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

(72) Inventors: **OTERI, Oghenekome**; 8488 Lower Scarborough Lane, San Diego, CA 92127 (US). **NAYEB NAZAR, Shahrokh**; 3489 Overpark Road, San Diego, CA 92130 (US).

(74) Agent: **ROCCIA, Vincent** et al.; Condo Roccia Koptiw LLP, 1800 JFK Blvd., Suite 1700, Philadelphia, PA 19103 (US).

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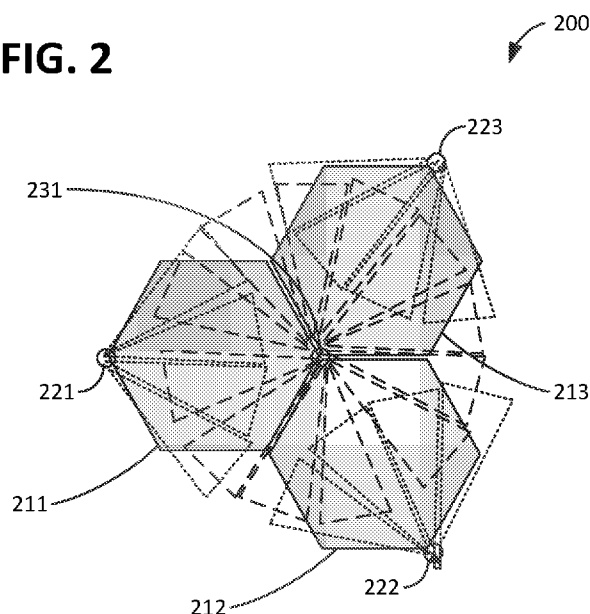
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FIG. 2



(57) Abstract: Systems and methods for beam synchronization and/or network information acquisition are set forth. Beam synchronization and/or network information acquisition may be initiated by a beam (e.g., by a base station via a beam) and/or by a wireless transmit/receive unit (WTRU). Beam synchronization may be periodic and/or aperiodic.



SYSTEMS AND METHODS FOR SYNCHRONIZATION, NETWORK INFORMATION ACQUISITION, AND BEAM MEASUREMENT IN BEAM-CENTRIC NETWORKS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. provisional patent application no. 62/335,043, filed May 11, 2016, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] In next generation mobile communications systems, applications using technologies such as enhanced mobile broadband (eMBB), massive Machine Type Communications (mMTC) and/or Ultra-Reliable Low Latency Communications (URLLC) may be supported. A wide range of spectrum bands, such as bands ranging from 700 MHz to 80 GHz, or any subset thereof, may be used in any of a variety of deployment scenarios. Either, or both, of licensed and unlicensed spectrum may be used in such deployment scenarios. In next generation mobile communications systems, network architectures may be desired that, for example, minimize a presence of always-on signals and/or adapt to beamforming.

SUMMARY

[0003] Systems and methods of beam synchronization are disclosed. A wireless transmit/receive unit (WTRU) may receive a beam, determine whether a signal is in the beam, and transmit a request for the signal to a base station. This request may include an indication of the beam and an indication of a signal characteristic. Determining whether a signal is in a beam may include determining that a beam component of the beam is signaled to a WTRU, determining a beam type of the beam, and/or determining a beam component of the beam. Beam components may be synchronization components, broadcast components, and/or a reference components. Signal characteristics may be synchronization characteristics, broadcast characteristics, measurement reference signal (MRS) characteristics, and/or a combination of such characteristics. Base stations with which such a WTRU may communicate may include one or more next generation Node Bs (gNBs).

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. 1A is a system diagram of an example communications system.

[0005] FIG. 1B is a system diagram of an example wireless transmit/receive unit (WTRU) that may be used within a communications system, such as the example communications system illustrated in FIG. 1A.

[0006] FIG. 1C is a system diagram of an example radio access network and/or an example core network that may be used within a communications system, such as the example communications system illustrated in FIG. 1A.

[0007] FIG. 1D is a system diagram of another example radio access network and/or an example core network that may be used within a communications system, such as the example communications system illustrated in FIG. 1A.

[0008] FIG. 1E is a system diagram of another example radio access network and/or an example core network that may be used within a communications system, such as the example communications system illustrated in FIG. 1A.

[0009] FIG. 2 illustrates an example beam-centric communications system superimposed on an example cell-centric system.

[0010] FIG. 3 illustrates an example beam-centric system and an example WTRU.

[0011] FIG. 4 illustrates an example of aggregated beams separated by beamwidth.

[0012] FIG. 5 illustrates an example of aggregated beams separated by frequency.

[0013] FIG. 6 illustrates an example of multi-beam transmission.

[0014] FIG. 7 illustrates an example of beam transmissions that may contain one or more beam synchronization sequences.

[0015] FIG. 8 illustrates an example of reserved time intervals that may be used for synchronization and/or broadcast signals and that may be interspaced with data transmissions.

[0016] FIG. 9 illustrates an example of reserved time intervals that may be used for beam reference signals (BRSs) and that may be interspaced with data transmissions.

[0017] FIG. 10 illustrates an example of a network having four beams and grouped periodic synchronization channel/BRS.

[0018] FIG. 11 illustrates an example of a network having four beams and individual periodic synchronization channel/BRS.

[0019] FIG. 12 illustrates an example of periodic synchronization, broadcast, and/or data transmission.

[0020] FIG. 13 illustrates an example of staggered signals.

[0021] FIG. 14 illustrates an example of aperiodic synchronization signaling.

[0022] FIG. 15 illustrates an example of synchronization and/or network acquisition signaling.

[0023] FIG. 16 illustrates an example of BRS signaling with scheduled data on connected beams.

[0024] FIG. 17 illustrates an example of random beamforming with data, broadcast, and/or sync signals.

[0025] FIG. 18 illustrates an example of random beamforming with BRS for measurement.

[0026] FIG. 19 illustrates exemplary time intervals that may be used with periodic synchronization with broadcast network information.

[0027] FIG. 20 illustrates an exemplary process for periodic beam synchronization and/or beam-initiated network information acquisition.

[0028] FIG. 21 illustrates an exemplary process for aperiodic beam synchronization and/or beam-initiated network information acquisition.

[0029] FIG. 22 illustrates an exemplary process for periodic beam synchronization and/or WTRU-initiated network information acquisition.

[0030] FIG. 23 illustrates an exemplary process for aperiodic beam synchronization and/or WTRU-initiated network information acquisition.

[0031] FIG. 24 illustrates an exemplary process for aperiodic and WTRU-initiated beam synchronization and/or WTRU-initiated network information acquisition.

[0032] FIG. 25 illustrates an exemplary process for multi-beam and/or multi-stream transmission.

DETAILED DESCRIPTION

[0033] A detailed description of illustrative examples is set forth herein with reference to various figures. Although this description provides detailed examples of possible implementations, it should be noted that these examples are intended to be nonlimiting examples and are not intended to limit the scope of this application in any way.

[0034] FIG. 1A is a diagram of an example communications system 100 in which one or more disclosed examples 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 system 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), and the like.

