtocell.
30 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.

[0043] 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 an NR radio technology, the CN 106/115 may also be in communication with another RAN (not shown) employing any of a GSM, UMTS, CDMA 2000, WiMAX, E-UTRA, or Wi-Fi radio technology.

[0044] 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 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 104/114 or a different RAT.

[0045] 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.

[0046] 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 elements/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.

[0047] 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, e.g., in an electronic package or chip.

[0048] 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 an 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 an 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.

[0049] 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. For example, the WTRU 102 may employ MIMO technology. Thus, in an 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.

[0050] 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.

[0051] 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).

[0052] 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.

[0053] 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.

[0054] The processor 118 may further be coupled to other elements/peripherals 138, which may include one or more software and/or hardware modules/units that provide additional features, functionality and/or wired or wireless connectivity. For example, the elements/peripherals 138 may include an accelerometer, an e-compass, a satellite transceiver, a digital camera (e.g., 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 elements/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.

[0055] 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 uplink (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 uplink (e.g., for transmission) or the downlink (e.g., for reception)).

[0056] 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, and 102c over the air interface 116. The RAN 104 may also be in communication with the CN 106.

[0057] 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 an 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 receive wireless signals from, the WTRU 102a.

[0058] Each of the eNode-Bs 160a, 160b, and 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 uplink (UL) and/or downlink (DL), and the like. As shown in FIG. 1C, the eNode-Bs 160a, 160b, 160c may communicate with one another over an X2 interface.

[0059] The CN 106 shown in FIG. 1C may include a mobility management entity (MME) 162, a serving gateway (SGW) 164, and a packet data network (PDN) gateway (PGW) 166. While each of the foregoing elements are depicted as part of the CN 106, it will be appreciated that any one of these elements may be owned and/or operated by an entity other than the CN operator.

[0060] The MME 162 may be connected to each of the eNode-Bs 160a, 160b, and 160c 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.

[0061] 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.

[0062] 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.

[0063] 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.

[0064] 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.

[0065] In representative embodiments, the other network 112 may be a WLAN.

[0066] 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 into 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.

5 [0067] 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
10 sense multiple access with collision avoidance (CSMA/CA) may be implemented, for example in 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.

15 [0068] 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.

[0069] Very high throughput (VHT) STAs may support 20 MHz, 40 MHz, 80 MHz, and/or 160 MHz wide channels. The 40 MHz, and/or 80 MHz, channels may be formed by combining
20 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.
25 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 a medium access control (MAC) layer, entity, etc.

[0070] Sub 1 GHz modes of operation are supported by 802.11af and 802.11ah. The channel
30 operating bandwidths, and carriers, are reduced in 802.11af and 802.11ah relative to those used in 802.11n, and 802.11ac. 802.11af supports 5 MHz, 10 MHz and 20 MHz bandwidths in the TV white space (TVWS) spectrum, and 802.11ah supports 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz bandwidths using non-TVWS spectrum. According to a representative embodiment, 802.11ah may support meter type control/machine-type communications (MTC), such as MTC

devices in a macro coverage area. MTC devices may have certain capabilities, for example, limited capabilities including support for (e.g., only support for) certain and/or limited bandwidths. The MTC devices may include a battery with a battery life above a threshold (e.g., to maintain a very long battery life).

5 [0071] 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
10 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
15 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.

[0072] 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
20 923.5 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.

[0073] 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
25 communication with the CN 115.

[0074] 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 an embodiment, the gNBs 180a, 180b,
30 180c may implement MIMO technology. For example, gNBs 180a, 180b may utilize beamforming to transmit signals to and/or receive signals from the WTRUs 102a, 102b, 102c. 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).

[0075] The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using transmissions associated with a scalable numerology. For example, 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., including a varying number of OFDM symbols and/or lasting varying lengths of absolute time).

[0076] 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.

[0077] 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 functions (UPFs) 184a, 184b, routing of control plane information towards access and mobility management functions (AMFs) 182a, 182b, and the like. As shown in FIG. 1D, the gNBs 180a, 180b, 180c may communicate with one another over an Xn interface.

[0078] 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 at least one 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.

[0079] 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 protocol data unit (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, e.g., to customize CN support for WTRUs 102a, 102b, 102c based on the types of services being utilized WTRUs 102a, 102b, 102c. For example, different network slices may be established for different use cases such as services relying on ultra-reliable low latency (URLLC) access, services relying on enhanced massive mobile broadband (eMBB) access, services for MTC access, and/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 Wi-Fi.

[0080] 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 UE 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.

[0081] 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, e.g., to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices. The UPF 184a, 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.

[0082] 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 an 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.

[0083] 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 any of: WTRUs 102a-d, base stations 114a-b, eNode-Bs 160a-c, MME 162, SGW 164, PGW 166, gNBs 180a-c, AMFs 182a-b, UPFs 184a-b, SMFs 183a-b, DNs 185a-b, and/or any other element(s)/device(s) described herein, may be performed by one or more emulation elements/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.

[0084] 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.

[0085] 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.

[0086] Introduction

[0087] The following acronyms and abbreviations may be used herein:

[0088] 5G-S-TMSI 5G Shortened Temporary Mobile Subscriber Identity

[0089] ACK Acknowledgement

5 [0090] BLER Block Error Rate

[0091] BWP Bandwidth Part

[0092] CAP Channel Access Priority

[0093] CAPC Channel access priority class

[0094] CCA Clear Channel Assessment

10 [0095] CCE Control Channel Element

[0096] CE Control Element

[0097] CG Configured grant or cell group

[0098] CMAS Commercial Mobile Alert Service

[0099] CN Core Network

15 [0100] CP Cyclic Prefix

[0101] CP-OFDM Conventional OFDM (relying on cyclic prefix)

[0102] CQI Channel Quality Indicator

[0103] CRC Cyclic Redundancy Check

[0104] CSI Channel State Information

20 [0105] CW Contention Window

[0106] CWS Contention Window Size

[0107] CO Channel Occupancy

[0108] DAI Downlink Assignment Index

[0109] DCI Downlink Control Information

25 [0110] DFI Downlink feedback information

[0111] DG Dynamic grant

[0112] DL Downlink

[0113] DM-RS Demodulation Reference Signal

[0114] DRB Data Radio Bearer

30 [0115] DRX Discontinuous Reception

[0116] eLAA enhanced Licensed Assisted Access

[0117] ETWS Earthquake and Tsunami Warning System

[0118] FeLAA Further enhanced Licensed Assisted Access

[0119] FR Frequency Range

	[0120]	HARQ	Hybrid Automatic Repeat Request
	[0121]	IMSI	International Mobile Subscriber Identity
	[0122]	LAA	License Assisted Access
	[0123]	LBT	Listen-Before-Talk
5	[0124]	LP-SS	Low Power-Synchronization Signal
	[0125]	LP-WUS	Low Power-Wake Up Signal
	[0126]	LP-WUR	Low Power-Wake Up Radio
	[0127]	LR	Low Power-Wake Up Radio
	[0128]	LSB	Least Significant Bit
10	[0129]	LTE	Long Term Evolution e.g. from 3GPP LTE R8 and up
	[0130]	NACK	Negative ACK
	[0131]	MCS	Modulation and Coding Scheme
	[0132]	MIB	Master Information Block
	[0133]	MIMO	Multiple Input Multiple Output
15	[0134]	MR	Main Radio
	[0135]	MSB	Most Significant Bit
	[0136]	NR	New Radio
	[0137]	OFDM	Orthogonal Frequency-Division Multiplexing
	[0138]	PDCCH	Physical Downlink Control Channel
20	[0139]	PDSCH	Physical Downlink Shared Channel
	[0140]	PEI	Paging Early Indication
	[0141]	PF	Paging Frame
	[0142]	PHY	Physical Layer
	[0143]	PID	Process ID
25	[0144]	PO	Paging Occasion
	[0145]	PRACH	Physical Random Access Channel
	[0146]	PSFCH	Physical Sidelink Feedback Channel
	[0147]	PSCCH	Physical Sidelink Control Channel
	[0148]	PSSCH	Physical Sidelink Shared Channel
30	[0149]	PSS	Primary Synchronization Signal
	[0150]	QoS	Quality of Service
	[0151]	RA	Random Access (or procedure)
	[0152]	RACH	Random Access Channel
	[0153]	RAR	Random Access Response

	[0154]	RCU	Radio access network Central Unit
	[0155]	RF	Radio Frequency
	[0156]	RLF	Radio Link Failure
	[0157]	RLM	Radio Link Monitoring
5	[0158]	RNTI	Radio Network Identifier
	[0159]	RO	RACH occasion
	[0160]	RRC	Radio Resource Control
	[0161]	RRM	Radio Resource Management
	[0162]	RS	Reference Signal
10	[0163]	RSRP	Reference Signal Received Power
	[0164]	RSSI	Received Signal Strength Indicator
	[0165]	SCS	Subcarrier Spacing
	[0166]	SDU	Service Data Unit
	[0167]	SI	System Information
15	[0168]	SIB	System Information Block
	[0169]	SRS	Sounding Reference Signal
	[0170]	SS	Synchronization Signal
	[0171]	SSS	Secondary Synchronization Signal
	[0172]	SWG	Switching Gap (in a self-contained subframe)
20	[0173]	SPS	Semi-persistent scheduling
	[0174]	SUL	Supplemental Uplink
	[0175]	TB	Transport Block
	[0176]	TBS	Transport Block Size
	[0177]	TMSI	Temporary Mobile Subscriber Identity
25	[0178]	TRP	Transmission / Reception Point
	[0179]	TSC	Time-sensitive communications
	[0180]	TSN	Time-sensitive networking
	[0181]	UL	Uplink
	[0182]	URLLC	Ultra-Reliable and Low Latency Communications
30	[0183]	WBWP	Wide Bandwidth Part
	[0184]	WLAN	Wireless Local Area Networks and related technologies (IEEE 802.xx domain)
	[0185]	WUS	Wake Up Signal
	[0186]	WUR	Wake Up Radio

[0187] FIG. 2 is a system diagram illustrating an example receiver architecture of a low-power wake-up radio receiver 202 and a main radio receiver 204. For example, the transceiver 120 may include the low-power wake-up radio receiver 202 and the main radio receiver 204. As another example, the transceiver 120 may include the main radio receiver 204, and the low-power wake-up radio receiver 202 may be implemented separately from the transceiver 120. Low power-wake up signal (LP-WUS) monitoring has the potential to reduce power consumption of WTRUs and other small battery powered devices. Power savings may be achieved by using a separate low (e.g., ultra-low) power consumption receiver, such as a wake-up radio receiver 202, and placing a main radio receiver 204 in a sleep state (e.g., a low power consumption state). The wake-up radio receiver 202 may monitor for a low-power wake-up signal (LP-WUS) and trigger the main radio receiver (MR) 204 which is dedicated for data and control signal transmission/reception to wake up. The low-power wake-up radio receiver 202 and the main radio receiver 204 may be communicatively coupled to a baseband processor 206 (e.g., of the transceiver 120). The baseband processor 206 may be communicatively coupled to an application processor 208 (e.g., the processor 118).

[0188] For example, a LP-WUS may be associated with one or more paging occasions (Pos). Multiple WTRUs may receive the LP-WUS (e.g., via group-based LP-WUS monitoring). These WTRUs may be intended to receive traffic with different QoS, such as with different latency requirements.

[0189] For example, QoS and/or latency requirements for a WTRU may also change (e.g., dynamically) based on the type of traffic the WTRU 102 is scheduled to be received, such as for a WTRU 102 that receives multiple types of traffic.

[0190] For example, end-to-end communication latency of a WTRU 102 in an IDLE and/or INACTIVE state (e.g., the time from the CN/gNB receiving DL data to the time the data is received by the WTRU 102) depends on the latency associated with the connection initiating procedure.

[0191] In certain representative embodiments, a WTRU 102 may select a connection initiating procedure based on a latency requirement of DL data which is to be received by the WTRU 102.

[0192] In certain representative embodiments, a LP-WUS may support multiple connection initiating procedures.

[0193] In certain representative embodiments, a WTRU may dynamically change the connection initiating procedure to be used (e.g., based on LP-WUS reception).

[0194] For example, when a LP-WUS is associated with one or more POs, multiple WTRUs 102 may receive the LP-WUS (e.g., via group-based LP-WUS monitoring). The LP-WUS may be capable of waking up a selected set of WTRUs 102 in the group (e.g., for monitoring PO) while

the remaining (e.g., non-selected) WTRUs 102 may not be expected to remain in the IDLE and/or INACTIVE state and continue to monitor for another LP-WUS.

[0195] Dividing the WTRUs 102 monitoring the same LP-WUS into subgroups and indicating which subgroups are to wake-up the MR (e.g., for monitoring PO) may be beneficial in that the LP-WUS overhead may be maintained at a manageable level while increasing power saving gains (e.g., across a group).

[0196] For example, in NR, a subgroup-based indication for PO monitoring may be provided via a paging early indication (PEI) and may avoid unnecessary PO monitoring (e.g., WTRUs monitoring a same PO are divided into subgroups and the subgroups that should monitor the PO are indicated via a PEI message).

[0197] For example, in NR, a WTRU 102 may receive a subgroup configuration via system information (SI), such as SIB1. A WTRU 102 may determine its subgroup ID based on the WTRU ID (e.g., a 5G-S-TMSI) or may receive a subgroup ID from the CN in a RRC release message (e.g., a CN assisted subgroup ID). The type of subgrouping (UE ID-based or CN-assisted) to be used and the number of subgroups per PO may be determined based on a subgroup configuration indicated via SIB1.

[0198] Dynamic modification of the subgrouping configuration (e.g., number of subgroups per PO, type of subgrouping) may reduce the number of WTRUs 102 that wake up their MR (e.g., for PO monitoring) unnecessarily (false alarms). This may save more power, while reducing LP-WUS payload size.

[0199] For example, if the NR PEI based subgrouping were re-used for LP-WUS monitoring and/or for modifying subgrouping configuration (type of subgroup ID, number of subgroups), all the WTRUs 102 associated with one or multiple POs must be woken-up. This is due to SI updates for WTRUs 102 in IDLE and/or INACTIVE states being indicated via paging. That is, the power saving gains achievable via LP-WUS monitoring may be reduced. In some examples, it may be beneficial for LP-WUS monitoring WTRUs 102 to be expected to avoid unnecessary PO monitoring (e.g., PDCCH monitoring).

[0200] For example, NR PEI based subgrouping may not support dynamically changing the subgroupings.

[0201] In certain representative embodiments, LP-WUSs may support efficient subgroup-based MR wake-up procedures.

[0202] Overview

[0203] In certain representative embodiments, a WTRU may determine a connection initiating procedure. The connection initiating procedure may be determined by the WTRU from a set of

(e.g., configured) connection initiating procedures based on any (e.g., combination) of a WTRU ID, a subgroup ID, and/or a SIB1 value tag related indication received via a LP-WUS.

[0204] In certain representative embodiments, a WTRU may receive a configuration for one or more wake-up procedures (e.g., first type, second type, and/or third type of wake-up procedure).

5 For example, a first type of wake-up procedure may include the WTRU waking up the MR and sending a physical random access channel (PRACH) transmission after LP-WUS reception. For example, a second type of wake-up procedure may include the WTRU waking up the MR, monitoring a PO, and following a legacy procedure thereafter. For example, a third type of wake-up procedure may include the WTRU skipping a PO and the MR remaining in a (e.g., deep) sleep
10 state (e.g., until a next LP-WUS is received).

[0205] In certain representative embodiments, a WTRU may receive a first WTRU ID (e.g., 5G-S-TMSI). The WTRU may receive and/or determine a second WTRU ID (e.g., which is LP-WUS and/or PO specific). The second WTRU ID may be determined by the WTRU 102 based on (e.g., as a portion of) the first WTRU ID.

15 [0206] In certain representative embodiments, a WTRU may receive and/or determine a subgroup ID (e.g., which is LP-WUS and/or PO specific).

[0207] In certain representative embodiments, a WTRU may receive a LP-WUS and determine whether the LP-WUS is intended for the WTRU 102 based on at least one of: (i) a time the WTRU 102 detects the LP-WUS compared with a PO or PF associated with the WTRU 102, (ii) a WTRU
20 ID (e.g., the second WTRU ID) and/or subgroup ID indicated by the LP-WUS (e.g., sequence of the LP-WUS, LP-WUS CRC scrambling, or by the LP-WUS payload). For example, the LP-WUS (e.g., signal, payload, or scrambling) may indicate the WTRU 102's second WTRU ID and/or the WTRU 102's subgroup ID, and the WTRU 102 may determine that the LP-WUS is intended for the WTRU 102.

25 [0208] In certain representative embodiments, a WTRU may determine that the LP-WUS is intended for the WTRU 102 and the WTRU 102 may determine its wake-up procedure. For example, the WTRU may determine the wake-up procedure based on which of its IDs were received and an indication of at least part of a current valueTag of SIB1 (e.g., ind_valuTagSIB1) received via the LP-WUS (e.g., received via the signal or payload of the LP-WUS). For example,
30 the LP-WUS may indicate the k (e.g., 2) LSBs of the current valueTag.

[0209] The WTRU may determine that the current valueTag (e.g., ind_valuTagSIB1) matches the last k bits of a stored SIB1 valueTag (e.g., based on the last successfully received SIB1). For example, if WTRU 102 receives its second WTRU ID via the LP-WUS, the WTRU 102 may perform the first type of wake-up procedure (e.g., the WTRU 102 wakes up the MR and sends a

PRACH). For example, if the WTRU 102 receives its subgroup ID via the LP-WUS (e.g., subgroup ID only, not the second WTRU ID), the WTRU 102 may perform the second type of wake-up procedure (e.g., the WTRU 102 monitors its PO and if a page is received for the WTRU 102 in its PO, the WTRU 102 sends a PRACH).

5 [0210] The WTRU may determine that the current valueTag (e.g., ind_valuTagSIB1) does not match with the last k bits of the stored SIB1 valueTag, and the WTRU 102 may wake up the MR and receive a (e.g., new) SIB1. For example, after receiving SIB1, the WTRU 102 may monitor for a LP-WUS based on the received new SIB1 (e.g., starting from a next discontinuous reception (DRX) cycle). For example, after receiving SIB1, the WTRU 102 may transmit a PRACH
10 preamble for initial access based on the received new SIB1.

[0211] In certain representative embodiments, a WTRU may determine a subgroup ID based on a subgrouping (e.g., dynamically) configured via a LP-WUS. The WTRU may determine whether or not to wake-up (e.g., the MR) based on the determined subgroup ID and a subgroup-based indication received via a LP-WUS.

15 [0212] In certain representative embodiments, a WTRU may receive configuration information for two or more subgroupings. The information for each subgrouping may include a respective number of subgroups per PO (e.g., a first number of subgroups per PO for a first subgrouping and a second number of subgroups per PO for a second subgrouping).

[0213] In certain representative embodiments, a WTRU may receive or determine one or more
20 WTRU IDs. For example, a first WTRU ID may be a 5G-S-TMSI, a second WTRU ID may be a portion of the first WTRU ID or may be determined from the first WTRU ID. A third WTRU ID may be an ID assigned by the CN.