[0035] As shown in FIG. 1A, the communications system 100 may include wireless transmit/receive units (WTRUs), *e.g.*, WTRUs, 102a, 102b, 102c, and/or 102d (which generally or collectively may be referred to as WTRU 102), a radio access network (RAN) 103/104/105, a core network 106/107/109, a public switched telephone network (PSTN) 108, the Internet 110, and other networks 112, though it will be appreciated that the disclosed examples 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 may be configured to transmit and/or receive wireless signals and may include user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a netbook, a personal computer, a wireless sensor, consumer electronics, and the like.

[0036] The communications system 100 may also include base station 114a and base station 114b. Each of the base stations 114a, 114b may be any type of device configured to wirelessly interface with at least one of the WTRUs 102a, 102b, 102c, 102d to facilitate access to one or more communication networks, such as the core network 106/107/109, the Internet 110, and/or the networks 112. By way of example, base stations 114a, 114b may be a base transceiver station (BTS), a Node-B, an eNode B, a Home Node B, a Home eNode B, a site controller, an access point (AP), a wireless router, a next generation Node B (gNB), 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.

[0037] The base station 114a may be part of the RAN 103/104/105, 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 within a particular geographic region, which may be referred to as a cell (not shown). 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 some examples, the base station 114a may include three transceivers, *e.g.*, one for each sector of the cell. In another example, the base station 114a may employ multiple-input multiple output (MIMO) technology and, therefore, may utilize multiple transceivers for each sector of the cell.

[0038] The base stations 114a, 114b may communicate with one or more of the WTRUs 102a, 102b, 102c, 102d over an air interface 115/116/117, which may be any suitable wireless communication link (*e.g.*, radio frequency (RF), microwave, infrared (IR), ultraviolet (UV), visible light, *etc.*). The air interface 115/116/117 may be established using any suitable radio access technology (RAT).

[0039] 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 103/104/105 and the WTRUs 102a, 102b, 102c may implement a radio technology such as Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA), which may establish the air interface 115/116/117 using wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet Access (HSPA) and/or Evolved HSPA (HSPA+). HSPA may include High-Speed Downlink Packet Access (HSDPA) and/or High-Speed Uplink Packet Access (HSUPA).

[0040] In another example, 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 115/116/117 using Long Term Evolution (LTE) and/or LTE-Advanced (LTE-A).

[0041] In other examples, the base station 114a and the WTRUs 102a, 102b, 102c may implement radio technologies such as IEEE 802.16 (*e.g.*, 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.

[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, and the like. In some examples, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In another example, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). In yet another example, the base station 114b and the WTRUs 102c, 102d may utilize a cellular-based RAT (*e.g.*, WCDMA, CDMA2000, GSM, LTE, LTE-A, *etc.*) to establish a picocell or femtocell. As shown in FIG. 1A, the base station 114b may have a direct connection to the Internet 110.

Thus, the base station 114b may not be required to access the Internet 110 via the core network 106/107/109.

[0043] The RAN 103/104/105 may be in communication with the core network 106/107/109, 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. For example, the core network 106/107/109 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 103/104/105 and/or the core network 106/107/109 may be in direct or indirect communication with other RANs that employ the same RAT as the RAN 103/104/105 or a different RAT. For example, in addition to being connected to the RAN 103/104/105, which may be utilizing an E-UTRA radio technology, the core network 106/107/109 may also be in communication with another RAN (not shown) employing a GSM radio technology.

[0044] The core network 106/107/109 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 the internet protocol (IP) in the TCP/IP internet protocol suite. The networks 112 may include wired or wireless communications networks owned and/or operated by other service providers. For example, the networks 112 may include another core network connected to one or more RANs, which may employ the same RAT as the RAN 103/104/105 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 of 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

other peripherals 138. It will be appreciated that the WTRU 102 may include any sub-combination of the foregoing elements while remaining consistent with an example. Also, examples contemplate that the base stations 114a and 114b, and/or the nodes that base stations 114a and 114b may represent, such as but not limited to transceiver station (BTS), a Node-B, a site controller, an access point (AP), a home node-B, an evolved home node-B (eNodeB), a home evolved node-B (HeNB or HeNodeB), a home evolved node-B gateway, and proxy nodes, among others, may include some or all of the elements depicted in FIG. 1B and described herein.

[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 Array (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The processor 118 may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the WTRU 102 to operate in a wireless environment. The processor 118 may be coupled to the transceiver 120, which may be coupled to the transmit/receive element 122. While FIG. 1B depicts the processor 118 and the transceiver 120 as separate components, it will be appreciated that the processor 118 and the transceiver 120 may be integrated together in an electronic package or chip.

[0048] The transmit/receive element 122 may be configured to transmit signals to, or receive signals from, a base station (*e.g.*, base station 114a) over the air interface 115/116/117. For example, in some examples, the transmit/receive element 122 may be an antenna configured to transmit and/or receive RF signals. In another example, the transmit/receive element 122 may be an emitter/detector configured to transmit and/or receive IR, UV, or visible light signals, for example. In yet another example, the transmit/receive element 122 may be configured to transmit and 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] In addition, although the transmit/receive element 122 is depicted in FIG. 1B as a single element, the WTRU 102 may include any number of transmit/receive elements 122. More specifically, the WTRU 102 may employ MIMO technology. Thus, in some examples, 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 115/116/117.

[0050] The transceiver 120 may be configured to modulate signals that may be transmitted by transmit/receive element 122 and to demodulate signals that may be received by transmit/receive element 122. As noted above, WTRU 102 may have multi-mode capabilities.

Thus, transceiver 120 may include multiple transceivers for enabling WTRU 102 to communicate via multiple RATs, such as UTRA 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 examples, 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 115/116/117 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 implementation while remaining consistent with an example.

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

[0055] FIG. 1C is a system diagram of the RAN 103 and the core network 106 according to an example. As noted above, the RAN 103 may employ a UTRA radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 115. The RAN 103 may also be in communication with the core network 106. As shown in FIG. 1C, the RAN 103 may include Node-Bs 140a, 140b, 140c, which may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 115. The Node-Bs 140a, 140b, 140c may each be associated with a particular cell (not shown) within the RAN 103. The RAN 103 may also include RNCs 142a, 142b. It will be appreciated that the RAN 103 may include any number of Node-Bs and RNCs while remaining consistent with an example.

[0056] As shown in FIG. 1C, the Node-Bs 140a, 140b may be in communication with the RNC 142a. Additionally, the Node-B 140c may be in communication with the RNC 142b. The Node-Bs 140a, 140b, 140c may communicate with the respective RNCs 142a, 142b via an Iub interface. The RNCs 142a, 142b may be in communication with one another via an Iur interface. Each of the RNCs 142a, 142b may be configured to control the respective Node-Bs 140a, 140b, 140c to which it is connected. In addition, each of the RNCs 142a, 142b may be configured to carry out or support other functionality, such as outer loop power control, load control, admission control, packet scheduling, handover control, macrodiversity, security functions, data encryption, and the like.

[0057] The core network 106 shown in FIG. 1C may include a media gateway (MGW) 144, a mobile switching center (MSC) 146, a serving GPRS support node (SGSN) 148, and/or a gateway GPRS support node (GGSN) 150. While each of the foregoing elements are depicted as part of the core network 106, it will be appreciated that any one of these elements may be owned and/or operated by an entity other than the core network operator.

[0058] The RNC 142a in the RAN 103 may be connected to the MSC 146 in the core network 106 via an IuCS interface. The MSC 146 may be connected to the MGW 144. The MSC 146 and the MGW 144 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.

[0059] The RNC 142a in the RAN 103 may also be connected to the SGSN 148 in the core network 106 via an IuPS interface. The SGSN 148 may be connected to the GGSN 150. The SGSN 148 and the GGSN 150 may provide the WTRUs 102a, 102b, 102c with access to packet-

switched networks, such as the Internet 110, to facilitate communications between and the WTRUs 102a, 102b, 102c and IP-enabled devices.

[0060] As noted above, the core network 106 may also be connected to the networks 112, which may include other wired or wireless networks that are owned and/or operated by other service providers.

[0061] FIG. 1D is a system diagram of the RAN 104 and the core network 107 according to an example. As noted above, the RAN 104 may employ an E-UTRA radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 104 may also be in communication with the core network 107.

[0062] The RAN 104 may include eNode-Bs 160a, 160b, 160c, though it will be appreciated that the RAN 104 may include any number of eNode-Bs while remaining consistent with an example. 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 some examples, 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.

[0063] Each of the eNode-Bs 160a, 160b, 160c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the uplink (UL) and/or downlink (DL), and the like. As shown in FIG. 1D, the eNode-Bs 160a, 160b, 160c may communicate with one another over an X2 interface.

[0064] The core network 107 shown in FIG. 1D may include a mobility management gateway (MME) 162, a serving gateway 164, and a packet data network (PDN) gateway 166. While each of the foregoing elements are depicted as part of the core network 107, it will be appreciated that any one of these elements may be owned and/or operated by an entity other than the core network operator.

[0065] The MME 162 may be connected to each of the eNode-Bs 160a, 160b, 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 also provide a control plane function for switching between the RAN 104 and other RANs (not shown) that employ other radio technologies, such as GSM or WCDMA.

[0066] The serving gateway 164 may be connected to each of the eNode-Bs 160a, 160b, 160c in the RAN 104 via the S1 interface. The serving gateway 164 may generally route and forward user data packets to/from the WTRUs 102a, 102b, 102c. The serving gateway 164 may also perform other functions, such as anchoring user planes during inter-eNode B handovers, triggering paging when downlink data is available for the WTRUs 102a, 102b, 102c, managing and storing contexts of the WTRUs 102a, 102b, 102c, and the like.

[0067] The serving gateway 164 may also be connected to the PDN gateway 166, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices.

[0068] The core network 107 may facilitate communications with other networks. For example, the core network 107 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 core network 107 may include, or may communicate with, an IP gateway (*e.g.*, an IP multimedia subsystem (IMS) server) that serves as an interface between the core network 107 and the PSTN 108. In addition, the core network 107 may provide the WTRUs 102a, 102b, 102c with access to the networks 112, which may include other wired or wireless networks that are owned and/or operated by other service providers.

[0069] FIG. 1E is a system diagram of the RAN 105 and the core network 109 according to an example. The RAN 105 may be an access service network (ASN) that employs IEEE 802.16 radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 117. As will be further discussed below, the communication links between the different functional entities of the WTRUs 102a, 102b, 102c, the RAN 105, and the core network 109 may be defined as reference points.

[0070] As shown in FIG. 1E, the RAN 105 may include base stations 180a, 180b, 180c, and an ASN gateway 182, though it will be appreciated that the RAN 105 may include any number of base stations and ASN gateways while remaining consistent with an example. The base stations 180a, 180b, 180c may each be associated with a particular cell (not shown) in the RAN 105 and may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 117. In some examples, the base stations 180a, 180b, 180c may implement MIMO technology. Thus, the base station 180a, for example, may use multiple antennas to transmit wireless signals to, and receive wireless signals from, the WTRU 102a. The base stations 180a, 180b, 180c may also provide mobility management functions, such

as handoff triggering, tunnel establishment, radio resource management, traffic classification, quality of service (QoS) policy enforcement, and the like. The ASN gateway 182 may serve as a traffic aggregation point and may be responsible for paging, caching of subscriber profiles, routing to the core network 109, and the like.

[0071] The air interface 117 between the WTRUs 102a, 102b, 102c and the RAN 105 may be defined as an R1 reference point that implements the IEEE 802.16 specification. In addition, each of the WTRUs 102a, 102b, 102c may establish a logical interface (not shown) with the core network 109. The logical interface between the WTRUs 102a, 102b, 102c and the core network 109 may be defined as an R2 reference point, which may be used for authentication, authorization, IP host configuration management, and/or mobility management.

[0072] The communication link between each of the base stations 180a, 180b, 180c may be defined as an R8 reference point that includes protocols for facilitating WTRU handovers and the transfer of data between base stations. The communication link between the base stations 180a, 180b, 180c and the ASN gateway 182 may be defined as an R6 reference point. The R6 reference point may include protocols for facilitating mobility management based on mobility events associated with each of the WTRUs 102a, 102b, 102c.

[0073] As shown in FIG. 1E, the RAN 105 may be connected to the core network 109. The communication link between the RAN 105 and the core network 109 may be defined as an R3 reference point that includes protocols for facilitating data transfer and mobility management capabilities, for example. The core network 109 may include a mobile IP home agent (MIP-HA) 184, an authentication, authorization, accounting (AAA) server 186, and a gateway 188. While each of the foregoing elements are depicted as part of the core network 109, it will be appreciated that any one of these elements may be owned and/or operated by an entity other than the core network operator.

[0074] The MIP-HA may be responsible for IP address management, and may enable the WTRUs 102a, 102b, 102c to roam between different ASNs and/or different core networks. The MIP-HA 184 may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices. The AAA server 186 may be responsible for user authentication and for supporting user services. The gateway 188 may facilitate interworking with other networks. For example, the gateway 188 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. In addition, the gateway 188 may provide the WTRUs 102a, 102b, 102c with access to the

networks 112, which may include other wired or wireless networks that are owned and/or operated by other service providers.

[0075] Although not shown in FIG. 1E, RAN 105 may be connected to other ASNs and the core network 109 may be connected to other core networks. The communication link between the RAN 105 the other ASNs may be defined as an R4 reference point, which may include protocols for coordinating the mobility of the WTRUs 102a, 102b, 102c between the RAN 105 and the other ASNs. The communication link between the core network 109 and the other core networks may be defined as an R5 reference, which may include protocols for facilitating interworking between home core networks and visited core networks.