[0214] In certain representative embodiments, a WTRU may receive a LP-WUS that provides an indication of any (e.g., combination) of a subgrouping from the configured subgroupings, one or
25 more subgroup IDs and/or a WTRU ID from the configured and/or determined WTRU IDs. For example, if the WTRU 102 receives a first indication (e.g., 2-bit value = 00), the WTRU 102 may determine the subgrouping configuration is the first subgrouping configuration and may (e.g., optionally) determine the WTRU ID is the first WTRU ID. For example, if the WTRU 102 receives a second indication (e.g., 2-bit value = 01), the WTRU 102 may determine the
30 subgrouping configuration is the second subgrouping configuration and may (e.g., optionally) determine the WTRU ID is the first WTRU ID. For example, if the WTRU 102 receives a third indication (e.g., 2-bit value = 10), the WTRU 102 may determine the subgrouping is the second subgrouping and may (e.g., optionally) determine the WTRU ID is the second or third WTRU ID.

[0215] In certain representative embodiments, a WTRU may determine a subgroup ID based on the indicated subgrouping configuration (e.g., based on the number of subgroups per PO associated with the indicated subgrouping configuration) and one of its WTRU IDs, such as where the WTRU ID to use may be (i) the optionally indicated WTRU ID, (ii) determined based on the indicated subgrouping configuration and/or (iii) a received WTRU ID (e.g., CN-assigned WTRU ID).

[0216] In certain representative embodiments, a WTRU may, if the determined subgroup ID matches one of the subgroup IDs indicated by the LP-WUS, wake up (e.g., turn on) the MR and monitor for a PDCCH in a PO associated with the received LP-WUS.

10 [0217] LP-WUS Monitoring

[0218] For example, LP-WUS monitoring may refer to monitoring, detecting, decoding, and/or receiving one or more signals associated with a low-power wake-up radio (LR). A low-power synchronization signal (LP-SS) may be transmitted by the network for the LR to maintain time synchronization with the gNB. The LP-WUS may indicate to the WTRU 102 to perform one or more operations based on the content and/or presence of the LP-WUS. For example, upon the reception of a LP-WUS, the WTRU 102 may wake-up the MR of the WTRU 102 for receiving one or more physical channels (e.g., PDCCH, PDSCH), receive SI updates, and/or perform an initial access procedure for connection establishment. In another example, upon the reception of a LP-WUS, a group of WTRUs 102 may wake up the MR at their next DRX on-duration for a paging PDCCH (e.g., DCI) reception or reception of a paging early indication (PEI). In some embodiments, the MR and LR may share the radio frequency hardware (e.g., the WTRU 102 may receive a LP-WUS by using the MR).

[0219] As used herein, the terms low power-wake up radio and wake up radio may be used interchangeably.

25 [0220] WTRU Determination of Connection Initiating Procedure

[0221] In certain representative embodiments, a WTRU may determine a connection initiating procedure. The connection initiating procedure may be determined by the WTRU from a set of (e.g., configured) connection initiating procedures based on any (e.g., combination) of a WTRU ID, a subgroup ID, and/or a SIB1 value tag related indication received via a LP-WUS.

30 [0222] In certain representative embodiments, a WTRU may receive a configuration for one or more wake-up procedures (e.g., first type, second type, and/or third type of wake-up procedure). For example, a first type of wake-up procedure may include the WTRU waking up the MR and sending a physical random access channel (PRACH) transmission after LP-WUS reception. For example, a second type of wake-up procedure may include the WTRU waking up the MR,

monitoring a PO, and following a legacy procedure thereafter. For example, a third type of wake-up procedure may include the WTRU skipping a PO and the MR remaining in a (e.g., deep) sleep state (e.g., until a next LP-WUS is received).

[0223] In certain representative embodiments, a WTRU may receive a first WTRU ID (e.g., 5G-S-TMSI). The WTRU may receive and/or determine a second WTRU ID (e.g., which is LP-WUS and/or PO specific). The second WTRU ID may be determined by the WTRU 102 based on (e.g., as a portion of) the first WTRU ID.

[0224] In certain representative embodiments, a WTRU may receive and/or determine a subgroup ID (e.g., which is LP-WUS and/or PO specific).

[0225] In certain representative embodiments, a WTRU may receive a LP-WUS and determine whether the LP-WUS is intended for the WTRU 102 based on at least one of: (i) a time the WTRU 102 detects the LP-WUS compared with a PO or PF associated with the WTRU 102, (ii) a WTRU ID (e.g., the second WTRU ID) and/or subgroup ID indicated by the LP-WUS (e.g., sequence of the LP-WUS, LP-WUS CRC scrambling, or by the LP-WUS payload). For example, the LP-WUS (e.g., signal, payload, or scrambling) may indicate the WTRU 102's second WTRU ID and/or the WTRU 102's subgroup ID, and the WTRU 102 may determine that the LP-WUS is intended for the WTRU 102.

[0226] In certain representative embodiments, a WTRU may determine that the LP-WUS is intended for the WTRU 102 and the WTRU 102 may determine its wake-up procedure. For example, the WTRU may determine the wake-up procedure based on which of its IDs were received and an indication of at least part of a current valueTag of SIB1 (e.g., ind_valuTagSIB1) received via the LP-WUS (e.g., received via the signal or payload of the LP-WUS). For example, the LP-WUS may indicate the k (e.g., 2) LSBs of the current valueTag.

[0227] The WTRU may determine that the current valueTag (e.g., ind_valuTagSIB1) matches the last k bits of a stored SIB1 valueTag (e.g., based on the last successfully received SIB1). For example, if WTRU 102 receives its second WTRU ID via the LP-WUS, the WTRU 102 may perform the first type of wake-up procedure (e.g., the WTRU 102 wakes up the MR and sends a PRACH). For example, if the WTRU 102 receives its subgroup ID via the LP-WUS (e.g., subgroup ID only, not the second WTRU ID), the WTRU 102 may perform the second type of wake-up procedure (e.g., the WTRU 102 monitors its PO and if a page is received for the WTRU 102 in its PO, the WTRU 102 sends a PRACH).

[0228] The WTRU may determine that the current valueTag (e.g., ind_valuTagSIB1) does not match with the last k bits of the stored SIB1 valueTag, and the WTRU 102 may wake up the MR and receive a (e.g., new) SIB1. For example, after receiving SIB1, the WTRU 102 may monitor

for a LP-WUS based on the received new SIB1 (e.g., starting from a next DRX cycle). For example, after receiving SIB1, the WTRU 102 may transmit a PRACH preamble for initial access based on the received new SIB1.

[0229] In certain representative embodiments, the WTRU may receive configuration information for determining paging and DRX cycle configurations and parameters via one or more of SI, RRC signaling, and/or a RRC release message. For example, the WTRU 102 may receive a DRX cycle, a number of paging frames (PFs) per paging cycle, a paging frame offset (e.g., PF_offset), and/or the number of POs per PF. The WTRU 102 may determine its PO, PF and DRX related parameters based on the received configuration.

[0230] The WTRU 102 may receive configuration information for one or more wake-up procedures. For example, a WTRU 102 may receive a configuration of a first type of wake-up procedure, a second type of wake-up procedure, and/or a third type of wake-up procedure (e.g., via RRC signaling, SI). The one or more types of wake-up procedures (or a set of wake-up procedures) may be associated with a wake-up (WU) indication. The WU indication may be predefined and/or determined based on one or more system parameters (e.g., BWP-id, carrier-ID, frequency range, subcarrier spacing, physical cell-ID, bandwidth, subframe number, slot number, radio-frame number, etc.), WTRU 102-specific parameters (e.g., WTRU 102-ID, C-RNTI, number of antennas, WTRU 102 types, WTRU 102 capability, etc.), and/or conditions.

[0231] As described herein, the type of wake-up procedure may be used interchangeably with wake-up procedure, triggering procedure, wake-up type, and WTRU 102 behavior triggered by wake-up signal. For example, a wake-up procedure may be referred to as a WTRU 102 behavior triggered by reception of a WU indication.

[0232] FIG. 3 is a timing diagram illustrating examples of LP-WUSs and different wake-up procedures. Three example wake-up procedures are shown in FIG. 3.

[0233] In certain representative embodiments, a LP-WUS may be transmitted aperiodically or periodically.

[0234] In certain representative embodiments, a WTRU may continuously monitor for a LP-WUS (e.g., after the MR is in a deep sleep state).

[0235] In certain representative embodiments, a LP-WUS may be decoded by a WTRU at specific times.

[0236] In certain representative embodiments, one or more types of wake-up procedures may be used, determined, defined, and/or configured. The types of wake-up procedures may include, but are not limited to, any (e.g., combination) of the following.

[0237] For example, a first type of wake-up procedure may correspond to the WTRU 102 waking-up the MR and transmitting a PRACH after receiving a LP-WUS indicating to wake-up (e.g., a lower latency wake-up procedure as shown in FIG. 3).

[0238] For example, a second type of wake-up procedure may correspond to the WTRU 102 waking-up the MR and monitoring a PO after receiving a LP-WUS indication to wake-up (e.g., a higher latency wake-up procedure with PO monitoring as shown in FIG. 3). Subsequently, the WTRU 102 may follow the legacy NR procedure where the WTRU 102 may receive a (e.g., paging) PDCCH in the PO which may indicate the resources for receiving a (e.g., paging) PDSCH associated with paging. Based on the indications received via the paging PDSCH, the WTRU 102 may determine to keep the MR awake (e.g., and transmit a PRACH for initial access, and/or receive one or more additional PDCCHs and/or PDSCHs), or resume LP-WUS monitoring after a configured time duration from the reception of the paging PDSCH.

[0239] For example, a third type of wake-up procedure may correspond to the WTRU 102 skipping the PO and continuing to stay in the same RRC state (e.g., the MR stays in a deep sleep state monitoring for LP-WUS while the WTRU 102 is in the RRC IDLE or RRC INACTIVE state) for a configured duration (e.g., until the next LP-WUS is received and determine a new wake-up procedure based on the newly received LP-WUS).

[0240] For example, a fourth type of wake-up procedure (e.g., a higher latency wake-up procedure with PEI monitoring as shown in FIG. 3) may correspond to the WTRU 102 waking-up the MR and monitoring a PEI after receiving a LP-WUS indicating to wake-up. Based on the indication and/or configuration received in the PEI, the WTRU 102 may determine to monitor an associated PO for receiving a paging PDCCH or skip monitoring the PO. Once the paging PDCCH is received, the WTRU 102 may follow the legacy NR procedure where the WTRU 102 may receive scheduling information of a paging PDSCH via a paging PDCCH. Subsequently, the WTRU 102 may receive a (e.g., paging) PDSCH associated with paging. Based on the indications received via the paging PDSCH, the WTRU 102 may determine to keep the MR awake (e.g., and transmit a PRACH for initial access, and/or receive one or more additional PDCCHs and/or PDSCHs), or resume LP-WUS monitoring after a configured time duration from the reception of the paging PDSCH.

[0241] For example, certain types of wake-up procedures may include waking-up the MR (e.g., based on a received LP-WUS) and triggering one or more of the following behaviors: (i) neighboring cell measurements (e.g., one or more sets of neighboring cells may be configured or predefined and a WU indication and/or LP-WUS may trigger neighboring cell measurement of a set of neighboring cells); (ii) sidelink (SL) transmission/reception (e.g., SL-SSB, PSSCH, PSCCH,

PSFCH transmission and/or reception); (iii) measurement reporting (e.g., coverage level, RLM, RRM, and/or CSI); and/or (iv) DRX configuration update (e.g., a WTRU 102 may be configured with one or more DRX configurations and the WTRU 102 may be indicated, such as by a WU indication, to switch from a first DRX configuration to a second DRX configuration).

5 [0242] In certain representative embodiments, a WTRU may receive a first WTRU ID (e.g., 5G-S-TMSI). The WTRU 102 may also receive and/or determine a second WTRU ID. The second WTRU ID may be LP-WUS- and/or PO-specific. In the case of a LP-WUS-specific second WTRU ID, more than one WTRU 102 may associate with a LP-WUS. Within the group of WTRUs 102 associated with the LP-WUS, the second WTRU ID can be used to (e.g., uniquely)
10 identify a WTRU 102. In some embodiments, the second WTRU ID is not shared by two or more WTRUs 102 associated with the same LP-WUS. In some embodiments, the same second WTRU ID may be shared by multiple WTRUs 102 associated with different LP-WUSs. In the case of a PO-specific second WTRU ID, more than one WTRU 102 may be associated with a PO. Within the group of WTRUs 102 associated with the PO, the second WTRU ID can be used to (e.g.,
15 uniquely) identify a WTRU 102. In some embodiments, the second WTRU ID is not shared by two or more WTRUs 102 associated with the same PO. In some embodiments, the same second WTRU ID may be shared by multiple WTRUs 102 associated with different POs.

[0243] In certain representative embodiments, to receive or determine a second WTRU ID, a WTRU 102 may use one or more of the following: (i) receive the second WTRU ID from the CN
20 in a RRC release message, or from a gNB via one or more of RRC signaling, MAC-CE indication, and/or DCI indication; (ii) determine a second WTRU ID based on the first WTRU ID; (iii) determine the second WTRU ID based on paging occasion ID and/or a preconfigured portion of the first WTRU ID (e.g., preconfigured via RRC signaling, SI, or RRC release message, MAC-CE indication, DCI indication); and/or (iv) determine the second WTRU ID based on an ID
25 received from the CN and/or a preconfigured portion of the first WTRU ID (e.g., preconfigured via RRC signaling, SI, or RRC release message, MAC-CE indication, DCI indication).

[0244] For example, the WTRU 102 may select a preconfigured portion or set of preconfigured bits (e.g., preconfigured via RRC signaling, SI, or RRC release message, MAC-CE indication, DCI indication) of the first WTRU ID and determine the second WTRU ID based on the selected
30 part of the first WTRU ID.

[0245] In certain representative embodiments, a WTRU 102 may receive and/or determine a subgroup ID. The subgroup ID may be LP-WUS-specific or PO-specific. In the case of a LP-WUS specific subgroup ID, more than one WTRU 102 may associate with a LP-WUS. Within the group of WTRUs 102 associate with a LP-WUS, the subgroup ID can be used to (e.g.,

uniquely) identify a WTRU 102. In some embodiments, the subgroup ID is not shared by two or more WTRUs 102 associated with the same LP-WUS. In some embodiments, the same subgroup ID may be shared by multiple WTRUs 102 associated with different LP-WUSs. In the case of a PO-specific subgroup ID, more than one WTRU 102 may be associated with a PO. Within the group of WTRUs 102 associated with the PO, subgroup ID can be used to (e.g., uniquely) identify a WTRU 102. In some embodiments, a subgroup ID is not shared by two or more WTRUs 102 associated with the same PO. In some embodiments, the same subgroup ID may be shared by multiple WTRUs 102 associated with different POs.

[0246] In certain representative embodiments, to receive or determine the subgroup ID, a WTRU 102 may use one or more of the following: (i) receive a subgroup ID from the CN in the RRC release message; (ii) receive a configuration for determining a subgroup ID within the group of WTRUs 102 associated with a PO or a LP-WUS based on a preconfigured WTRU ID (e.g., preconfigured via RRC signaling, SI, MAC-CE indication, DCI indication, RRC release message); (iii) receive both a CN-assisted subgroup ID and a configuration for a WTRU ID based on a subgroup determination (e.g., the WTRU 102 determines to use one of the subgrouping configurations based on a configuration or indication received from the gNB or the CN, such as via SI, LP-WUS, etc.); (iv) one or more system parameters (e.g., BWP-ID, carrier-ID, frequency band, subcarrier spacing, physical cell ID, SSB configuration, common search space configuration); and/or (v) one or more WTRU 102-specific parameters/configurations (e.g., IMSI, S-TMSI, WTRU 102 capability, WTRU 102 type, WTRU 102 categories, etc.)

[0247] For example, a WTRU 102 may use the first WTRU ID and/or the second WTRU ID to determine a subgroup ID. The WTRU 102 may determine its subgroup ID based on a received configuration (e.g., number of subgroups per PO or number of subgroups per LP-WUS) and the preconfigured WTRU ID for subgroup ID determination.

[0248] For example, the WTRU 102 may receive (e.g., via SI, such as SIB1, or RRC signaling) a number of subgroups per LP-WUS (e.g., denoted by subgroupsNumPerLPWUS) and/or a number of subgroups per PO (e.g., denoted by subgroupsNumPerPO). The WTRU 102 may determine its subgroup ID based on a WTRU ID (e.g., second WTRU ID or first WTRU 102-ID) and a subgroupsNumPerLPWUS parameter. For example, the subgroup ID may be determined as the second WTRU ID mod subgroupsNumPerLPWUS. In another example, the subgroup ID may be determined as the first WTRU ID mod subgroupsNumPerPO.

[0249] Determination of LP-WUS Intended for WTRU

[0250] In certain representative embodiments, a WTRU 102 may identify, receive and/or decode LP-WUSs intended for the WTRU 102 using any (e.g., combination) of the following techniques.

[0251] In certain representative embodiments, a time at which the WTRU 102 detects a LP-WUS compared with a PO and/or PF associated with the WTRU 102 may be used to identify whether the LP-WUS is intended for the WTRU 102.

[0252] For example, the WTRU 102 may be preconfigured (e.g., via RRC signaling, SI, RRC release message, MAC-CE indication, DCI indication) with a time offset with respect to its PO and/or PF for receiving a LP-WUS. The WTRU 102 may receive the configuration and/or indication of the frequency resources for LP-WUS (e.g., via RRC signaling, SI, or RRC release message, MAC-CE indication, DCI indication). The WTRU 102 may determine time-frequency resources for receiving a LP-WUS based on the time offset with respect to its PO and/or PF and frequency resources configured for LP-WUS reception. The WTRU 102 may determine that a LP-WUS received in the determined time-frequency resources is intended for the WTRU 102. The WTRU 102 may determine the presence of a LP-WUS in the determined time-frequency resources (e.g., via energy and/or sequence detection). When a LP-WUS is detected in the determined time-frequency resources, the WTRU 102 may decode or attempt to decode the LP-WUS.

[0253] In certain representative embodiments, a WTRU ID (e.g., the second WTRU ID) and/or subgroup ID received in the LP-WUS or indicated by the LP-WUS signal may be used to identify whether the LP-WUS is intended for the WTRU 102.

[0254] For example, the WTRU 102 may be preconfigured with a scrambling sequence (e.g., by indicating an ID of a sequence or indicating an ID for a scrambling sequence initialization via RRC signaling, DCI indication, MAC-CE indication, SI, and/or RRC release message) and/or determine a scrambling sequence based on one or more WTRU IDs (e.g., first WTRU ID, second WTRU ID, ID of PO and/or PF). The WTRU 102 may receive a LP-WUS scrambled by a scrambling sequence (e.g., modulated symbols are scrambled by a scrambling sequence). The WTRU 102 may attempt to decode the LP-WUS by using the preconfigured and/or determined scrambling sequence (e.g., by descrambling the LP-WUS). If the attempt is successful, the WTRU 102 may determine that the LP-WUS was intended for the WTRU 102.