[0076] Multiple antenna techniques, such as Multiple Input Multiple Output (MIMO) transmission, Single Input Multiple Output (SIMO), and Multiple Input Single Output (MISO) techniques, may be used in telecommunications systems (*e.g.*, sub-6 GHz transmissions). Different MIMO techniques may deliver different benefits, such as diversity gain, multiplexing gain, beamforming, array gain, *etc.* In a system where one or more user terminals (UTs) communicate with a central node, use of multi-user MIMO (MU-MIMO) may increase system throughput, for example, by facilitating transmission of multiple data streams to different UTs (*e.g.*, at a same time) on a same and/or an overlapping set of resources in a time domain and/or a frequency domain. Use of single-user MIMO (SU-MIMO) may facilitate transmission of multiple data streams by a central node to a same UT.

[0077] Multiple antenna transmission at millimeter wave frequencies may differ from sub-6 GHz multiple antenna techniques due to different propagation characteristics at millimeter wave frequencies as compared to propagation characteristics at sub-6 GHz frequencies. Multiple antenna transmission at millimeter wave frequencies may also, or instead, differ from sub-6 GHz multiple antenna techniques due to a possibility of a base station (*e.g.*, a base transceiver station (BTS) or a gNB) and/or a WTRU having a limited number of radio frequency (RF) chains, for example, as compared to RF chains associated with antenna elements. Precoding at millimeter wave frequencies may be digital, analog, and/or a hybrid of digital and/or analog.

[0078] Digital precoding may be precise. Digital precoding may be combined with equalization. Digital precoding may enable single user (SU), multi-user (MU), and/or multi-cell precoding. Digital precoding may be similar to precoding that may be used in systems supporting sub-6 GHz transmissions, such as IEEE 802.11n systems, 3GPP LTE systems, and other systems that may be more advanced than IEEE 802.11n systems and 3GPP LTE systems. In millimeter wave frequencies, a presence of a limited number of RF chains, for example, as

compared to RF chains associated with antenna elements, and/or the sparse nature of a channel may increase the complexity of using digital beamforming.

[0079] Analog beamforming may overcome limitations associated with a limited number of RF chains available in millimeter wave frequencies by using one or more analog phase shifters on an antenna element, for example on each antenna element. One or more analog phase shifters may be used in an IEEE 802.11ad system, for example, during a sector level sweep procedure (*e.g.*, that may identify a “best” sector), during a beam refinement procedure (*e.g.*, that may refine a sector to an antenna beam), and/or during a beam tracking procedure (*e.g.*, that may adjust one or more sub-beams over time to account for a change in a channel).

[0080] In an example, analog beamforming may be used in an IEEE 802.15.3 system. A binary search beam training algorithm that may use a layered multi-resolution beamforming codebook may be used. Analog beamforming may be limited to single stream transmission.

[0081] In hybrid beamforming examples, a precoder may be divided between an analog domain and a digital domain. Each such domain may have associated precoding and/or combining matrices that may each have different structural constraints, such as a constant modulus constraint for combining matrices in an analog domain. Example hybrid beamforming designs may represent a compromise between hardware complexity and system performance. Hybrid beamforming may achieve digital precoding performance, for example, due to a sparse nature of a channel and/or due to support for multi-user and/or multi-stream multiplexing. Hybrid beamforming may be limited by a number of RF chains. A limited number of RF chains may not be problematic in millimeter wave systems as millimeter wave channels may be sparse in an angular domain.

[0082] Systems that use higher band frequencies may be designed to account for propagation characteristics of such higher band frequencies. As frequencies increase, a channel may experience higher path losses and/or more abrupt changes in a mean signal level, for example, due to walls and/or objects. Successful transmission through objects may be reduced, while reflections may be amplified.

[0083] Beamforming (*e.g.*, analog, digital, hybrid) may help overcome path loss and/or penetration loss for some or all channels (*e.g.*, not only data channels). A network design may be a beam-centric design (*e.g.*, as opposed to a cell-based design). In a beam-centric design, coverage may be provided by beams (*e.g.*, as opposed to cells). In a beam-centric design, one or more channels and/or signals may be beamformed. To ensure a unified network design over some or all frequencies, a beam-centric design may be used in lower frequencies, where, for example, a beam may be as wide as a sector.

[0084] In a beam-centric network, one or more WTRUs that may not be connected to a network may associate with one or more beams. Signaling may be used to facilitate one or more of synchronization, beam acquisition, beam identification, and/or acquisition of network information to facilitate an association of such one or more WTRUs with one or more beams. Such one or more beams may be self-contained, may be standalone beams, and/or may be aggregated beams.

[0085] Self-contained transmissions from different beams may be separated. Such transmissions may be from different physical base stations. In a beam-centric network, one or more WTRUs may each be associated with multiple beams. Such one or more WTRUs may receive simultaneous transmissions from two or more independent beams (*e.g.*, where such independent beams may each be from one or more base stations). Example methods and systems may facilitate a separation of information received from each of such multiple independent beams at a WTRU.

[0086] FIG. 2 illustrates example scenario 200 where beam-centric communications are used. For exemplary purposes, beam-centric communications are super-imposed on a cell-centric system. Cells 211, 212, 213 may represent cells (shown in shaded hexagons) that may be implemented in a cell-centric system. Each of base stations 221, 222, 223 may be transmitting four beams (shown in short dashes). Centrally located base station 231 may be transmitting twelve beams (shown in long dashes).

[0087] A beam-centric architecture may be implemented at a communications system. In such a system, a WTRU may be associated with a set of beams. Each beam in such a set may be formed at a same base station or a different base station. In an example system, a WTRU may connect to a base station that is geographically farther away than another base station. For example, such a WTRU may connect to a geographically farther away base station if a beam from the geographically farther away base station may be stronger than the beam from a geographically closer base station.

[0088] FIG. 3 illustrates example scenario 300 where WTRU 310 receives control beam 320 from base station 325 and control beam 330 from base station 335. Base station 335 may be geographically closer to WTRU 310 than base station 325. Control beam 320 may be stronger than control beam 330, despite base station 335 being geographically closer to WTRU 310 than base station 325. WTRU 310 may connect to a base station having a stronger signal regardless of a geographical distance from associated base stations. For example, WTRU 310 may connect to base station 325 because beam 320 may be stronger than beam 330, even though base station 335 may be geographically closer to WTRU 310 than base station 325.

[0089] Channels and/or signals may be beamformed. Beams used for such channels and/or signals may be self-sufficient beams, self-contained beams, and/or aggregated beams. Self-sufficient and/or self-contained beams may include a single beam with one or more beamformed synchronization channels, beamformed broadcast channels, beamformed downlink/uplink data channels, and/or beamformed downlink/uplink control channels.

[0090] Multiple aggregated beams may transmit a subset of available channels. For example, multiple aggregated beams may be transmitted by one or more base stations. Aggregated channels may be separated by direction, beamwidth, frequency, and/or power. Aggregated channels may also, or instead, be separated by channel type and/or a type of signal that each aggregated channel may be permitted to carry.

[0091] FIG. 4 illustrates example scenario 400 where aggregated beams may be separated by beamwidth. Beam 430 may be a control beam that may be transmitted by base station 425. Data beam 440 may also be transmitted by base station 425. WTRU 410 may receive one or both of beams 430 and 440. Control beam 430 may be transmitted using a different beamwidth than a beamwidth used to transmit data beam 440.