[0255] For example, the WTRU 102 may be preconfigured with a sequence (e.g., by indicating an ID of a sequence and/or indicating an ID for a scrambling sequence initialization via RRC signaling, DCI indication, MAC-CE indication, SI, and/or RRC release message) and/or determined a sequence based on one or more WTRU IDs (e.g., first WTRU ID, second WTRU ID, ID of PO and/or PF). The WTRU 102 may receive a sequence as a part of the LP-WUS. The WTRU 102 may determine that the LP-WUS is intended for the WTRU 102 by comparing the preconfigured sequence with the sequence received as a part of the LP-WUS.

[0256] For example, the WTRU 102 may receive an ID (e.g., an ID associated with a PF and/or PO of the WTRUs 102 expected to receive and decode the LP-WUS) in the payload of the LP-WUS. The WTRU 102 may determine its LP-WUS reception ID by using the PF and/or PO (e.g., PF index and/or PO index). The WTRU 102 may receive and decode a LP-WUS and compare the determined LP-WUS reception ID with the ID in the LP-WUS. If the two IDs match, the WTRU 102 may determine that the LP-WUS is intended for the WTRU 102. If the two IDs do not match, the WTRU 102 may determine that the LP-WUS is not intended for the WTRU 102.

[0257] In certain representative embodiments, if the WTRU 102 determines that a LP-WUS is intended for the WTRU 102, the WTRU 102 may decode or attempt to decode the LP-WUS (e.g., if not already decoded in the process of identifying the LP-WUS intended for the WTRU 102). The WTRU 102 may determine its wake-up procedure based on an indication received via the LP-WUS.

[0258] Determination of Wake-Up Procedure

[0259] In certain representative embodiments, a WTRU may determine a wake-up procedure (e.g., after decoding a LP-WUS and/or WU indication) based on an indication received via a LP-WUS and/or a bit sequence of the LP-WUS.

[0260] In certain representative embodiments, a WTRU 102 may determine a wake-up procedure using any (e.g., combination) of the following techniques.

[0261] Indicated IDs Received Via LP-WUS

[0262] In certain representative embodiments, a WTRU 102 may determine its wake-up procedure based on which of its IDs (e.g., second WTRU ID, subgroup ID, etc.,) were received and an indication of the current SI (e.g., SIB1). To this end, the WTRU 102 may use any (e.g., combination) of the following procedures.

[0263] For example, the WTRU 102 may receive at least part of a valueTag of a current SIB1 (e.g., denoted by `ind_valuTagSIB1`) via the LP-WUS. For example, the WTRU 102 may receive k (e.g., $k = 2$) LSBs of the current SIB1 valueTag via the LP-WUS. The `ind_valuTagSIB1` may include the k LSBs of the current SIB1 valueTag. The WTRU 102 may determine the number of bits in the valueTag (e.g., `ind_valuTagSIB1`) based on any (e.g., combination) of the following procedures.

[0264] The WTRU 102 may receive an indication and/or configuration for the number of bits of a SIB1 valueTag for `ind_valuTagSIB1` (i.e., k) from the gNB or the CN (e.g., in RRC release message, RRC signaling, SI, MAC-CE indication, and/or DCI indication).

[0265] The WTRU 102 may determine the number of bits of a SIB1 valueTag for `ind_valuTagSIB1` (i.e., k) based on a LP-WUS configuration. For example, the WTRU 102 may

determine the value k based on any of: (i) periodicity of the LP-WUS; (ii) modulation type of the LP-WUS; (iii) coding rate of the LP-WUS; (iv) frequency range (FR); and/or (v) subcarrier spacing (SCS).

[0266] For example, if the periodicity of the LP-WUS is greater than a periodicity threshold for k , the WTRU 102 may determine a first value of k . If the periodicity is less than or equal to the periodicity threshold for k , the WTRU 102 may determine a second value of k . The WTRU 102 may be preconfigured with the periodicity threshold for k , first value of k , and/or second value of k , such as via one or more of SI, RRC release message, RRC signaling, MAC-CE indication, and/or DCI indication.

[0267] For example, if the type of modulation used for the LP-WUS is a first type, the WTRU 102 may use first value of k . If the type of modulation used for LP-WUS is a second type, the WTRU 102 may use a second value of k . The WTRU 102 may receive a configuration and/or indication of an association between the type of modulation and the first and/or second values of k from the gNB and/or the CN (e.g., via SI, RRC signaling, RRC release message, MAC-CE indication, and/or DCI indication).

[0268] For example, if the coding rate of LP-WUS is greater than a preconfigured threshold for the coding rate, the WTRU 102 may use a first value of k . If the coding rate of LP-WUS less than or equal to the preconfigured threshold of the coding rate, the WTRU 102 may use a second value of k . The WTRU 102 may receive a configuration for the threshold of the coding rate and/or the first and/or second values of k from the CN and/or the gNB (e.g., via SI, RRC signaling, RRC release message, MAC-CE indication, and/or DCI indication).

[0269] For example, if the FR of the LP-WUS is a first frequency range (e.g., FR1), the WTRU 102 may use a first value of k . If the FR of LP-WUS is a second frequency range (e.g., FR2), the WTRU 102 may use a second value of k . The WTRU 102 may receive a configuration and/or indication of an association between the FR of the LP-WUS and/or any of the values of k from the gNB and/or the CN (e.g., via SI, RRC signaling, RRC release message, MAC-CE indication, DCI indication).

[0270] For example, if the SCS of the (e.g., an OFDM-based) LP-WUS is greater than a (e.g., preconfigured) threshold for the SCS, the WTRU 102 may use a first value of k . If the SCS of the (e.g., an OFDM-based) LP-WUS is less than or equal to the (e.g., preconfigured) threshold for the SCS, the WTRU 102 may use a second value of k . The WTRU 102 may receive configuration for the threshold for SCS and/or first and/or second values of k from the CN and/or gNB (e.g., via SI, RRC signaling, RRC release message, MAC-CE indication, and/or DCI indication).

[0271] In certain representative embodiments, a WTRU 102 may determine a validity of a last received SI (e.g., SIB1). For example, the WTRU 102 may compare a part of a current valueTag of SIB1 received via a LP-WUS (e.g., ind_valuTagSIB1) and the corresponding part of a SIB1 valueTag stored by the WTRU 102 based on a last received SIB1. For example, if the ind_valueTagSIB1 received via the LP-WUS is k (e.g., $k = 2$) LSB bits of the current valueTag of SIB1, the WTRU 102 may compare the ind_valueTagSIB1 with the k LSBs of the saved valueTag of SIB1 based on the last received SIB1. If ind_valueTagSIB1 and the k LSBs of the saved SIB1 valueTag match, the WTRU 102 may determine that the last received SI (e.g., SIB1) is valid. That is the WTRU 102 may determine that the SI (e.g., SIB1) available at the WTRU 102 may be valid for determining the resources and transmitting and receiving one or more signals (e.g., determining PRACH resources, determining PO and/or PF for monitoring paging PDCCH, and/or determining PRACH resource for initial access). If the ind_valueTagSIB1 and the k LSB bits of the saved SIB1 valueTag do not match, the WTRU 102 may determine that the last received SI (e.g., SIB1) is invalid.

[0272] In certain representative embodiments, the WTRU 102 may determines that the SI is valid (e.g., ind_valuTagSIB1 matches the last k bits of the stored SIB1 valueTag based on the last successfully received SIB1), the WTRU 102 may follow any (e.g., combination) of the following procedures to determine a wake-up procedure for the WTRU 102.

[0273] For example, if the WTRU 102 receives its second WTRU ID via the LP-WUS (e.g., the WTRU 102 receives second WTRU ID or both second WTRU ID and the subgroup ID), the WTRU 102 may perform the first type of wake-up procedure via the MR. For example, if the WTRU 102 receives its second WTRU ID via the LP-WUS, the WTRU 102 may determine a PRACH resource and transmit the determined PRACH resource for initial access via the MR.

[0274] For the initial access, the WTRU 102 may determine the type of initial access procedure (e.g., 2-step RACH or 4-step RACH) based on any (e.g., combination) of the following. The WTRU 102 may use signal strengths (e.g., L1-RSRP) associated with the LP-WUS and/or LP-SS, and/or an indication received via LP-WUS. For example, if the signal strength of the LP-WUS is greater than a threshold for signal strength, the WTRU 102 may determine to use a 2-step RACH for initial access. If the signal strength of the LP-WUS is less than or equal to the threshold for signal strength, the WTRU 102 may determine to use a 4-step RACH for initial access. The WTRU 102 may receive the threshold for signal strength via one or more of RRC signaling, SI, MAC-CE indication, and/or DCI indication.

[0275] For example, the WTRU 102 may use the time duration the WTRU 102 has been in LP-WUS monitoring. For example, if the time duration the WTRU 102 has been in LP-WUS

monitoring less than a threshold for time duration, the WTRU 102 may determine to use 2-step RACH for initial access. If the time duration the WTRU 102 has been in LP-WUS monitoring is greater than or equal to the threshold for time duration, the WTRU 102 may determine to use 4-step RACH for initial access. The WTRU 102 may receive the threshold for time duration via one or more of RRC signaling, SI, MAC-CE indication, and/or DCI indication.

[0276] The WTRU 102 may follow the legacy NR procedure for initial access after transmitting the PRACH resource (e.g., msg1 or MsgA based on the type of determined initial access procedure by the WTRU 102) for initial access. For example, if the 4-step RACH procedure was determined for initial access, the WTRU 102 may receive a RAR (e.g., msg2) from the gNB. In response, the WTRU 102 may transmit msg3 on a PUSCH resource configured by the gNB via msg2. Finally, the WTRU 102 may receive msg4 from the gNB for contention resolution.

[0277] In certain representative embodiments, the WTRU 102 may receive its subgroup ID via LP-WUS (e.g., the WTRU 102 receives the subgroup ID only, not the second WTRU ID), the WTRU 102 may perform the second type of wake-up procedure. For example, if the WTRU 102 receives the subgroup ID, the WTRU 102 may wake-up the MR and monitor its PO. The WTRU 102 may follow the legacy NR procedure after monitoring its PO. For example, the WTRU 102 may receive a PDCCH in the PO which indicates the resources for receiving a PDSCH associated with paging. The WTRU 102 may receive the paging PDSCH in the resources indicated and/or configured via the paging PDCCH. Based on the indications received via the paging PDSCH, the WTRU 102 may determine to keep the MR awake (e.g., PRACH for initial access, receive one or more additional PDCCHs and/or PDSCHs) or resume LP-WUS monitoring after a configured time duration from the reception of the paging PDSCH. If the WTRU 102 determines to perform to send a PRACH for initial access, the WTRU 102 may determine the type of initial access procedure (e.g., 2-step RACH or 4-step RACH) based on one or more of signal strength associated with LP-WUS and/or LP-SS, an indication received via LP-WUS, and/or the time duration the WTRU 102 has been in LP-WUS monitoring.

[0278] For example, if the WTRU 102 does not receive its WTRU ID or the subgroup ID in the LP-WUS, the WTRU 102 may perform the third type of wake-up procedure. For example, the WTRU 102 may skip the PO and the MR may stay in the deep sleep state until it receives the next LP-WUS or until the WTRU 102 determines to wake-up (e.g., the WTRU 102 wakes-up due to loss of LP-WUS coverage, the WTRU 102 determines to report/transmit data).

[0279] In certain representative embodiments, the WTRU 102 may determine that the SI is invalid. For example, the WTRU 102 may determine that ind_valuTagSIB1 does not match with the last k bits of the SIB1 valueTag stored by the WTRU 102 (e.g., based on the last successfully

received SIB1), and the WTRU 102 may wake-up the MR and receive a SIB1. For example, the WTRU 102 may receive a MIB and using the information in the MIB, the WTRU 102 may receive the SIB1. Once the SIB1 is received, the WTRU 102 may follow one of the following procedures.

[0280] For example, after receiving a (e.g., new) SIB1, the WTRU 102 may put the MR in a deep sleep state, and monitor for a LP-WUS via the LR (e.g., starting from the subsequent DRX cycle). The WTRU 102 may proceed with any (e.g., combination) of the following procedures. The WTRU 102 may determine a configuration for receiving a LP-WUS, and/or paging based on the new received SIB1. The determined configuration may include any of the PF, PO, subgroup ID configuration and subgroup ID, LP-WUS time-frequency resources, t_{offset} , and so forth. The WTRU 102 may receive the LP-WUS using the determined configuration based on the received SIB1. The WTRU 102 may determine its wake-up procedure based on which of its IDs (e.g., second WTRU ID, subgroup ID, etc.,) were received in the LP-WUS and an indication of the current SI (e.g., SIB1).

[0281] For example, after receiving a (e.g., new) SIB1, the WTRU 102 may transmit a PRACH preamble for initial access based on the received SIB1. For example, the WTRU 102 may determine PRACH resources for initial access based on the received new SIB1 and send the PRACH.

[0282] For example, after receiving a (e.g., new) SIB1, the WTRU 102 may start monitoring for NR paging. The WTRU 102 may receive a PEI and/or paging PDCCH. The WTRU 102 may indicate to the gNB that it stopped monitoring for LP-WUS and the indication may include a reason or cause for switching to legacy NR paging monitoring (e.g., the WTRU 102 detected a SI mismatch, such as a mismatched SIB1). The WTRU 102 may transmit a preconfigured PRACH resource (e.g., preconfigured via RRC signaling, SI, MAC-CE indication, and/or DCI indication) or transmit the indication in a granted PUSCH or PUCCH resource. In response to the indication of switching to legacy NR paging monitoring, the WTRU 102 may receive a confirmation indication from the gNB (e.g., via RAR message, configured PDCSCH, and/or PDCCH resource).

[0283] Bit Sequence Received Via LP-WUS

[0284] In certain representative embodiments, a WTRU 102 may determine a wake-up procedure based on a sequence of bits received via a LP-WUS.

[0285] In certain representative embodiments, a WTRU 102 may receive a configuration and/or indication of any (e.g., combination) of the following. For example, the WTRU 102 may receive information indicating the number of LP-WUS sequence bits and/or an ID of a wake-up procedure.

[0286] For example, the number of LP-WUS sequence bits (e.g., NUM_LBITS) may be associated to the WTRU 102 in any (e.g., combination) of the following. In an example, the

WTRU 102 may receive a configuration and/or indication of the number of LP-WUS sequence bits associated to the WTRU 102 via RRC/MAC-CE and/or DCI (e.g., in RRC CONNECTED mode). In an example, the WTRU 102 may receive a configuration and/or indication of the number of LP-WUS sequence bits associated to the WTRU 102 as part of a RRC release message received by the WTRU 102. In an example, the WTRU 102 may receive a configuration and/or indication of the number of LP-WUS sequence bits associated to the WTRU 102 as part of system information received by the WTRU 102 (e.g., via SIB1). In an example, the WTRU 102 may determine the number of LP-WUS sequence bits based on a WTRU ID (e.g., second WTRU ID) configured for wake-up indication. In an example, the WTRU 102 may determine the number of LP-WUS sequence bits based on one or more of a payload, modulation type, SCS, and/or FR associated with the wake-up indication.

[0287] For example, the WTRU 102 may receive information indicating an ID of the wake-up procedure. For example, the first type of wake-up procedure may be configured with a first ID (e.g., '00'), the second type of wake-up procedure may be configured with a second ID (e.g., '01'), and/or the third type of wake-up procedure may be configured with a third ID (e.g., '10').

[0288] In certain representative embodiments, a WTRU 102 may receive a sequence of bits via the LP-WUS. Based on the received bit sequence, the WTRU 102 may determine any (e.g., combination) of the following: (i) SIB1 ValueTag identifier; and/or (ii) the type of wake-up procedure.

[0289] For example, the SIB1 ValueTag identifier may be denoted by ind_valuTagSIB1. In an example, the WTRU 102 may associate a subset of the LP-WUS bits as an identifier for the SIB1 ValueTag. For example, the WTRU 102 may associate, select, and/or determine the first or last k bits of the LP-WUS sequence as the identification bits for the SIB1 ValueTag.

[0290] For example, the WTRU 102's wake-up procedure may be determined based on the condition that the SIB1 valueTag identifier bits match with a subset (e.g., first k bits, e.g., last k bits) of bits associated with the valueTag of a SIB1 received by the WTRU 102 in the past (e.g., the last received SIB1). The WTRU 102 may determine a wake-up procedure based on the indicated and/or determined second WTRU ID and/or an indication received via the configured number of LP-WUS bits (e.g., NUM_LBITS). In an example, the WTRU 102 may determine a wake-up procedure based on a subset of LP-WUS sequence bits where the size of the subset may be equal to NUM_LBITS. The NUM_LBITS determined for each WTRU 102 may indicate the ID of the wake-up procedure. In an example, the WTRU 102 may determine a wake-up procedure based on a first, second, and/or subsequent subset of LP-WUS sequence bits where the selection

of the subset (e.g., whether first or second or any other) of bits may be based on second WTRU ID.

[0291] For example, if the configured NUM_LBITS is equal to 2 and the second WTRU ID of the WTRU 102 is 0, the WTRU 102 may determine its wake procedure based on the first set of 2-bits associated to the LP-WUS bit sequence (or the portion of the LP-WUS bit sequence configured/determined for indicating the wake-up procedure). If the second WTRU ID of the WTRU 102 is 1, the WTRU 102 may determine its wake procedure based on the second set of 2-bits associated to the LP-WUS bit sequence. If the second WTRU ID of the WTRU 102 is n , the WTRU 102 may determine its wake procedure based on the $(n+1)^{\text{th}}$ set of 2-bits associated to the LP-WUS bit sequence.

[0292] In certain representative embodiments, based on the condition that the SIB1 valueTag identifier bits do not match with the corresponding subset (e.g., first k bits, e.g., last k bits) of bits associated to the valueTag of a SIB1 received by the WTRU 102 in the past, the WTRU 102 may wake up the MR and receive a (e.g., new) SIB1. Based on the received (e.g., the newly received) SIB1 the WTRU 102 may perform any (e.g., combination) of the following.

[0293] For example, the WTRU 102 may continue to monitor LP-WUS and PO (e.g., at the start of the next DRX cycle). In an example, the WTRU 102 may determine one more of the following configuration parameters based on the received SIB1 (i.e., by decoding the payload carried by SIB1): (i) PO; (ii) PF; (iii) LP-WUS resources in time-frequency; and/or (iv) T_offset associated with the LP-WUS. The WTRU 102 may measure and/or decode a new LP-WUS based on the determined configuration parameters.

[0294] For example, the WTRU 102 may determine PRACH transmission time-frequency resources based on the received SIB1. The WTRU 102 may transmit a PRACH preamble (e.g., for initial access) in the determined time-frequency resources.

[0295] For example, the WTRU 102 may start to monitor for NR paging (e.g., PEI and/or paging PDDCH). The WTRU 102 may send an indication indicating a pause or suspension in LP-WUS monitoring (e.g., via msg1/msg3). Additionally, the WTRU 102 may send an indication indicating the cause of the LP-WUS monitoring suspension or pause (e.g., loss of SI and/or missed SIB1s). In an example, the WTRU 102 may transmit a specific preamble in msg1 indicating the suspension of LP-WUS monitoring caused by missed SI. In an example solution, the WTRU 102 may send an indication (e.g., 1-bit) indicating the suspension via PUSCH on msg3 (e.g., as part of a RRC request).

[0296] **Dynamic Subgroupings and Subgroup-based Wake-Up Indications**

[0297] In certain representative embodiments, a WTRU may determine a subgroup ID based on a subgrouping (e.g., dynamically) configured via a LP-WUS. The WTRU may determine whether or not to wake-up (e.g., the MR) based on the determined subgroup ID and a subgroup-based indication received via a LP-WUS.

5 [0298] In certain representative embodiments, a WTRU 102 may receive information indicating a subgrouping (e.g., a subgrouping configuration) and a subgroup-based wake-up indication (e.g., a bit map or subgroup IDs) in an early indication (e.g., LP-WUS, NR PEI). The WTRU 102 may determine one or more of its subgroup IDs based on the indicated subgrouping configuration. Subsequently, the WTRU 102 may determine to wake up (e.g., use the MR for monitoring a PO)
10 or not to wake up (e.g., use the LR continue to monitor LP-WUS) based on the received subgroup-based wake-up indication and determined subgroup IDs.

[0299] In certain representative embodiments, a WTRU may receive configuration information for two or more subgroupings. The information for each subgrouping may include a respective number of subgroups per PO (e.g., a first number of subgroups per PO for a first subgrouping and
15 a second number of subgroups per PO for a second subgrouping).

[0300] In certain representative embodiments, a WTRU may receive or determine one or more WTRU IDs. For example, a first WTRU ID may be a 5G-S-TMSI, a second WTRU ID may be a portion of the first WTRU ID or may be determined from the first WTRU ID. A third WTRU ID may be an ID assigned by the CN.

20 [0301] In certain representative embodiments, a WTRU may receive a LP-WUS that provides an indication of any (e.g., combination) of a subgrouping from the configured subgroupings, one or more subgroup IDs and/or a WTRU ID from the configured and/or determined WTRU IDs. For example, if the WTRU 102 receives a first indication (e.g., 2-bit value = 00), the WTRU 102 may determine the subgrouping configuration is the first subgrouping configuration and may (e.g.,
25 optionally) determine the WTRU ID is the first WTRU ID. For example, if the WTRU 102 receives a second indication (e.g., 2-bit value = 01), the WTRU 102 may determine the subgrouping configuration is the second subgrouping configuration and may (e.g., optionally) determine the WTRU ID is the first WTRU ID. For example, if the WTRU 102 receives a third
30 indication (e.g., 2-bit value = 10), the WTRU 102 may determine the subgrouping is the second subgrouping and may (e.g., optionally) determine the WTRU ID is the second or third WTRU ID.

[0302] In certain representative embodiments, a WTRU may determine a subgroup ID based on the indicated subgrouping configuration (e.g., based on the number of subgroups per PO associated with the indicated subgrouping configuration) and one of its WTRU IDs, such as where the

WTRU ID to use may be (i) the optionally indicated WTRU ID, (ii) determined based on the indicated subgrouping configuration and/or (iii) a received WTRU ID (e.g., CN-assigned WTRU ID).

[0303] In certain representative embodiments, a WTRU may, if the determined subgroup ID matches one of the subgroup IDs indicated by the LP-WUS, wake up (e.g., turn on) the MR and monitor for a PDCCH in a PO associated with the received LP-WUS.

[0304] In certain representative embodiments, a WTRU 102 may receive an early indication message (e.g., LP-WUS, NR PEI) which includes information indicating a subgrouping configuration and a subgroup-based wake up indication. For example, the subgroup-based wake-up indication may include one or more subgroup IDs and/or a bit map indicating which WTRUs 102 that are associated with which subgroup IDs should wake up (e.g., for PO monitoring). The WTRU 102 may determine one or more of its subgroup IDs based on the indicated subgroup configuration and determine to wake up (e.g., use the MR for monitoring PO) or not to wake up (e.g., use the LR continue to LP-WUS monitoring) based on the determined subgroup IDs and received subgroup-based wake up indication.

[0305] In certain representative embodiments, a WTRU 102 may use reception of a LP-WUS via the LR as an early indication.

[0306] In certain representative embodiments, a WTRU 102 may use another early indication method, such as reception of a NR PEI.

[0307] In certain representative embodiments, a WTRU 102 may use reception of a LP-WUS via the LR and/or a NR PEI as early indications.

[0308] In certain representative embodiments, a WTRU 102 may receive configuration information for determining paging and DRX cycle configurations and parameters via one or more of SI, RRC signaling, and/or a RRC release message. For example, the WTRU 102 may receive any of a DRX cycle, a number of PFs per paging cycle, a paging frame offset (e.g., PF_offset), and/or a number of POs per PF. For example, the WTRU 102 may determine its PO, PF and DRX related parameters based on the received configuration.

[0309] In certain representative embodiments, a WTRU 102 may receive configuration information for two or more subgroupings (e.g., subgrouping configurations). For example, the WTRU 102 may receive two or more subgrouping configurations via any of RRC signaling, SI, RRC release message, MAC-CE, and/or DCI indication. The configuration information (e.g., for each subgrouping configuration) may include at least a respective number of subgroups per PO. For example, the WTRU 102 may receive a first number of subgroups per PO for a first

subgrouping configuration, a second number of subgroups per PO for a second subgrouping configuration, and so forth.

[0310] For example, the WTRU 102 may receive an ID for each subgrouping configuration. For example, the WTRU 102 may receive a first subgrouping configuration ID for the first subgrouping configuration, a second subgrouping configuration ID for the second subgrouping configuration, and so forth. The WTRU 102 may receive or determine one or more IDs (UE IDs).

[0311] In certain representative embodiments, a WTRU 102 may receive a first WTRU ID (e.g., 5G-S-TMSI received from the CN). The WTRU 102 may receive configuration for determining a second WTRU ID from the first WTRU ID. For example, the WTRU 102 may receive configuration information to determine the second ^{WTRU ID} to be a portion of the first WTRU ID, or to determine the second WTRU ID from the first WTRU ID. For example, the second WTRU 102_ID may be determined as (N+M)th LSB of first WTRU ID, ..., (N+2)th LSB of first WTRU ID, (N+1)th LSB of first WTRU ID. As an example, N and M may be preconfigured via SI, RRC release message, and/or RRC signaling. As another example, N may be equal to the number of PFs per paging cycle × number of POs per PF. The WTRU 102 may receive a third WTRU ID from the CN (e.g., a third WTRU ID is received in the RRC release message or RRC signaling).

[0312] For example, the WTRU 102 may receive one or more subgroup IDs from the CN or the gNB. For example, the WTRU 102 may receive a first CN-assigned subgroup ID, a second CN-assisted subgroup ID, and so forth via RRC release message and/or RRC signaling.

[0313] For example, the WTRU 102 may receive an association between the subgrouping configuration and the WTRU IDs. For example, the first subgrouping configuration may be associated with the first WTRU ID, the second subgrouping configuration may be associated with the second WTRU ID, and the third subgrouping configuration may be associated with the third WTRU ID. The WTRU 102 may receive the association between the subgrouping configurations and WTRU IDs from any of SI, a RRC release message, RRC signaling, MAC-CE indication, and/or DCI indication.

[0314] **Determination of Subgrouping Configuration for Subgroup-based WU**

[0315] In certain representative embodiments, a WTRU 102 may determine a subgrouping configuration for a subgroup-based wake-up indication via a LP-WUS.

[0316] In certain representative embodiments, a WTRU 102 may receive any (e.g., combination) of the following via a LP-WUS. For example, the WTRU 102 may receive a LP-WUS where the LP-WUS provides an indication of a subgrouping configuration from the configured subgrouping configurations. For example, the WTRU 102 may receive an ID of a subgrouping configuration

via a LP-WUS. For example, the WTRU 102 may (e.g., optionally) receive an indication for WTRU ID from the configured or determined WTRU IDs.

[0317] For example, the WTRU 102 may receive any of a first indication for WTRU ID (e.g., a 2-bit value '01' for first WTRU ID), a second indication for WTRU ID (e.g., a 2-bit value '10' for second WTRU ID), a third indication for WTRU ID (e.g., a 2-bit value '11' for third WTRU ID), and/or a fourth indication for WTRU ID (e.g., a 2-bit value '00' for WTRU ID, such as when the WTRU ID is not specified) via LP-WUS. In some embodiments, when the (e.g., optional) WTRU ID indication is not received (or a fourth WTRU ID indication is received which indicates that WTRU ID is not specified), the WTRU 102 may determine a WTRU ID to be used for subgroup ID determination based on an association between the WTRU IDs and subgrouping configurations. When a WTRU 102 receives the (e.g., optional) WTRU ID indication (e.g., first, second, or third indication for WTRU ID) and a subgrouping configuration which is configured with an associated WTRU ID via LP-WUS, the WTRU 102 may give priority to the indicated (e.g., optional) WTRU ID over the WTRU ID determined based on the preconfigured association between the subgrouping configurations and WTRU IDs.

[0318] For example, the WTRU 102 may receive an indication of one or more subgroup IDs via a LP-WUS. The WTRU 102 may determine to wake-up (e.g., for monitoring a PO after waking up the MR) or not to wake-up (e.g., skip monitoring the PO and the MR stay in deep sleep state at least until the next LP-WUS is received) based on the received subgroup IDs. For example, the WTRU 102 may receive a bit map where each bit is associated with a subgroup ID. A bit value of 1 may indicate that the associated subgroup ID (e.g., WTRUs 102 with the subgroup ID) is indicated to wake-up. A bit value of '0' may indicate that the associated subgroup ID (e.g., WTRUs 102 with the subgroup ID) is not indicated to wake-up.

[0319] In certain representative embodiments, a WTRU 102 may determine a subgrouping configuration based on a subgrouping configuration indication received via a LP-WUS. The WTRU 102 may (e.g., optionally) receive a WTRU ID from the configured or determined WTRU IDs (e.g., first WTRU ID, second WTRU ID, third WTRU ID). Based on the received WTRU ID, the WTRU 102 may determine which WTRU ID is to be used for subgroup ID determination.

[0320] For example, if the WTRU 102 receives a first indication (e.g., a 2-bit value = 00) for subgrouping configuration, the WTRU 102 may determine the subgrouping configuration is the first subgrouping configuration. The WTRU 102 may determine that the WTRU ID is the first WTRU ID based on the preconfigured association between the subgrouping configurations and the WTRU IDs.

[0321] For example, if the WTRU 102 receives a second indication (e.g., 2-bit value = 01) for subgrouping configuration, the WTRU 102 may determine the subgrouping configuration is the second subgrouping configuration. The WTRU 102 may receive a first indication for WTRU ID via a LP-WUS (e.g., optional WTRU ID indication via the LP-WUS). The WTRU 102 may determine that the WTRU ID to be used with the indicated subgrouping configuration is the first WTRU ID based on the received (e.g., optional) WTRU ID indication.

[0322] For example, if the WTRU 102 receives a third indication (e.g., 2-bit value = 10) for subgrouping configuration, the WTRU 102 may determine that the subgrouping configuration is the third subgrouping configuration. The WTRU 102 may receive a fourth indication for WTRU ID via the LP-WUS (e.g., optional WTRU ID indication via a LP-WUS which indicates that a WTRU ID is not specified). The WTRU 102 may determine that the WTRU ID is the third WTRU ID (e.g., determined based on the preconfigured association between the third subgrouping configuration and the third WTRU ID).

[0323] For example, if the WTRU 102 receives a fourth indication (e.g., 2-bit value = 11) for subgrouping configuration, the WTRU 102 may determine the subgrouping configuration is the fourth subgrouping configuration in which the WTRU 102 may determine one or more subgroup IDs based on the received subgroup IDs from the CN or the gNB.

[0324] In certain representative embodiments, a WTRU 102 may determine a subgroup ID based on the indicated subgrouping configuration and one of its WTRU IDs. In certain representative embodiments, a WTRU 102 may determine one or more subgroup IDs based on received subgroup IDs (e.g., CN assigned subgroup IDs) from the CN or the gNB (e.g., via RRC release message). For example, the WTRU 102 may perform any (e.g., combination) of the following.

[0325] For example, the WTRU 102 may determine the number of subgroups per PO based on the indicated subgrouping configuration. The WTRU 102 may determine the WTRU ID to use for subgroup ID determination based on an (e.g., optionally) indicated WTRU ID and/or a WTRU ID determined based on the indicated subgrouping configuration (e.g., by using a preconfigured association between the subgrouping configurations and the WTRU IDs).

[0326] For example, if the WTRU 102 receives the first indication (e.g., a 2-bit value = 00) for subgrouping configuration, the WTRU 102 may determine that the number of subgroups per PO is the first number of subgroups per PO. The WTRU 102 may also determine to use a first WTRU ID for subgroup ID determination (e.g., WTRU 102 determined based on the preconfigured association between the first WTRU ID and the first subgrouping configuration). The WTRU 102 may determine its subgroup ID based on the first number of subgroups per PO and the first WTRU

ID. For example, the WTRU 102 may determine its subgroup ID based on a formula, such as where the subgroup ID is equal to the first WTRU ID *mod* first number of subgroups per PO.

[0327] For example, if the WTRU 102 receives the second indication (e.g., a 2-bit value = 01) for subgrouping configuration and (e.g., optionally) receives an indication for the first WTRU ID, the WTRU 102 may determine its subgroup ID based on the second number of subgroups per PO and the first WTRU ID. For example, the WTRU 102 may determine its subgroup ID based on a formula, such as where the subgroup ID is equal to the first WTRU ID *mod* second number of subgroups per PO.

[0328] For example, if the WTRU 102 receives the third indication (e.g., a 2-bit value = 10) for subgrouping configuration and (e.g., optionally) receives an indication for the fourth WTRU ID (e.g., WTRU ID is not specified), the WTRU 102 may determine that the number of subgroups per PO is the third number of subgroups per PO. The WTRU 102 may determine that the WTRU ID is the third WTRU ID based on a preconfigured association between the third subgrouping configuration and the third WTRU ID. The WTRU 102 may determine its subgroup ID based on the third number of subgroups per PO and the third WTRU ID. For example, the WTRU 102 may determine its subgroup ID based on a formula, such as where the subgroup ID is equal to third WTRU ID *mod* third number of subgroups per PO.

[0329] In certain representative embodiments, a WTRU 102 may, based on the indicated subgrouping configuration, determine to use one or more received subgroup IDs (e.g., CN assigned subgroup IDs) from the CN and/or the gNB (e.g., via RRC release message).

[0330] For example, if the WTRU 102 receives a fourth indication (e.g., a 2-bit value = 11) for subgrouping configuration, the WTRU 102 may determine that the number of subgroups per PO is a fourth number of subgroups per PO. The WTRU 102 may determine to use one or more received subgroup IDs (e.g., via RRC release message) from the CN and/or the gNB (e.g., first CN assigned subgroup ID, and/or second CN assisted subgroup ID, etc.).

[0331] The WTRU 102 may determine to wake-up (e.g., turn on the MR and monitor its PO) or not to wake up (e.g., continue LP-WUS monitoring) based on the one or more subgroup IDs received via a LP-WUS (e.g., the WTRU 102 may receive one or more subgroup IDs or a bit sequence via LP-WUS). For example, the WTRU 102 may receive a bit sequence via a LP-WUS, where each bit in the sequence may correspond to a subgroup ID). The WTRU 102 may receive one or more of its subgroup IDs via the bitmap. For example, the WTRU 102 may use any (e.g., combination) of the following.

[0332] For example, if the WTRU 102 determined a subgroup ID based on the indicated subgrouping configuration and one of its WTRU IDs, the WTRU 102 may compare the received

subgroup IDs via the LP-WUS with its own determined subgroup ID. If the WTRU 102 determines that its determined subgroup ID is among the indicated subgroup IDs via the LP-WUS, the WTRU 102 may turn on the MR and monitor for paging signals (e.g., paging PDCCH) in its POs. If the WTRU 102 determines that its subgroup ID does not match any of the subgroup IDs indicated by the LP-WUS, the WTRU 102 may continue to monitor for a (e.g., next) LP-WUS (e.g., while keeping the MR in the deep sleep state).

[0333] For example, if the WTRU 102 determines one or more subgroup IDs based on received subgroup IDs from the CN and/or the gNB, the WTRU 102 may compare one or more of its subgroup IDs with the subgroup IDs received via the LP-WUS. If the WTRU 102 determines that any of its subgroup IDs are among the subgroup IDs received via the LP-WUS, the WTRU 102 may turn on the MR and monitor for paging signals (e.g., paging PDCCH) in its PO. If the WTRU 102 determines that none of its subgroup IDs match any of the subgroup IDs indicated by the LP-WUS, the WTRU 102 may continue to monitor for LP-WUS (e.g., while keeping the MR in the deep sleep state).

[0334] In certain representative embodiments, the WTRU 102 may wake-up the MR. For example, if the WTRU 102 woke-up based on a subgroup-based wake-up indication via LP-WUS, based on the PDCCH received in the PO configured for the WTRU 102, the WTRU 102 may receive one or more paging PDSCHs. Based on an indication received via the paging PDCCH and/or the paging PDSCHs, the WTRU 102 may determine to perform any (e.g., combination) of the following.

[0335] For example, the WTRU 102 may send a PRACH for initial access. For example, after receiving a paging PDSCH, the WTRU 102 may select a PRACH resource and send a PRACH for initial access.

[0336] For example, the WTRU 102 may receive SI (e.g., updated SI). For example, after receiving a paging PDSCH, the WTRU 102 may receive a MIB and, using the information in the MIB, the WTRU 102 may receive a (e.g., new) SIB1. Based on the information indicated via SIB1, the WTRU 102 may receive one or more additional SIBs.

[0337] For example, the WTRU 102 may receive a ETWS message. For example, based on an indication received via a paging PDCCH, the WTRU 102 may determine that reception of an ETWS message is requested by the CN. The WTRU 102 may receive a SIB which contains a ETWS message.

[0338] For example, the WTRU 102 may receive a CMAS message. For example, based on an indication received via a paging PDCCH, the WTRU 102 may determine that reception of a CMAS

message is requested by the CN. The WTRU 102 may receive a SIB which contains a CMAS message.

[0339] FIG. 4 is a procedural diagram illustrating an example of performing a wake-up procedure by a WTRU 102 configured with a plurality of wake-up procedures. As shown in FIG. 4, a WTRU 102 may receive configuration information indicating a plurality of wake-up procedures (e.g., first, second, and/or third wake-up procedures) at 402. At 404, the WTRU 102 may receive a first identifier of the WTRU 102. At 406, the WTRU 102 may receive a subgroup identifier. At 408, the WTRU 102 may determine a second identifier of the WTRU based on the first identifier of the WTRU. At 408, the WTRU 102 may receive a SIB. At 410, the WTRU 102 may receive a LP-WUS. At 412, the WTRU 102 may perform (e.g., a selected) one of the plurality of wake-up procedures based on (i) an indication of the LP-WUS matching information included in the SIB, and (ii) one of the second identifier of the WTRU or the subgroup identifier matching an identifier indicated by the LP-WUS.