[0092] FIG. 5 illustrates example scenario 500 where aggregated beams may be separated by frequency. Beam 530 may be a control beam that may be transmitted by base station 525. Data beam 540 may also be transmitted by base station 525. WTRU 510 may receive one or both of beams 530 and 540. Control beam 530 may be transmitted using a first frequency that may be different than a frequency used to transmit data beam 540.

[0093] FIG. 6 illustrates example scenario 600 where a control beam may be transmitted by a base station that may be different from a base station that may transmit a data beam. Beam 630 may be a data beam that may be transmitted by base station 635. Beam 620 may be a control beam that may be transmitted by base station 625. WTRU 610 may receive beams 620 and 630 from different base stations, *e.g.*, base station 625 and base station 635.

[0094] A base station may transmit one or more primary beams that may include one or more beamformed synchronization channels, one or more beamformed broadcast channels, and/or one or more beamformed uplink/downlink control channels. A base station may also, or instead, transmit one or more secondary beams that may include one or more beamformed synchronization channels and/or one or more beamformed uplink/downlink data channels.

[0095] A primary beam may be transmitted using a larger beamwidth than a beamwidth used for one or more secondary beams. Using a larger beamwidth for a primary beam than that used for one or more secondary beams may facilitate a greater number of WTRUs decoding information and may prevent repetition

[0096] Transmitting one or more aggregated secondary beams using a beamwidth less than that used to transmit a primary beam may increase a link budget and/or may facilitate direct, targeted information transfer between a base station and a WTRU. A beam may be determined based on one or more network-specific parameters and/or one or more WTRU-specific parameters. In an example, a larger beamwidth beam may be determined based on one or more network-specific parameters while a smaller beamwidth beam may be determined based on one or more WTRU-specific parameters.

[0097] A primary beam may be transmitted at a lower frequency than one or more associated secondary beams, for example, in an effort to reduce an effect of propagation loss and/or to ensure that less beamforming may be used to close a link budget. A beamformer with lower gain (*e.g.*, a wider beamwidth beamformer) may be used, for example, due to an operation at a lower frequency and/or to satisfy a link budget for transmission. One or more aggregated secondary beam may be transmitted at a higher frequency relative to a primary beam, for example, where more bandwidth and/or less interference is present.

[0098] A transmission may be beam-based. An aggregated beam may be located (*e.g.*, physically) at another base station. A backhaul between multiple base stations may or may not be used. Use of a backhaul may depend, for example, on a specific transmission scheme that may be used.

[0099] A WTRU may be associated with and/or connected to multiple beams, in an example, simultaneously. A beam associated with a WTRU may be a beam with which the WTRU may be synchronized and/or a beam that the WTRU may be monitoring. A connected beam may be a beam that a WTRU may be able to decode. A connected beam may be a beam with which a WTRU may be synchronized and/or a beam having a broadcast channel that a WTRU may have decoded. A WTRU may be able to send and/or receive data on a connected beam. Interaction of beams at WTRUs (*e.g.*, WTRUs located at boundaries) may use more management resources than resources that may be used for the interaction of beams at cell-boundaries. A WTRU and/or a base station may determine a beam handover (*e.g.*, in a mobility scenario) and/or may determine whether to use multi-beam and/or multi-stream transmission.

[0100] A WTRU may seamlessly handover between beams in an environment that may be mobile and/or changing, for example, by allowing for multiple associated beams. Such a WTRU may handover from one standalone beam to another standalone beam. Such a WTRU may aggregate multiple beams, for example, where each of such aggregated beams may have a relatively large beamwidth and/or a relatively low frequency beam that may serve as an anchor beam. Such an anchor beam may be a beam to which one or more WTRUs may be connected, in

some examples, may be always connected. For example, one or more WTRUs may be connected to a base station via an anchor beam. A WTRU may use one or more small beamwidth beams and/or one or more high frequency beams to provide data transmission (*e.g.*, high throughput data transmission) and/or as a mobility layer (*e.g.*, to facilitate high throughput connectivity as a WTRU may move within a system).

[0101] A WTRU may acquire, determine, and/or store a list of candidate beams (and/or indications thereof) that the WTRU may use for handover. Such a WTRU may monitor a strength of each candidate beam, in some examples, continuously. Such a WTRU may use such strength information in various ways. For example, such a WTRU may switch beams (*e.g.*, autonomously) based on its own determination. Alternatively, or in addition, such a WTRU may send a list of candidate beams and/or information associated with such candidate beams to an anchor beam (*e.g.*, to a base station) that may, for example, provide such a list and/or information to one or more anchor beam engineers. Such information may be used to determine whether to switch beams, and, if a switch is determined, to determine a beam to which to switch.

[0102] A network (*e.g.*, a base station) may switch beams, for example, based on a list of candidate beams and/or candidate beam information (*e.g.*, candidate beam strength information). For example, an anchor beam in a beam-centric network may serve a role of a base station operating in a beam-centric network. A handover may be a soft handover or a hard handover. In a hard handover, a WTRU may drop a beam as it picks up another beam. In a soft handover, a WTRU may be connected to multiple beams at a same time and switch between beams, for example, without dropping a beam, and may reduce the probability of a dropped call.

[0103] A WTRU or a base station may determine to use multi-beam and/or multi-stream transmission. A beam-centric network may facilitate multiple stream transmission to and/or from multiple beams. For example, beams may be standalone and/or self-contained and a WTRU may have each of such beams scheduled independently by a base station or jointly by multiple base stations. Beams may be aggregated. A beam, such as one of a set of aggregated beams, may serve as a control beam. Such a control beam may indicate resources on other beams that may be available for use by a WTRU (*e.g.*, for uplink/downlink transmission).

[0104] A WTRU may measure an effective channel to (*e.g.*, in uplink) and/or from (*e.g.*, in downlink) to, for example, perform beam tracking for handover and/or multi-beam transmission. Sounding reference signals (SRSs) may be transmitted by a WTRU to a base station, for example in an uplink. Location, granularity, and/or periodicity of an SRS may be determined and/or set to limit overhead and/or to limit interference to other beams in one or more networks. A Beam Reference Signal (BRS) and/or Measurement Reference Signal (MRS) may

be sent in downlink from a beam to one or more WTRUs associated with the beam. For example, a BRS may be transmitted periodically to one or more WTRUs in such a beam. A BRS may be transmitted to a specific WTRU. A BRS may be identify a quality of a channel and/or may be associated with a single stream. A BRS may facilitate multi-stream and/or multi-port measurement. A BRS and/or MRS may be selected from any reference signal that may be associated with a specific beam-based channel, for example, a reference signal that may be associated with one or more of a downlink NR-PDCCH, a NR-broadcast channel, and/or a NR-PDSCH.

[0105] A beam, for example, each beam in a system, may be assigned a beam-identification (beam-ID). A beam ID may be independent of a physical array or a base station. One or more WTRUs may associate with one or more beams based on, for example, energy. A WTRU may connect to multiple beams, for example, where such beams are transmitted from different base stations.

[0106] A hybrid beam-ID/cell-ID labeling implementation may be used in an example. A beam-ID may be identified, in an example, in addition to an identification of a cell-ID of a physical array or base station. In an example, this process may be part of a phase (*e.g.*, a first phase) of a New Radio (NR) standardization process.

[0107] WTRU synchronization may use acquisition of time, frequency, and/or beam (*e.g.*, spatial direction). A beam (*e.g.*, each beam) may be assigned a beam-specific synchronization sequence and/or a set of synchronization sequences. A WTRU detecting available signals may synchronize to a signal and/or a set of signals. Such a WTRU may (*e.g.*, based on a synchronization process) acquire timing and/or frequency synchronization and/or a beam-ID of a beam that may be sending the signal and/or the set of signals.

[0108] Synchronization and/or network acquisition may be performed using periodic beam synchronization and/or beam-initiated network information acquisition, for example, using a broadcast channel. Synchronization and/or network acquisition may be performed using aperiodic and/or random beam synchronization and/or beam-initiated network information acquisition. Synchronization and/or network acquisition may be performed using beam-initiated synchronization with WTRU initiated network information acquisition. Synchronization and/or network acquisition may be performed using WTRU-initiated synchronization with WTRU-initiated network information acquisition.

[0109] A base station may “sweep” through beams (*e.g.*, periodically) to enable one or more WTRUs that may not have been connected to a network to synchronize to such a network.

For example, a base station may use a synchronization sequence and/or a measuring of such a network using a BRS to facilitate a connection of such WTRUs to the network.

[0110] For synchronization, one or more WTRUs may configure their respective receive antennas to use a maximum beamwidth (*e.g.*, an omni beam pattern or a quasi-omni beam pattern). Once a beam has been identified, such one or more WTRUs may further refine a beamwidth of its receive antennas. For beam measurement, such one or more WTRUs may utilize received antenna patterns.

[0111] Where periodic beam-initiated synchronization may be in use, or where periodic BRS may be in use, one or more synchronization signals and/or BRSs may be transmitted regardless of whether there may be data to be transmitted.

[0112] FIG. 7 illustrates scenario 700 where N beams may be transmitted by each transmission point of an exemplary network. Each beam (*e.g.*, each of beams 1-N) may contain one or more beam synchronization sequences.

[0113] A periodicity and/or a frequency of one or more beam sweeps may be based on a network and/or may be based on or associated with one or more characteristics. Such characteristics may include a periodicity and/or a frequency of beam sweeps that may occur at network reserved time intervals that may be interspaced with data transmission. FIG. 8 illustrates exemplary scenario 800 where synchronization and broadcast signals may be transmitted in reserved time intervals 810 and data transmissions may be sent in time intervals 820. Such intervals may be statically determined or dynamically determined. For example, static intervals may be based on a standard and/or dynamic intervals may be based on a process or algorithm set forth in a standard. In other examples, intervals may be static and/or dynamic based on system load. Any criteria may be used to determine intervals, statically and/or dynamically, and all such criteria are contemplated as within the scope of the instant disclosure.

[0114] Beams may be grouped and/or transmitted together. FIG. 9 illustrates exemplary scenario 900 where BRS and/or synchronization signals may be transmitted in reserved time intervals 910 interspaced with data transmissions sent in intervals 920. A base station may form multiple beams simultaneously and a synchronization signal and/or a BRS (*e.g.*, BRS and/or synchronization signals in intervals 910) may be transmitted simultaneously.

[0115] Signals for one or more beams may be transmitted individually. FIG. 10 illustrates exemplary scenario 1000 where signals for each beam may be transmitted individually. As shown in FIG. 10, signals for each of beams 1, 2, 3, 4 may be transmitted at intervals 1010 with data transmissions sent in intervals 1020. In an example, any beam (*e.g.*, any of beams 1, 2, 3, 4 in FIG. 10) may be used during a data interval (*e.g.*, any of data intervals

1020 in FIG. 10). In an example, signaling may be transmitted simultaneously with data transmission. In an example (*e.g.*, such as that shown in FIG. 10), a periodicity restriction may require that data access on a beam may occur periodically.

[0116] A periodicity and frequency of one or more beam sweeps may be coordinated between multiple physical base stations, which may reduce interference due to overlapping beams. One or more beam sweeps may be sent with additional beamformed channels and/or such beam sweeps may be sent even when there are no additional beamformed channels to send. One or more beam sweeps may be sent independently on each aggregated beam. One or more beam sweeps may be sent on a single beam for all aggregated beams. A number and beamwidth of beams may be based on a standardized beam set. Alternatively, a number and beamwidth of beams may be implementation dependent.

[0117] FIG. 11 illustrates exemplary scenario 1100 having four beams. At each of intervals 1101, 1102, 1103, 1104, periodic synchronization may occur for a respective beam (*e.g.*, b1, b2, b3, b4). Data transmission may occur at any of data intervals 1120. Scenario 1100 illustrates an example of a use of individual periodic synchronization channel/BRS. In scenario 1100, data transmission latency may be reduced. In scenario 1100, channel acquisition latency may be increased. Any beam may be used during a data interval (*e.g.*, data intervals 1120).

[0118] Signaling may occur simultaneously with data transmission. A periodicity restriction may cause data access on a beam to occur periodically. FIG. 12 illustrates example scenario 1200 showing intervals 1210 that may include one or more of periodic synchronization, broadcast, and/or data transmission. A periodicity and/or a frequency of beam sweeps may be coordinated between multiple physical base stations, for example, in an effort to reduce interference due to overlapping beams. A periodicity and/or frequency of beam sweeps may be sent with additional beamformed channels. A periodicity and/or frequency of beam sweeps may be sent, for example, when there are no additional beamformed channels to send.

[0119] A periodicity and/or frequency of beam sweeps may be sent independently on each of one or more beams of a set of aggregated beams. A periodicity and/or frequency of beam sweeps may be sent on a single beam for one or more of a set of aggregated beams. A number and/or beamwidth of beams may be based on a beam set (*e.g.*, a standardized beam set). A number and/or beamwidth of beams may be implementation dependent.

[0120] A base station may send out each beam sequentially. A base station may send out one or more beams in parallel. A base station may sequentially send out groups of beams. Multiple synchronization/BRS processes may be set up simultaneously, for example, in

examples using group signal/beam transmission. Transmission of signals (*e.g.*, specialized signals) may be staggered to reduce data transmission latency.

[0121] Exemplary scenario 1300 is illustrated in FIG. 13, showing four example beams and/or four example signal processes. As shown in FIG. 13, specialized signals 1301, 1302, 1303, 1304 may be staggered, as may be data intervals 1311, 1312, 1313, 1314, in an example, as a result of the staggering of signals 1301, 1302, 1303, 1304.