[0340] For example, the LP-WUS may be received using a LR of the WTRU 102.

[0341] For example, the second identifier may be determined from a portion of the first identifier.

[0342] For example, the performing the one of the plurality of wake-up procedures may include waking-up a MR of the WTRU 102, and sending a physical random access channel transmission. The one of the plurality of wake-up procedures may be selected based on (i) the first indication of the LP-WUS matches information included in the SIB, and (ii) the second identifier of the WTRU matching the identifier indicated by the LP-WUS.

[0343] For example, the performing the one of the plurality of wake-up procedures may include waking-up a MR of the WTRU 102, and receiving paging information during a paging occasion associated with the received LP-WUS. The one of the plurality of wake-up procedures may be selected based on (i) the first indication of the LP-WUS matching information included in the SIB, and (ii) the subgroup identifier matching the identifier indicated by the LP-WUS.

[0344] For example, the WTRU 102 may determine the indication of the LP-WUS matches a set of bits of a value tag included in the SIB (e.g., when selecting and/or performing the one of the wake-up procedures).

[0345] FIG. 5 is a procedural diagram illustrating an example of determining to perform a wake-up procedure by a WTRU 102 configured with a plurality of subgrouping configurations. As shown in FIG. 5, a WTRU 102 may receive configuration information indicating a plurality of subgrouping configurations at 502. Each subgrouping configuration may be associated with a respective number of subgroups per paging occasion (PO). At 504, the WTRU 102 may determine and/or receive a set of identifiers of the WTRU 102. At 506, the WTRU 102 may receive a LP-

WUS. The LP-WUS may include information indicating one of the subgrouping configurations and a first subgroup identifier. At 508, the WTRU 102 may determine a second subgroup identifier based on the respective number of subgroups associated with the indicated one of the subgrouping configurations and the set of identifiers of the WTRU 102. At 510, the WTRU 102 may wake-up a MR of the WTRU 102, and monitor for paging information (e.g., paging signal) during a PO associated with the LP-WUS based on the indicated first subgroup identifier matching the determined second subgroup identifier.

[0346] For example, the set of identifiers may include a first identifier which is a temporary mobile subscriber identity (TMSI), a second identifier which is determined from the first identifier, and/or a third identifier which is assigned by a core network.

[0347] For example, the LP-WUS may include information indicating the first identifier of the WTRU 102. The determination of the second subgroup identifier may be based on the respective number of subgroups associated with the indicated one of the subgrouping configurations and the indicated first identifier of the WTRU 102.

[0348] For example, the determination of the second subgroup identifier may be based on the respective number of subgroups associated with the indicated one of the subgrouping configurations and the first identifier of the WTRU 102.

[0349] For example, the determination of the second subgroup identifier may be based on the respective number of subgroups associated with the indicated one of the subgrouping configurations and the second identifier or the third identifier of the WTRU 102.

[0350] For example, the LP-WUS may be received using a LR of the WTRU 102.

[0351] FIG. 6 is a procedural diagram illustrating an example of a subgroup-based wake-up procedure, according to one or more embodiments of the present disclosure. As shown in FIG. 6, a WTRU 102 may have a low-power radio and a main radio. The WTRU 102 may receive configuration information indicating a plurality of subgroupings at 602. For example, each subgrouping may be associated with a respective number of subgroups per PO. The WTRU 102 may determine a set of identifiers of the WTRU 102 at 604. The WTRU 102 may receive, via the low-power radio, a LP-WUS at 606. For example, the LP-WUS may include information indicating (i) a subgrouping of the plurality of subgroupings, and (ii) one or more first subgroup identifiers. The WTRU 102 may determine a second subgroup identifier based on the indicated subgrouping and an identifier of the set of identifiers of the WTRU 102 at 608. The WTRU 102 may monitor, using the main radio, for a PDCCH transmission during a PO associated with the LP-WUS at 610 based on the determined second subgroup identifier matching one of the indicated one or more first subgroup identifiers.

[0352] In certain representative embodiments, the set of identifiers may be associated with the LP-WUS and/or the PO.

[0353] In certain representative embodiments, the set of identifiers may include any of a first mobile subscriber identifier of the WTRU, a second identifier determined from the first mobile subscriber identifier, and/or a third core network-assigned identifier.

[0354] In certain representative embodiments, the WTRU 102 may determine the second identifier from the first mobile subscriber identifier (e.g., TMSI).

[0355] In certain representative embodiments, the WTRU 102 may receive information indicating first bit information. For example, the second identifier may be determined from the mobile subscriber identifier using the first bit information.

[0356] In certain representative embodiments, the WTRU 102 may determine second bit information based on a number of paging frames (PFs) per paging cycle and a number of POs per PF. For example, the second identifier may be determined from the mobile subscriber identifier using the second bit information.

[0357] In certain representative embodiments, the second subgroup identifier may be determined based on the respective number of subgroups associated with the indicated subgrouping and the identifier of the set of identifiers of the WTRU 102.

[0358] In certain representative embodiments, the second subgroup identifier may be determined based on the identifier of the set of identifiers of the WTRU 102 which is associated with the indicated subgrouping.

[0359] In certain representative embodiments, the second subgroup identifier may be determined based on the indicated subgrouping and the identifier, of the set of identifiers of the WTRU 102, which is a core network-assigned identifier.

[0360] In certain representative embodiments, the LP-WUS may include information indicating (i) the subgrouping of the plurality of subgroupings, (ii) the one or more first subgroup identifiers, and (iii) an identifier of the set of identifiers of the WTRU 102. For example, the second subgroup identifier may be determined based on the indicated subgrouping and the indicated identifier of the set of identifiers of the WTRU 102.

[0361] In certain representative embodiments, at least one identifiers of the set of identifiers may be assigned by a core network.

[0362] In certain representative embodiments, at least one identifiers of the set of identifiers is received in RRC signaling or messaging.

[0363] In certain representative embodiments, the WTRU 102 may receive, using the main radio, the PDCCH transmission during the PO associated with the LP-WUS. The WTRU 102 may

receive a PDSCH transmission based on scheduling information indicated by the PDCCH transmission.

[0364] In certain representative embodiments, the main radio may be in a low-power state during a time the low-power radio is powered on. For example, the main radio may enter the low-power state based on reception of a RRC message.

[0365] FIG. 7 is a procedural diagram illustrating another example of a subgroup-based wake-up procedure, according to one or more embodiments of the present disclosure. As shown in FIG. 7, a WTRU 102 may have a low-power radio and a main radio. The WTRU 102 may receive information indicating a plurality of subgroupings at 702. For example, each subgrouping may be associated with a respective number of subgroups per PO. The WTRU 102 may determine a set of identifiers of the WTRU 102 at 704. The WTRU 102 may receive, via the low-power radio, a LP-WUS. For example, the LP-WUS may include information indicating (i) a subgrouping of the plurality of subgroupings, and (ii) one or more first subgroup identifiers at 706. The WTRU 102 may determine a second subgroup identifier based on the indicated subgrouping and an identifier of the set of identifiers of the WTRU 102 at 708. The WTRU 102 may receive, using the main radio, paging information during a PO associated with the LP-WUS at 710 based on the determined second subgroup identifier matching one of the indicated one or more first subgroup identifiers.

[0366] In certain representative embodiments, the WTRU 102 may trigger an initial access procedure using the main radio based on the received paging information.

[0367] In certain representative embodiments, the WTRU 102 may receive a MIB based on the received paging information.

[0368] In certain representative embodiments, the WTRU 102 may receive an ETWS message based on the received paging information.

[0369] In certain representative embodiments, the WTRU 102 may receive a CMAS message based on the received paging information.

[0370] In certain representative embodiments, the main radio may be in a low-power state during a time the low-power radio is powered on. For example, the main radio may enter a low-power state based on reception of a RRC message.

[0371] In certain representative embodiments, the paging information may be received via PDCCH transmission and/or a PDSCH transmission.

[0372] FIG. 8 is a procedural diagram illustrating an example of a first subgroup-based wake-up procedure, according to one or more embodiments of the present disclosure. As shown in FIG. 8, a WTRU 102 may have a low-power radio and a main radio. The WTRU 102 may receive information indicating a plurality of subgroupings at 802. For example, each subgrouping may be

associated with a respective number of subgroups per PO. The WTRU 102 may determine a set of identifiers of the WTRU 102 at 804. The WTRU 102 may receive, via the low-power radio, a LP-WUS at 806. For example, the LP-WUS may include information indicating (i) a subgrouping of the plurality of subgroupings, and (ii) one or more first subgroup identifiers. The WTRU 102 may determine a second subgroup identifier based on the indicated subgrouping and an identifier of the set of identifiers of the WTRU 102 at 808. The WTRU 102 may receive, using the main radio, paging information during a PO associated with the LP-WUS at 810 based on the determined second subgroup identifier matching one of the indicated one or more first subgroup identifiers. The WTRU 102 may send, using the main radio, a PRACH transmission based on the paging information at 812.

[0373] FIG. 9 is a procedural diagram illustrating an example of a second subgroup-based wake-up procedure, according to one or more embodiments of the present disclosure. As shown in FIG. 9, a WTRU 102 may have a low-power radio and a main radio. The WTRU 102 may receive information indicating a plurality of subgroupings at 902. For example, each subgrouping may be associated with a respective number of subgroups per PO. The WTRU 102 may determine a set of identifiers of the WTRU 102 at 904. The WTRU 102 may receive, via the low-power radio, a LP-WUS at 906. For example, the LP-WUS may include information indicating (i) a subgrouping of the plurality of subgroupings, and (ii) one or more first subgroup identifiers. The WTRU 102 may determine a second subgroup identifier based on the indicated subgrouping and an identifier of the set of identifiers of the WTRU 102 at 908. The WTRU 102 may receive, using the main radio, paging information during a PO associated with the LP-WUS at 910 based on the determined second subgroup identifier matching one of the indicated one or more first subgroup identifiers. The WTRU 102 may receive, using the main radio, a MIB and/or a SIB at 912 based on the paging information.

[0374] FIG. 10 is a procedural diagram illustrating an example of a third subgroup-based wake-up procedure, according to one or more embodiments of the present disclosure. As shown in FIG. 10, a WTRU 102 may have a low-power radio and a main radio. The WTRU 102 may receive information indicating a plurality of subgroupings at 1002. For example, each subgrouping may be associated with a respective number of subgroups per PO. The WTRU 102 may determine a set of identifiers of the WTRU 102 at 1004. The WTRU 102 may receive, via the low-power radio, a LP-WUS at 1006. For example, the LP-WUS may include information indicating (i) a subgrouping of the plurality of subgroupings, and (ii) one or more first subgroup identifiers. The WTRU 102 may determine a second subgroup identifier based on the indicated subgrouping and an identifier of the set of identifiers of the WTRU 102 at 1008. The WTRU 102 may receive,

using the main radio, paging information during a PO associated with the LP-WUS at 1010 based on the determined second subgroup identifier matching one of the indicated one or more first subgroup identifiers. The WTRU 102 may receive, using the main radio, a ETWS message at 1012 based on the paging information.

5 [0375] FIG. 11 is a procedural diagram illustrating an example of a fourth subgroup-based wake-up procedure, according to one or more embodiments of the present disclosure. As shown in FIG. 11, a WTRU 102 may have a low-power radio and a main radio. The WTRU 102 may receive information indicating a plurality of subgroupings at 1102. For example, each subgrouping may be associated with a respective number of subgroups per PO. The WTRU 102 may determine a
10 set of identifiers of the WTRU 102 at 1104. The WTRU 102 may receive, via the low-power radio, a LP-WUS at 1106. For example, the LP-WUS may include information indicating (i) a subgrouping of the plurality of subgroupings, and (ii) one or more first subgroup identifiers. The WTRU 102 may determine a second subgroup identifier based on the indicated subgrouping and an identifier of the set of identifiers of the WTRU 102 at 1108. The WTRU 102 may receive,
15 using the main radio, paging information during a PO associated with the LP-WUS at 1110 based on the determined second subgroup identifier matching one of the indicated one or more first subgroup identifiers. The WTRU 102 may receive, using the main radio, a CMAS message at 1112 based on the paging information.

[0376] In certain representative embodiments, a WTRU 102 may receive configuration
20 information indicating a plurality of subgrouping configurations. For example, each subgrouping configuration may be associated with a respective number of subgroups per paging occasion PO. The WTRU 102 may determine a set of identifiers of the WTRU 102. The WTRU 102 may receive a LP-WUS. For example, the LP-WUS may include information indicating one of the subgrouping configurations and a first subgroup identifier. The WTRU 102 may determine a second subgroup
25 identifier based on the respective number of subgroups associated with the indicated one of the subgrouping configurations and the set of identifiers of the WTRU 102. The WTRU 102 may wake-up a main radio of the WTRU 102 and monitor for paging information (e.g., using the main radio) during a PO associated with the LP-WUS based on the indicated first subgroup identifier matching the determined second subgroup identifier.

30 [0377] In certain representative embodiments, the set of identifiers may include a first identifier which is a temporary mobile subscriber identity (TMSI), a second identifier which is determined from the first identifier, and a third identifier which is assigned by a core network.

[0378] In certain representative embodiments, the LP-WUS may include information indicating the first identifier of the WTRU 102. For example, the determination of the second subgroup

identifier may be based on the respective number of subgroups associated with the indicated one of the subgrouping configurations and the indicated first identifier of the WTRU 102.

[0379] In certain representative embodiments, the determination of the second subgroup identifier may be based on the respective number of subgroups associated with the indicated one of the subgrouping configurations and the first identifier of the WTRU 102.

[0380] In certain representative embodiments, the determination of the second subgroup identifier may be based on the respective number of subgroups associated with the indicated one of the subgrouping configurations and the second identifier (or the third identifier) of the WTRU.

[0381] In certain representative embodiments, the LP-WUS may be received using a low-power radio receiver of the WTRU 102.

[0382] One or more embodiments provide a computer program comprising instructions which when executed by one or more processors cause such processors to perform the encoding and/or decoding methods according to any of the embodiments described above. One or more embodiments also provide a computer readable storage medium having stored thereon instructions for encoding or decoding video data according to the methods described above.

[0383] One or more embodiments provide a computer readable storage medium having stored thereon video data generated according to the methods described above. One or more embodiments also provide a method and apparatus for transmitting or receiving video data generated according to the methods described above.

[0384] The embodiments described herein may be implemented in, for example, a method or a process, an apparatus, a software program, a data stream, or a signal. Even if only discussed in the context of a single form of implementation (e.g., as a method), the implementation of such features may also be implemented in other forms. An apparatus may be implemented in, for example, appropriate hardware, software, and firmware. Corresponding methods may be implemented in, for example, a processor.

[0385] Various numeric values are used in the present application. Such specific values are for example purposes and the embodiments described are not limited to these specific values.

[0386] Various methods are described herein, and such methods comprise one or more steps or actions for achieving the described method. Unless a specific order of steps or actions is required for the proper operation of the method, the order and/or use of specific steps and/or actions may be modified or combined. Additionally, terms such as “first”, “second”, etc. may be used in various embodiments to modify an element, component, step, operation, etc., for example, a “first decoding” and a “second decoding”. Use of such terms does not imply an order to the operations unless specifically required.

[0387] The present disclosure may refer to “determining” various pieces of information. Determining information may include one or more of, for example, estimating, calculating, predicting, or retrieving (e.g., from memory) the information.

[0388] The present disclosure may refer to “accessing” various pieces of information. Accessing information may include one or more of, for example, receiving, retrieving (e.g., from memory), storing, moving, copying, calculating, determining, predicting, or estimating the information. Similarly, the present disclosure may refer to “receiving” various pieces of information. Receiving information may include one or more of, for example, accessing or retrieving (e.g., from memory) the information.

[0389] It is to be understood that use of any of the following “/”, “and/or”, and “at least one of” is intended to encompass all possible selections of listed items, taken either individually or in any combination thereof.

[0390] While specific embodiments have been described in the foregoing description in connection with the accompanying drawings, it should be understood that embodiments described herein are examples only and should not be taken as limiting the scope of the present disclosure or the following claims. Although features and elements are described herein in particular combinations, those of ordinary skill in the art will appreciate that such features or elements may be used alone or in any combination with the other features and elements. It is understood, therefore, that the overall teachings of the present disclosure are not limited to the particular embodiments, implementations, and examples disclosed herein, but are intended to cover variations, modifications, and alternatives as defined by the appended claims and any and all equivalents thereof.

CLAIMS

What is claimed is:

1. A method implemented by a wireless transmit/receive unit (WTRU) having a low-power radio and a main radio, the method comprising:

receiving configuration information indicating a plurality of subgroupings, wherein each subgrouping is associated with a respective number of subgroups per paging occasion (PO);

determining a set of identifiers of the WTRU;

receiving, via the low-power radio, a low-power-wake up signal (LP-WUS), wherein the LP-WUS includes information indicating (i) a subgrouping of the plurality of subgroupings, and (ii) one or more first subgroup identifiers;

determining a second subgroup identifier based on the indicated subgrouping and an identifier of the set of identifiers of the WTRU;

monitoring, using the main radio, for a physical downlink control channel (PDCCH) transmission during a PO associated with the LP-WUS based on the determined second subgroup identifier matching one of the indicated one or more first subgroup identifiers.

2. The method of claim 1, wherein the set of identifiers are associated with the LP-WUS and/or the PO.

3. The method of any of claims 1-2, wherein the set of identifiers include any of a first mobile subscriber identifier of the WTRU, a second identifier determined from the first mobile subscriber identifier, and/or a third core network-assigned identifier.

4. The method of claim 3, further comprising:

determining the second identifier from the first mobile subscriber identifier.

5. The method of any of claims 3-4, further comprising:

receiving information indicating first bit information,

wherein the second identifier is determined from the mobile subscriber identifier using the first bit information.

6. The method of any of claims 3-5, further comprising:

determining second bit information based on a number of paging frames (PFs) per paging cycle and a number of POs per PF,

wherein the second identifier is determined from the mobile subscriber identifier using the second bit information.

7. The method of any of claims 1-6, wherein the second subgroup identifier is determined based on the respective number of subgroups associated with the indicated subgrouping and the identifier of the set of identifiers of the WTRU.

8. The method of any of claims 1-7, wherein the second subgroup identifier is determined based on the identifier of the set of identifiers of the WTRU which is associated with the indicated subgrouping.

9. The method of any of claims 1-7, wherein the second subgroup identifier is determined based on the indicated subgrouping and the identifier, of the set of identifiers of the WTRU, which is a core network-assigned identifier.

10. The method of any of claims 1-7, wherein the LP-WUS includes information indicating (i) the subgrouping of the plurality of subgroupings, (ii) the one or more first subgroup identifiers, and (iii) an identifier of the set of identifiers of the WTRU, and

wherein the second subgroup identifier is determined based on the indicated subgrouping and the indicated identifier of the set of identifiers of the WTRU.

11. The method of any of claims 1-10, wherein at least one identifiers of the set of identifiers is assigned by a core network.

12. The method of any of claims 1-11, wherein at least one identifiers of the set of identifiers is received in radio resource control (RRC) signaling or messaging.

13. The method of any of claims 1-12, further comprising:

receiving, using the main radio, the PDCCH transmission during the PO associated with the LP-WUS; and

receiving a physical downlink shared channel (PDSCH) transmission based on scheduling information indicated by the PDCCH transmission.

14. The method of any of claims 1-13, wherein the main radio is in a low-power state during a time the low-power radio is powered on.
15. The method of any of claims 1-14, wherein the main radio enters a low-power state based on reception of a radio resource control (RRC) message.
16. A wireless transmit/receive unit (WTRU) comprising:
- a low-power radio;
 - a main radio; and
 - a processor and memory which are configured to:
 - receive configuration information indicating a plurality of subgroupings, wherein each subgrouping is associated with a respective number of subgroups per paging occasion (PO),
 - determine a set of identifiers of the WTRU,
 - receive, via the low-power radio, a low-power-wake up signal (LP-WUS), wherein the LP-WUS includes information indicating (i) a subgrouping of the plurality of subgroupings, and (ii) one or more first subgroup identifiers,
 - determine a second subgroup identifier based on the indicated subgrouping and an identifier of the set of identifiers of the WTRU, and
 - monitor, using the main radio, for a physical downlink control channel (PDCCH) transmission during a PO associated with the LP-WUS based on the determined second subgroup identifier matching one of the indicated one or more first subgroup identifiers.
17. The WTRU of claim 16, wherein the set of identifiers are associated with the LP-WUS and/or the PO.
18. The WTRU of any of claims 16-17, wherein the set of identifiers include any of a first mobile subscriber identifier of the WTRU, a second identifier determined from the first mobile subscriber identifier, and/or a third core network-assigned identifier.
19. The WTRU of claim 18, wherein the processor and memory are configured to:
- determine the second identifier from the first mobile subscriber identifier.
20. The WTRU of any of claims 18-19, wherein the processor and memory are configured to:

receive information indicating first bit information,
wherein the second identifier is determined from the mobile subscriber identifier using the first bit information.

21. The WTRU of any of claims 18-20, wherein the processor and memory are configured to:
determine second bit information based on a number of paging frames (PFs) per paging cycle and a number of POs per PF,

wherein the second identifier is determined from the mobile subscriber identifier using the second bit information.

22. The WTRU of any of claims 16-21, wherein the second subgroup identifier is determined based on the respective number of subgroups associated with the indicated subgrouping and the identifier of the set of identifiers of the WTRU.

23. The WTRU of any of claims 16-22, wherein the second subgroup identifier is determined based on the identifier of the set of identifiers of the WTRU which is associated with the indicated subgrouping.

24. The WTRU of any of claims 16-22, wherein the second subgroup identifier is determined based on the indicated subgrouping and the identifier, of the set of identifiers of the WTRU, which is a core network-assigned identifier.

25. The WTRU of any of claims 16-22, wherein the LP-WUS includes information indicating (i) the subgrouping of the plurality of subgroupings, (ii) the one or more first subgroup identifiers, and (iii) an identifier of the set of identifiers of the WTRU, and

wherein the second subgroup identifier is determined based on the indicated subgrouping and the indicated identifier of the set of identifiers of the WTRU.

26. The WTRU of any of claims 16-25, wherein at least one identifiers of the set of identifiers is assigned by a core network.

27. The WTRU of any of claims 16-26, wherein at least one identifiers of the set of identifiers is received in radio resource control (RRC) signaling or messaging.

28. The WTRU of any of claims 16-27, wherein the processor and memory are configured to:
- receive, using the main radio, the PDCCH transmission during the PO associated with the LP-WUS, and
 - receive a physical downlink shared channel (PDSCH) transmission based on scheduling information indicated by the PDCCH transmission.
29. The WTRU of any of claims 16-28, wherein the main radio is in a low-power state during a time the low-power radio is powered on.
30. The WTRU of any of claims 16-29, wherein the main radio enters a low-power state based on reception of a radio resource control (RRC) message.

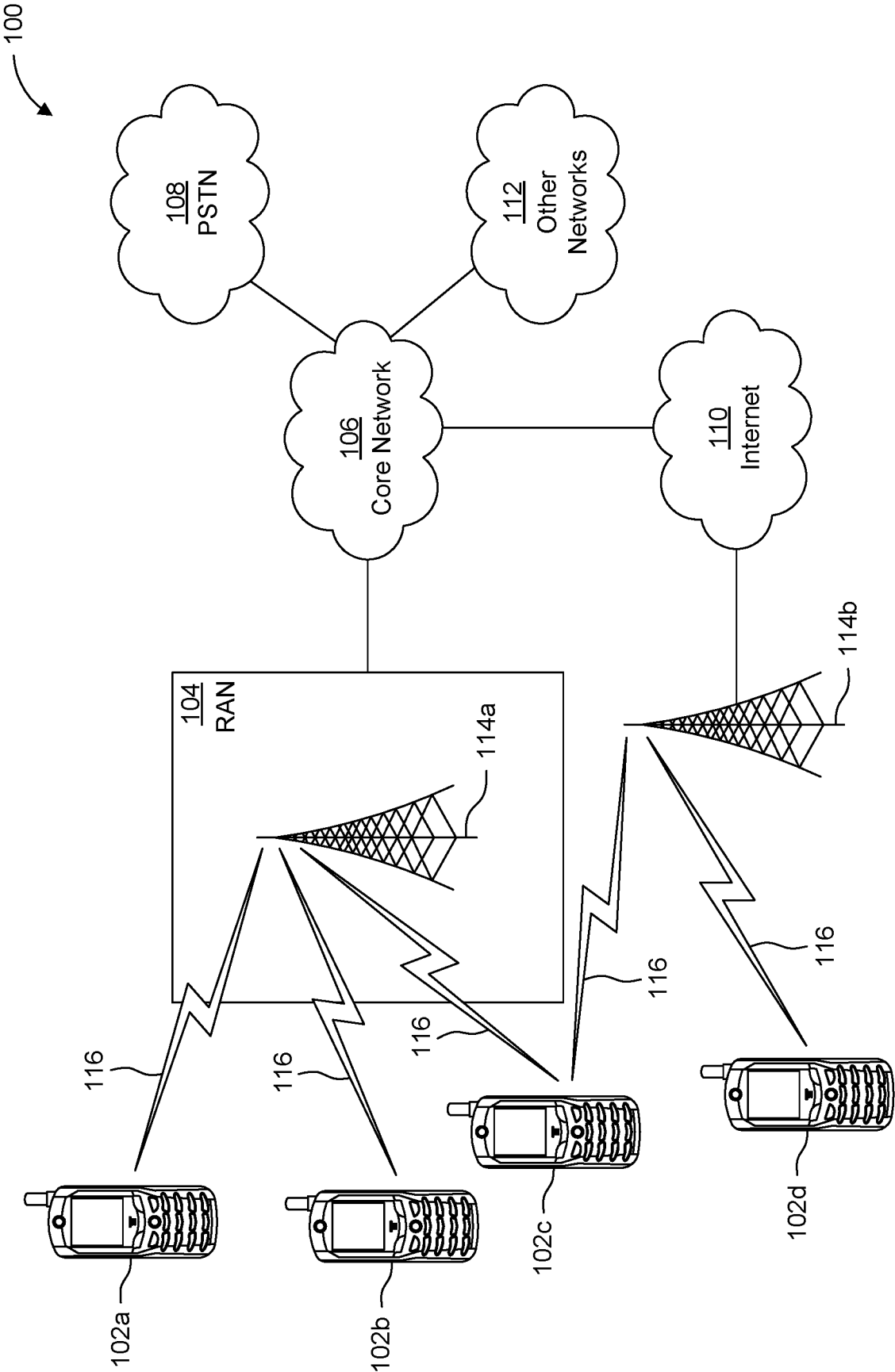


FIG. 1A

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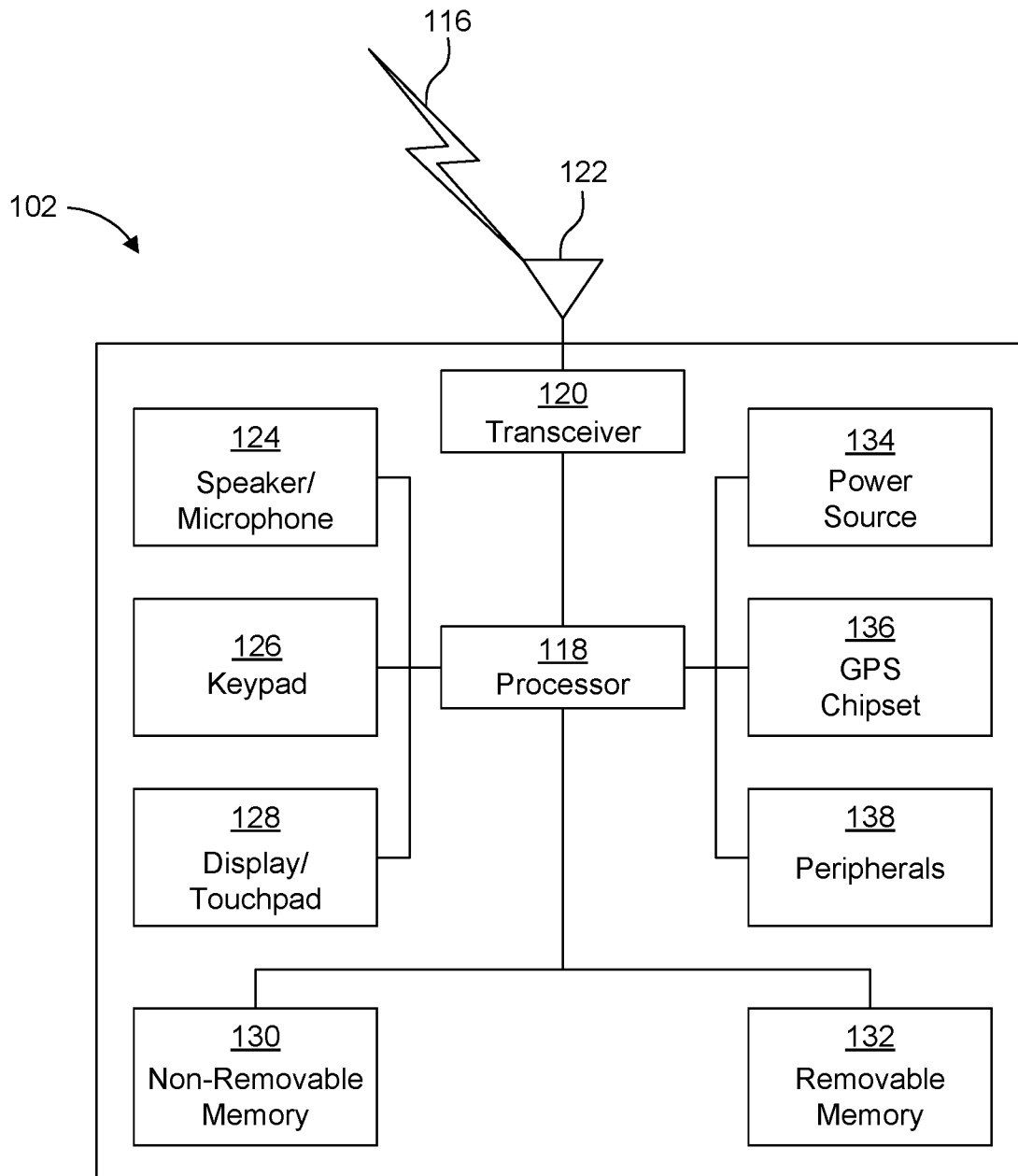