[0122] A network may classify one or more beams as idle beams (*e.g.*, beams that may have no WTRUs synchronized and/or connected) or connected beams (*e.g.*, beams that may have one or more WTRUs synchronized and/or connected in such a manner that such WTRUs may be able to transmit and/or receive data). Connected beams may transmit synchronization, broadcast, and/or BRS signals with a different periodicity from a periodicity of idle beams. Additional classes of beams may be defined (*e.g.*, beams that may be directed to high mobility areas rather than low mobility areas). Additional periodicities may be defined for classes of beams. For example, high mobility beams may be signaled with low (*e.g.*, relatively lower) periodicities.

[0123] Periodic beam processes and systems may use transmission of at least one of a synchronization signal, a broadcast signal, and/or a BRS. A base station may transmit one or more synchronization signals and/or one or more BRSs in an aperiodic and/or random manner, in an example, to reduce an amount of interference and/or to improve efficiency of a network.

[0124] Transmitting one or more synchronization signals and/or BRSs in an aperiodic and/or random manner may reduce the amount of interference in the network and/or may increase the energy efficiency of a network.

[0125] A base station may transmit one or more synchronization sequences and/or BRSs, in an example, simultaneously with transmitted scheduled data and/or one or more control beams. WTRUs that may be located within a beamwidth of a data transmission may acquire and/or measure a beam.

[0126] FIG. 14 illustrates exemplary scenario 1400 demonstrating an example of aperiodic synchronization signaling. Beams 1, 2, 1 in Sweep 1, beams 2, 2, 1 in Sweep 2, and/or beams 4, 2, 4 in Sweep 3 may be transmitted with beamformed data. Beams 3, 4 in Sweep 1, beams 3, 4 in Sweep 2, and/or beams 1, 3 in Sweep 3 may be transmitted without data.

[0127] In an example, where data may not be scheduled in a beam, an unconnected WTRU (*e.g.*, that may desire to connect) may not be able to connect to a beam. In an example, beams transmitted from various different base stations may overlap and may provide an improved opportunity for such an unconnected WTRU to connect to a beam. A base station may, at certain points in time, send one or more beams that may include one or more

synchronization sequences and/or BRSs, *e.g.*, only (*e.g.*, with no data and/or control beams) to facilitate servicing of WTRUs that may be located within beamwidths of such beams.

[0128] Examples of systems and methods that may be used to schedule no-data beams include periodic scheduling, where, after a time period, beams that may not have been serviced may be transmitted. Other examples include use of a proportional fair method, where a scheduling metric may be used to determine when each beam may be sent. Other examples include determining a scheduling priority based, at least in part, on one or more beam types that may be associated with each of multiple beams. Such beam types (*e.g.*, scheduled beams, connected but not scheduled beams, idle beams) may be considered when determining a scheduling priority.

[0129] In an example, where data may not be scheduled in a beam, an unconnected WTRU (*e.g.*, that may desire to connect) may not be able to connect to a beam. To address this situation, a base station may transmit one or more synchronization signals that may each utilize a relatively larger beamwidth beam. Where a WTRU may connect and may feed back information to such a base station, the base station may schedule smaller beamwidth beams to be directed to the WTRU.

[0130] A connected WTRU that may desire to perform a measurement on a beam may not be able to perform such a measurement on such a beam. Various methods may be used to enable synchronization, network information acquisition (*e.g.*, through a broadcast channel), and/or measurement for a WTRU that may not be scheduled in a beam, for example, where no data may be present on the beam and/or where the beam may not be randomly scheduled. Such methods include those set forth herein.

[0131] FIG. 15 illustrates exemplary scenario 1500 representing example synchronization and/or network acquisition signaling, for example, with scheduled data 1501 on connected beams. Unscheduled beams may use intervals 1502 and may be periodically transmitted (*e.g.*, with a size of beams being either the same or changeable).

[0132] FIG. 16 illustrates exemplary scenario 1600 representing an exemplary use of BRS with scheduled data on connected beams at intervals 1601. Unscheduled beams may be periodically transmitted at intervals 1602.

[0133] FIG. 17 illustrates exemplary scenario 1700 representing an exemplary use of random beamforming with data, broadcast, and/or sync signals, for example, at intervals 1701. Intervals 1702 may be used for random broadcasts and/or sync signaling.

[0134] FIG. 18 illustrates exemplary scenario 1800 where random beamforming may be used with BRS for measurement. Intervals 1801 may be used for random data and/or may be

used for one or more BRSs that, in an example, may be transmitted simultaneously with data transmitted in intervals 1801. Intervals 1802 may be used for BRS transmissions.

[0135] When one or more beams may be scheduled and/or transmitted, methods for synchronization, network information acquisition, data transmission and/or channel measurement may be performed. In an example, such methods may be similar to a periodic method as set forth herein. Alternatively, or in addition, a base station may schedule one or more beams randomly or pseudo-randomly within a network and may transmit one or more synchronization signals, broadcast signals, and/or BRS signals.

[0136] A network may initially use a periodic method (*e.g.*, as set forth herein) for scheduling beams. Such a network may subsequently use an aperiodic method and/or a random method for scheduling beams, for example, when such a network becomes more populated.

[0137] A method using beam-initiated synchronization with WTRU-initiated broadcast may be implemented in an example. In an aperiodic example, broadcast channel information may be transmitted whether such information desired or not. For example, broadcast channel information may be transmitted regardless of whether there are WTRUs that may use such information for updates, associations, and/or data on a specific beam.

[0138] A base station may transmit synchronization information and/or broadcast information, in an example, only to one or more connected beams. In an example, a BTA may transmit synchronization information and/or broadcast information to one or more connected beams that may be used to transmit a beamformed channel (*e.g.*, data, control, *etc.*) and/or that may be identified as having one or more WTRUs connected to one or more such beams.

[0139] Idle beams may be used to transmit one or more synchronization signals. In an example, idle beams may be used to transmit one or more synchronization signals.

[0140] One or more connected beams may be used to send broadcast information (*e.g.*, only if there may be a need to communicate a system information change to one or more WTRUs). If a WTRU synchronizes to a beam that may have no broadcast information and/or may need an update of a network's system information, such a WTRU may explicitly request (*e.g.*, from a base station) broadcast information associated with the beam.

[0141] An uplink random access channel may be monitored by a base station. Such a channel may be referred to as a beam basis random access channel (BBRACH). A WTRU may have little or no information about a system that may include a BBRACH. Such a WTRU may select a BBRACH based on energy detection and/or a non-coherent detection of a signal derived from a base station ID.

[0142] A BBRACH may have a fixed bandwidth that, in an example, may correspond to a bandwidth associated with a beam primary synchronization sequence (BPSS) and/or a bandwidth associated with a beam secondary synchronization sequence (BSSS).

[0143] A BBRACH may function as a signaling channel and/or a contention channel that may provide a signal to a base station that may cause such a base station to transmit broadcast information on a beam (*e.g.*, a specific beam). If such a base station receives a relatively significant amount of energy (*e.g.*, based on its ID) and/or a positive detection on such a BBRACH, the base station may schedule a beam and/or may transmit broadcast information on the BBRACH.

[0144] A base station may transmit one or more synchronization signals on a beam (*e.g.*, only on a beam) that may have no data and no connected WTRUs that may enable a WTRU to synchronize to an associated channel. A WTRU may synchronize with a primary beam synchronization signal and a secondary beam synchronization signal.