FIG. 1B

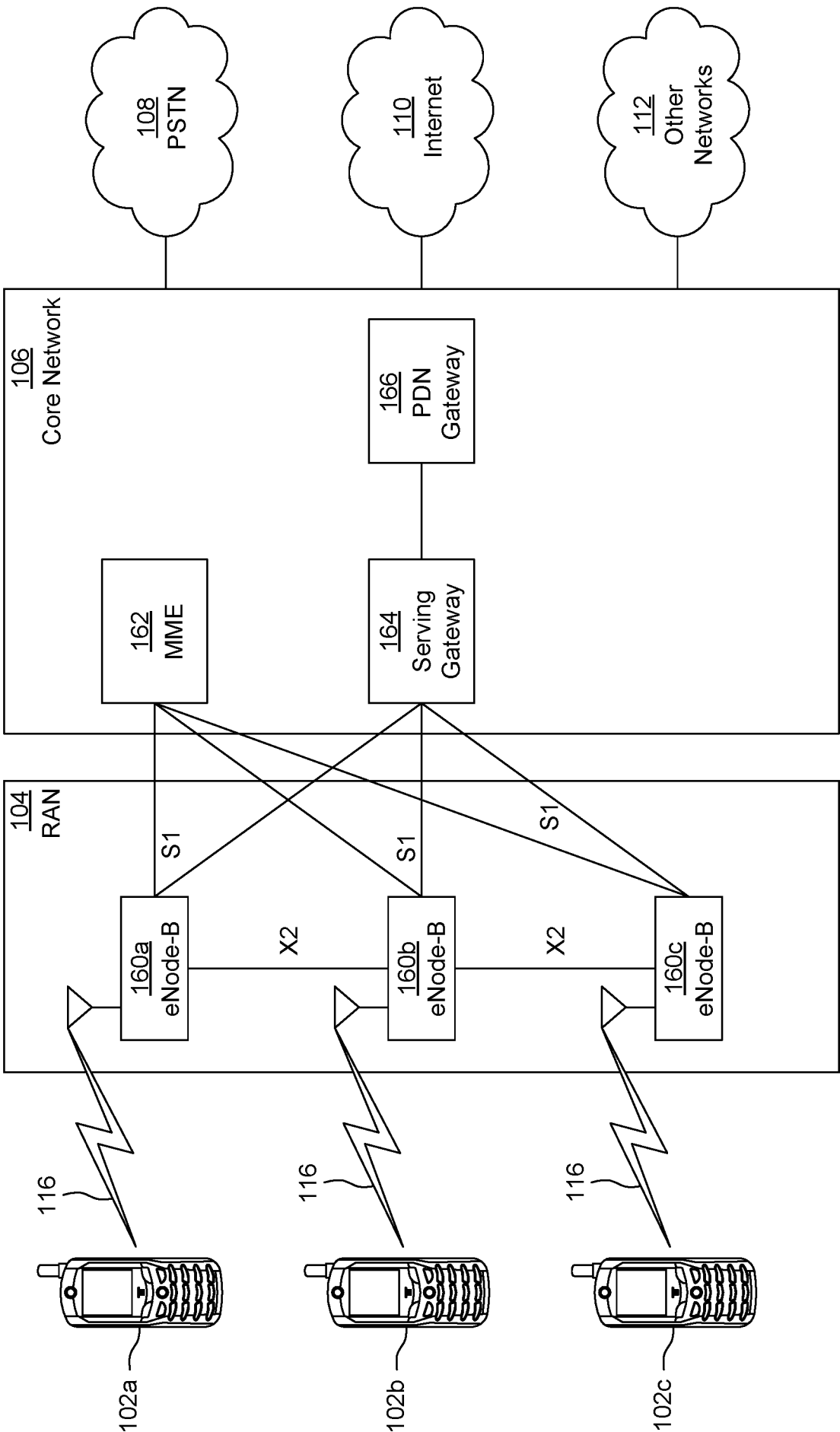


FIG. 1C

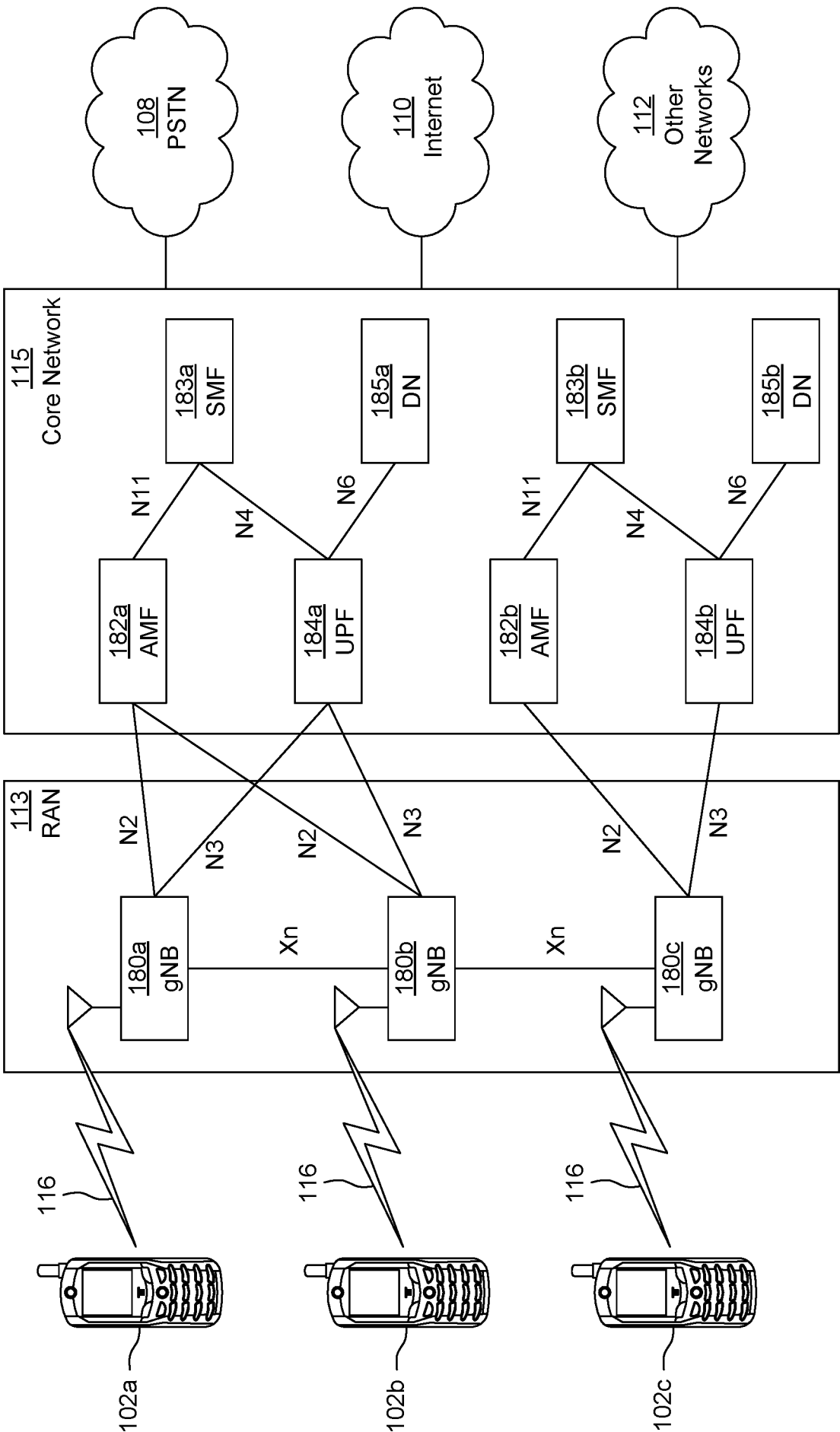


FIG. 1D

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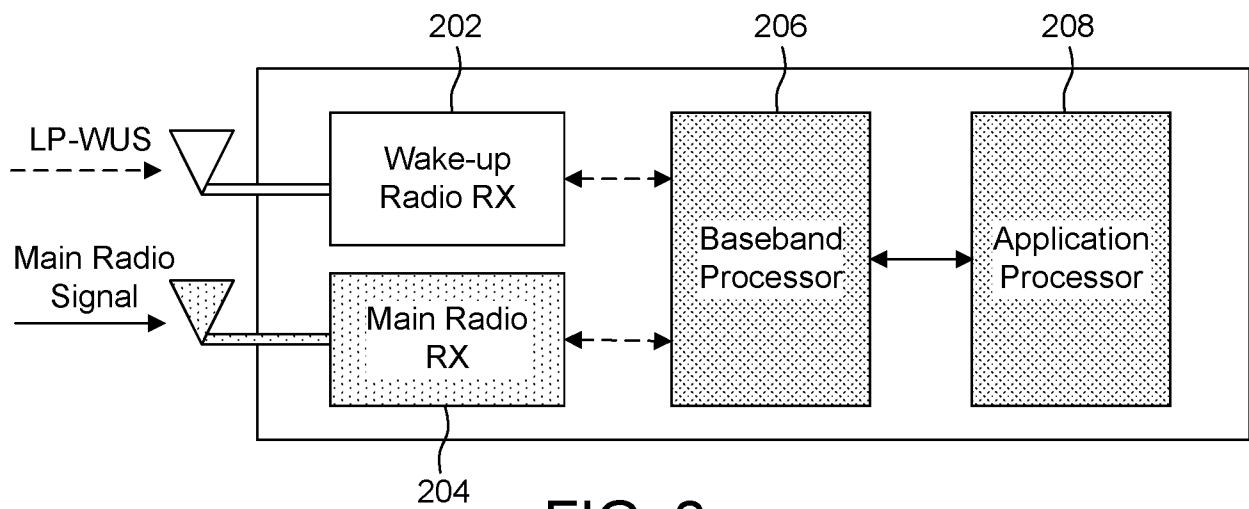
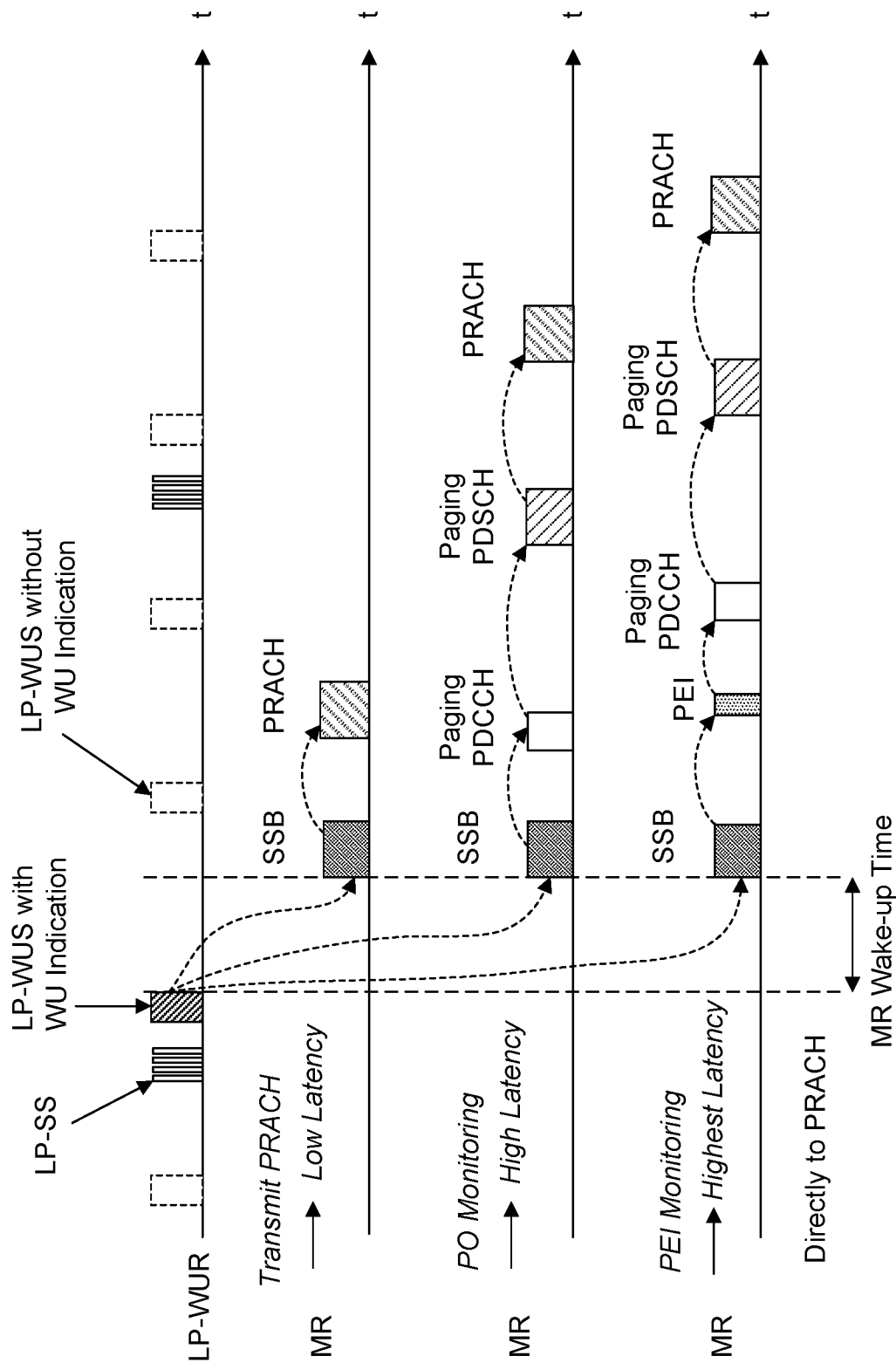


FIG. 2



Note: LP-WUS can be Aperiodic (i.e., UEs Monitor LP-WUS Continuously), but Decoded at Specific Times

FIG. 3

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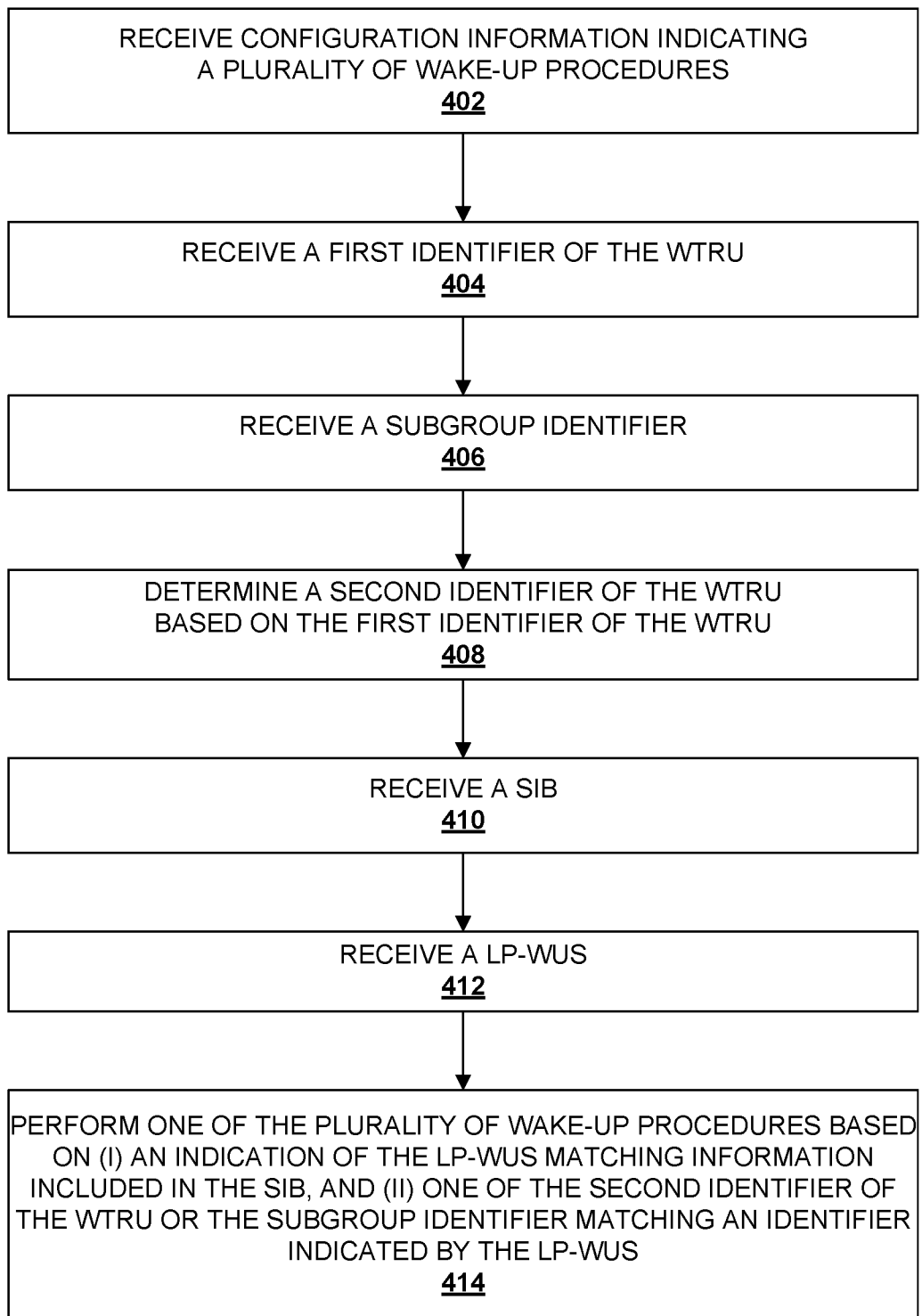


FIG. 4

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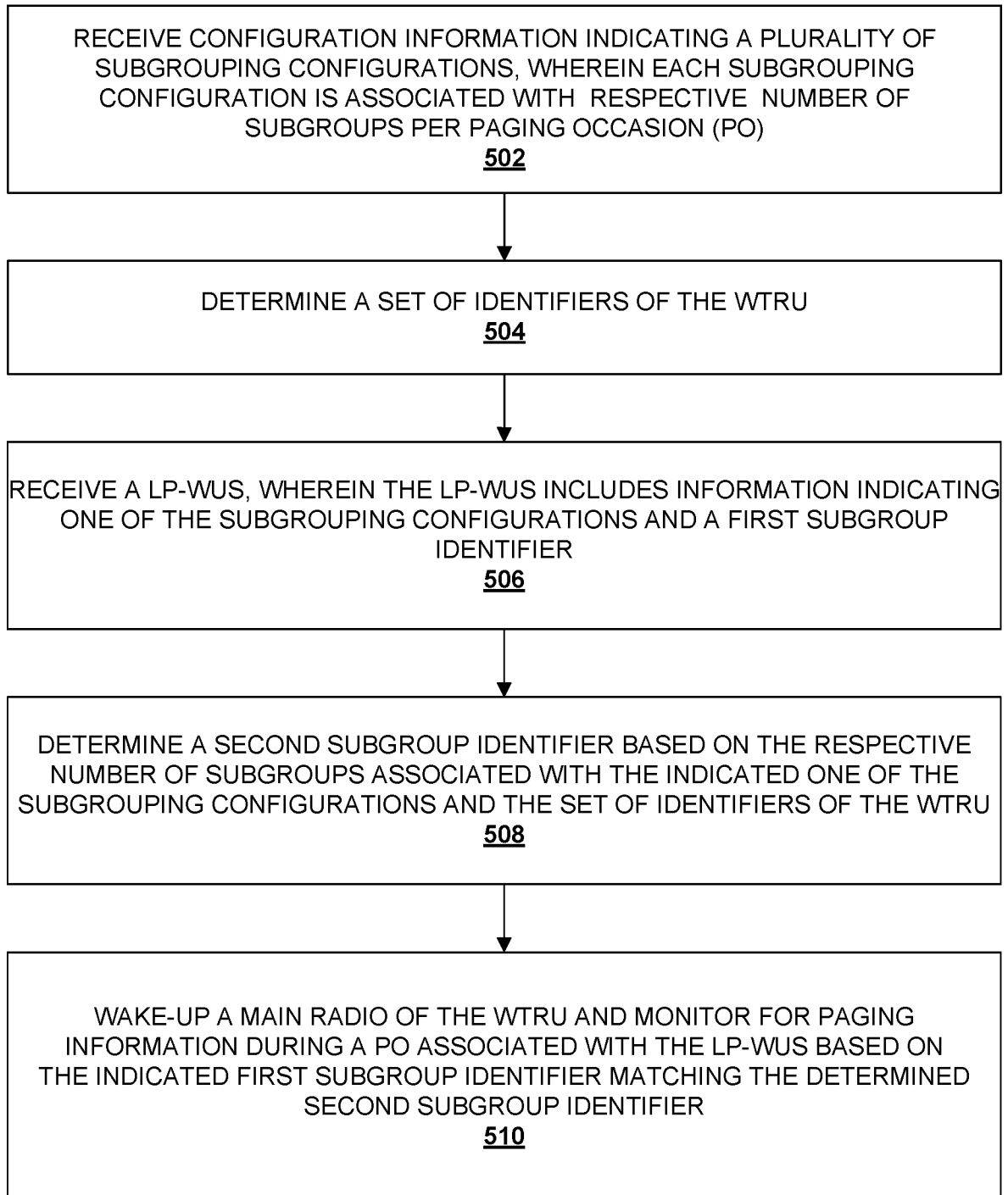


FIG. 5

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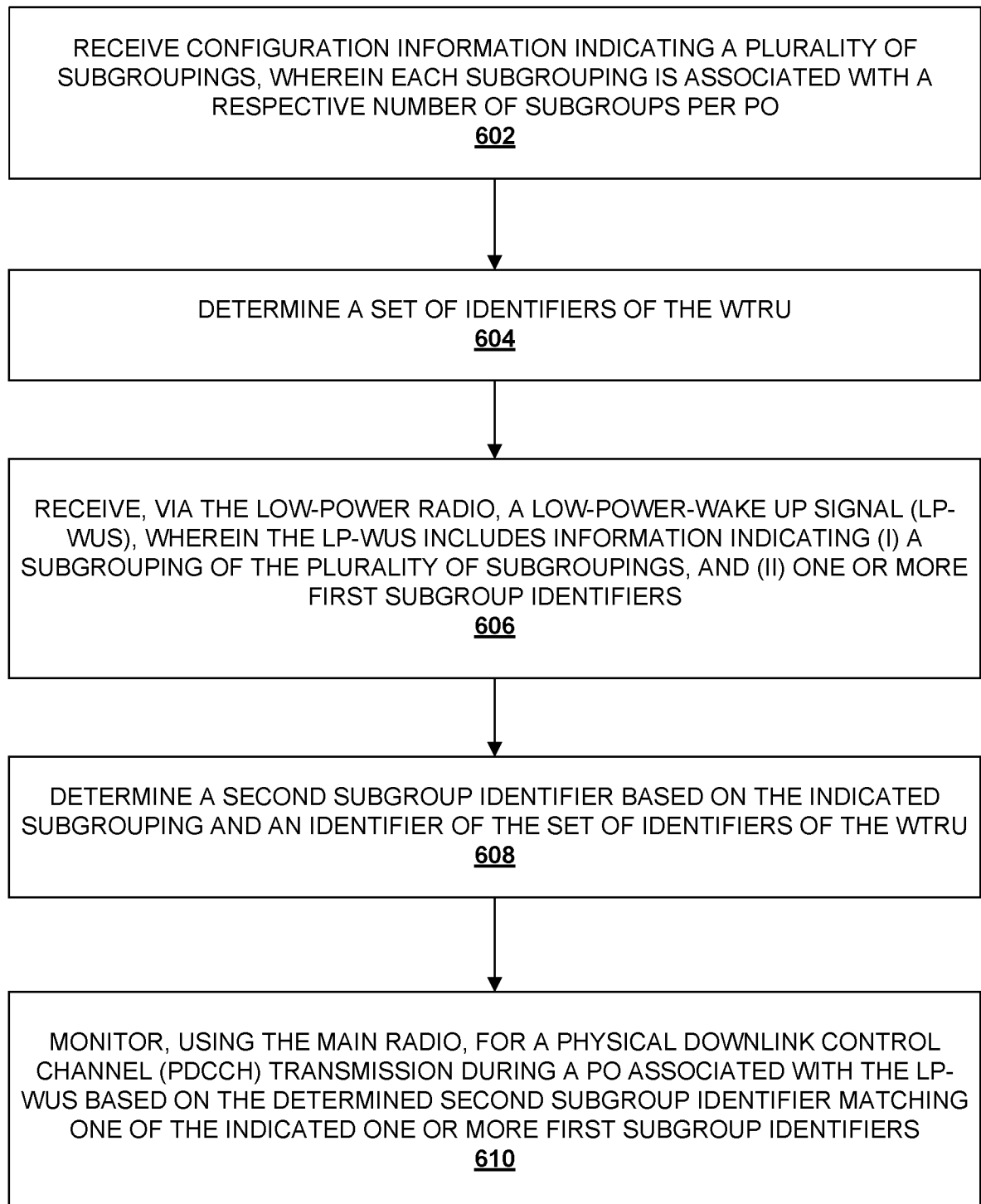


FIG. 6

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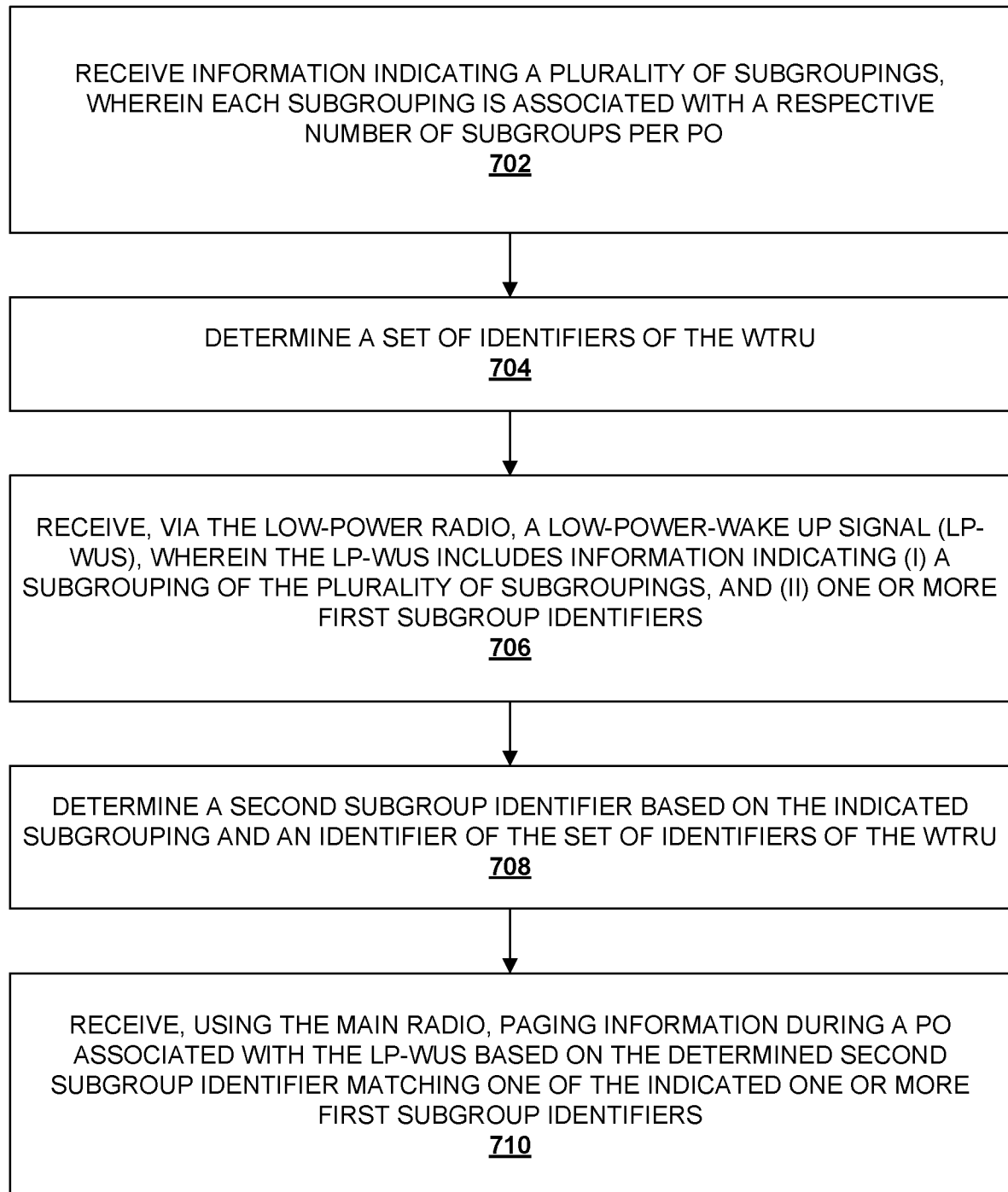


FIG. 7

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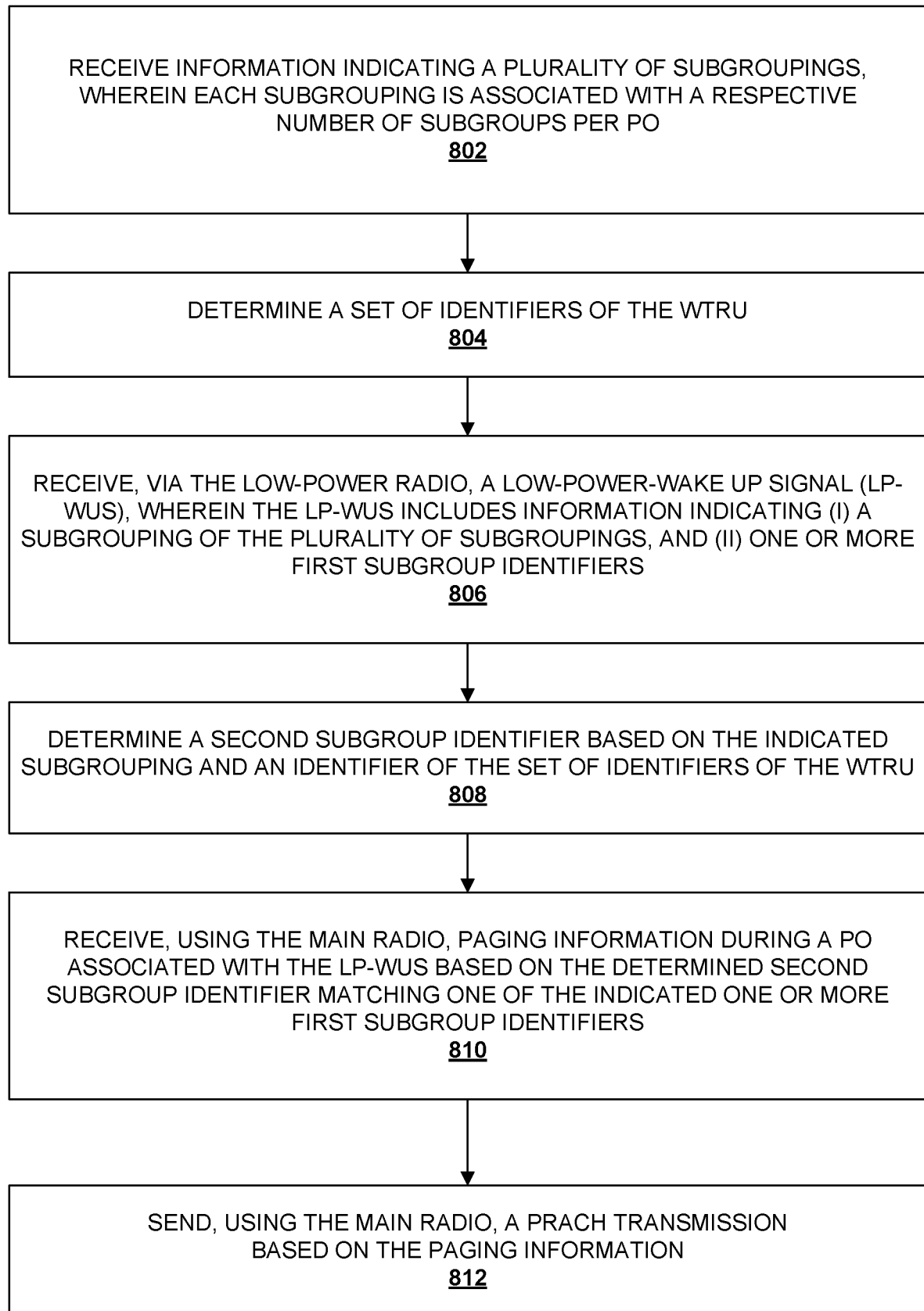


FIG. 8

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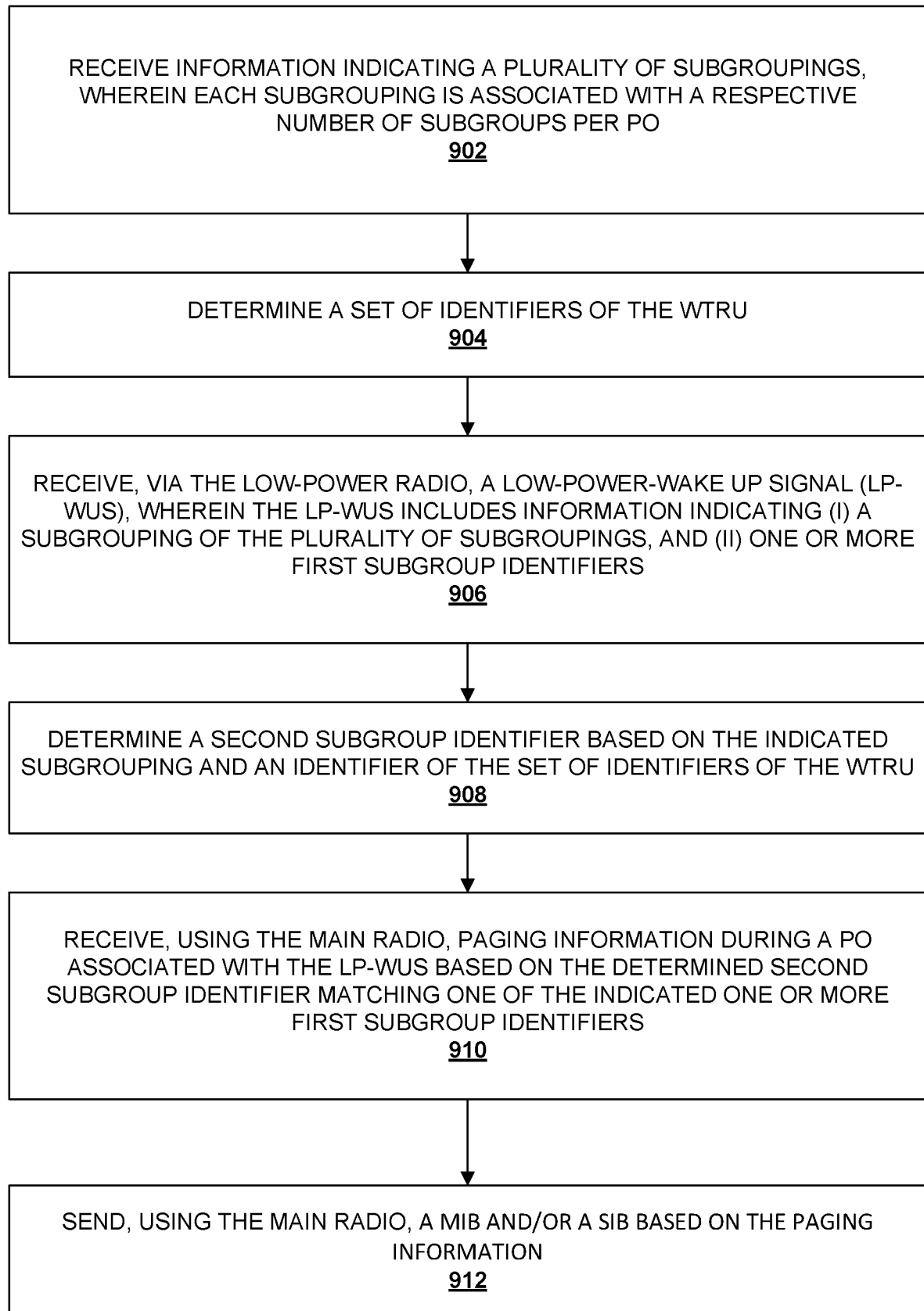


FIG. 9

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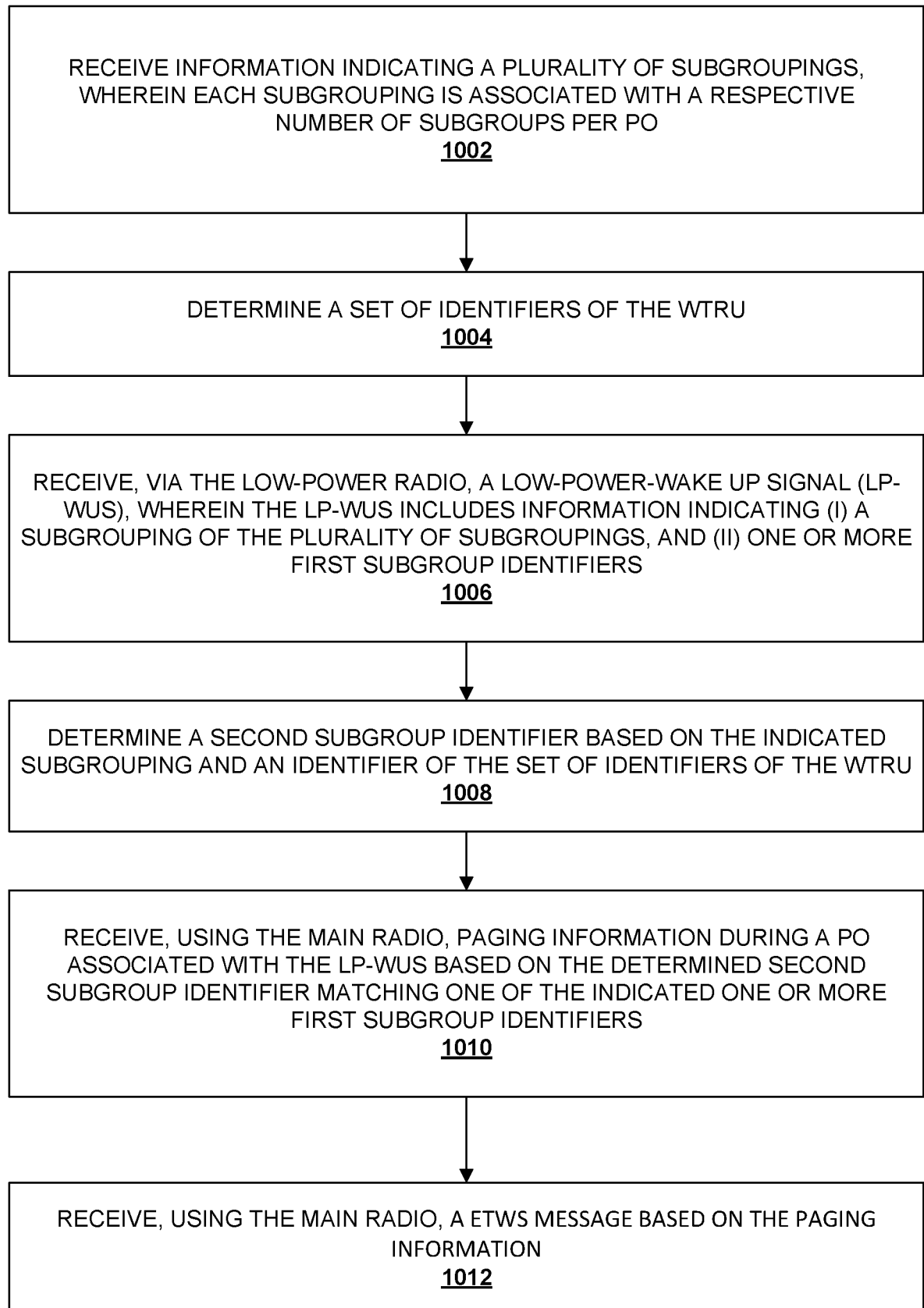


FIG. 10

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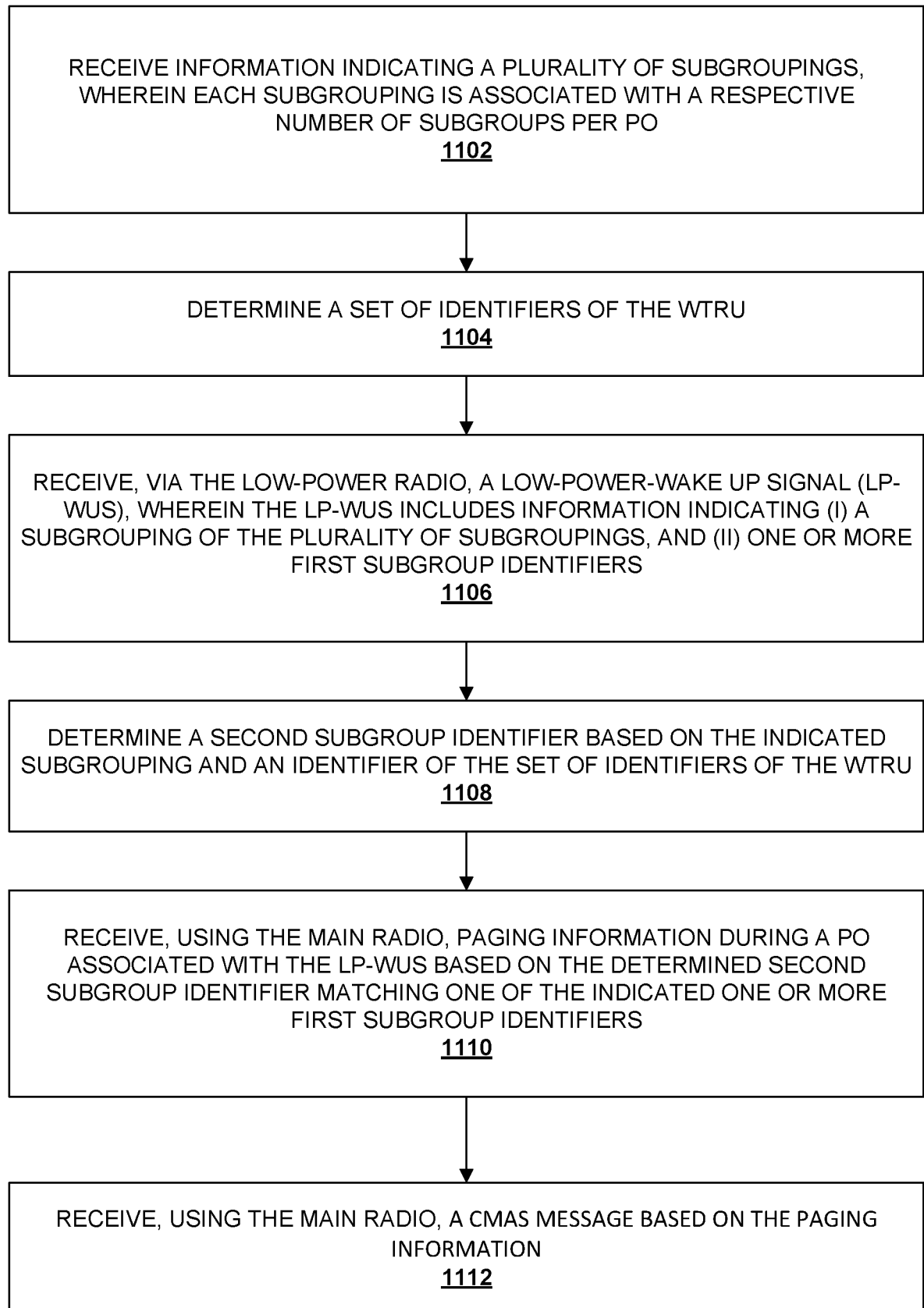


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2025/010392

A. CLASSIFICATION OF SUBJECT MATTER INV. H04W52/02 H04W68/02 H04W76/28 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) H04W Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2021/306953 A1 (HWANG SEUNGGYE [KR] ET AL) 30 September 2021 (2021-09-30) abstract paragraph [0226] paragraph [0242] - paragraph [0262] paragraph [0300] paragraph [0325] - paragraph [0334] ----- - / - -	1 - 30
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 19 March 2025		Date of mailing of the international search report 27/03/2025
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 Hornik, Valentin

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2025/010392

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	LI CHEN ET AL: "Update of TR 38.869 for LP-WUS WUR", 3GPP DRAFT; R2-2309311; TYPE DISCUSSION; FS_NR_LPWUS, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG2, no. Toulouse, FR; 20230821 - 20230825 8 September 2023 (2023-09-08), XP052502795, Retrieved from the Internet: URL:https://www.3gpp.org/ftp/TSG_RAN/WG2_RL2/TSGR2_123/Docs/R2-2309311.zip R2-2309311_Update of TR 38.869 for LP-WUS WUR.docx [retrieved on 2023-09-08] clause 6.3.1 clause 7.3.1.2 -----	1 - 30

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2025/010392

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		EP 3820204 A1	12-05-2021
		EP 4236601 A2	30-08-2023
		US 2021306953 A1	30-09-2021
		US 2023092099 A1	23-03-2023
		US 2024155496 A1	09-05-2024
		WO 2020032751 A1	13-02-2020