[0145] Upon determining that there may be no broadcast information, a WTRU may send a signal on a broadcast request random access channel. In an example periodic scenario, such a signal may be located anywhere in a beam when such a beam returns. In an example aperiodic scenario, such a signal may be after a PSSS and/or a secondary synchronization sequence (SSS) and before an associated beam ends. In an example, if a base station receives a relatively significant amount of energy (*e.g.*, based on its ID) and/or a positive detection on such a channel, the base station may schedule the beam and may send broadcast information on the channel. Otherwise, such a base station may move to a next beam in a sequence of beams.

[0146] An uplink random access channel may be associated with a fixed set of parameters. Such parameters may include bandwidth, for example, a bandwidth of a BPSS and/or a BSSS. An uplink random access channel may function as a signaling channel and/or a contention channel that may provide a signal to a base station that may cause such a base station to, for example, transmit broadcast information on a specific beam.

[0147] A beam may determine that it may send additional information (*e.g.*, rather than identifying a specific WTRU). A base station may schedule a beam and/or may send broadcast information on a channel, for example, if such a base station receives a relatively significant amount of energy (*e.g.*, based on the beam's ID) and/or a positive detection on the channel. A WTRU may send a signal that may be derived from a beam's ID. If a beam receives a signal that may not be based on its ID, the beam may ignore the signal. Such a signal may not have been meant for the beam. A base station may schedule a beam and/or send broadcast information on a channel if such a beam receives energy (*e.g.*, whether or not based on the beam's ID).

[0148] A base station may send synchronization and/or broadcast information and/or BRS (*e.g.*, only) to connected beams. Such connected beams may include one or more beams that may be used to send a beamformed channel. Such a channel may, for example, include data, control information, *etc.* Such connected beams may include one or more beams that may be identified as having one or more WTRUs connected to the respective beam.

[0149] No information may be sent on idle beams. Idle beams may be cycled through. For example, in a four-beam scenario, beam 1 and/or beam 2 may be connected while beam 3 and/or beam 4 may not be connected. A base station may send synchronization information and/or broadcast information and/or BRS (*e.g.*, only) via beam 1 and/or beam 2. The base station may switch to beam 3 and/or beam 4, in an example, without sending synchronization information and/or broadcast information and/or BRS (*e.g.*, only) via beam 3 or beam 4. Beam 3 and/or beam 4 may be in a listen mode in which beam 3 and/or beam 4 listen (*e.g.*, the base station listens via beam 3 and/or beam 4) to determine whether a (*e.g.*, any) WTRU sends information. If beam 3 and/or beam 4 receives energy, beam 3 and/or beam 4 may be activated and/or may start being used to send information/sync/BRS (*e.g.*, by one or more base station).

[0150] In an example, a primary beam synchronization signal (PBSS) (*e.g.*, only a PBSS) may be sent on one or more idle beams. Beams with data (*e.g.*, only beams with data) may have synchronization information and/or broadcast information and/or BRS. For idle beams, a WTRU may request that a signal (*e.g.*, a secondary beam synchronization signal (SBSS), a broadcast signal, and/or a measurement signal) be sent in a BBRACH. An identification of a BBRACH signal may result in sending one or more (*e.g.*, three) signal types, such as those described herein.

[0151] A BBRACH signal may distinguish between multiple options, such as sending a SBSS signal (*e.g.*, only), sending a PBSS/SBSS/broadcast signal, and/or sending a BRS. Such a BBRACH signal may distinguish between signal types, such as the signal types set forth herein. A sequence may request a desired beam ID. A base station may respond with a synchronization sequence on a beam (*e.g.*, on an appropriate beam).

[0152] An association with a beam may be based on detection of a primary and/or principal beam synchronization sequence transmitted by a beam. Such a synchronization sequence may be used for timing detection and/or to acquire an initial physical layer beam identifier.

[0153] A beam may also, or instead, send out a secondary beam synchronization sequence and/or a non-principal beam synchronization sequence. A secondary and/or non-principal beam synchronization sequence may be used for radio frame identification, full beam

index identification, beam sweep sequence identification (*e.g.*, identification of where in a beam sweep period a beam may be located), cyclic prefix length detection, and/or duplexing type identification.

[0154] A location of a secondary beam synchronization sequence relative to a primary beam synchronization sequence may be used to (*e.g.*, blindly) indicate a number and/or periodicity of beams in a sweep and/or an index of a beam (*e.g.*, a current beam) in a periodic beam sweep. A distance between a secondary beam synchronization sequence and/or a primary beam synchronization sequence may be less than a coherence time, for example, to allow for coherent detection of a secondary beam synchronization signal (SBSS).

[0155] A WTRU may identify a broadcast channel mode that a beam is in such that the WTRU may waste no or relatively little power attempting to decode a broadcast channel that may not be available. A WTRU may identify a broadcast channel mode that a beam is in such that the WTRU may know to send a signal to a BBRACH to request a broadcast channel from the beam.

[0156] Upon acquisition of synchronization, a broadcast channel may be used to send information (*e.g.*, higher priority information) to a WTRU. An example of higher priority information may include a frame number (*e.g.*, if not acquired blindly). A beam (*e.g.*, each beam) may send (*e.g.*, may be used by a base station to send) a broadcast channel with relevant information to a WTRU (*e.g.*, a separate broadcast channel with minimum relevant information to a WTRU).

[0157] A periodicity of a broadcast channel transmission may differ from that of a synchronization sequence. FIG. 19 illustrates scenario 1900 that demonstrates an example of periodic synchronization with broadcast network information at different periodicities. As shown in FIG. 19, sweeps 1-6 may each include N beams. With reference to the legend of FIG. 19, sweep 1 and sweep 4 of scenario 1900 may include beams that may contain synchronization information and broadcast information. Sweeps 2, 3, 5, and 6 may include beams that may contain, for example, only synchronization information (*e.g.*, without broadcast information).

[0158] Information that may be sent in a broadcast channel may include one or more of a frame number (*e.g.*, if not acquired blindly), a number of antennas, a transmission bandwidth, one or more allowed beam aggregation types (*e.g.*, beamwidth-based, frequency-based, *etc.*), and/or a hybrid automatic repeat request (HARQ) channel type (*e.g.*, dedicated, immediate, *etc.*).

[0159] A WTRU may be connected to a primary control beam, for example, upon acquisition of information in a broadcast channel. Beamformed control channels and/or data channels may be transmitted on a primary control beam to/from a WTRU. Beamformed control

channels may be transmitted to/from a WTRU. Data channels may be transmitted to/from a WTRU on an aggregated beam in a same or different direction/beamwidth and/or on a same or different (*e.g.*, higher) frequency.

[0160] Information from a primary beam may be used to facilitate base station and/or WTRU acquisition of one or more secondary beams, for example, in implementations using one or more aggregated beams. For example, a direction of a primary beam at a first frequency may be used to assist in synchronization of an aggregated beam at a second, different frequency. A direction of a primary beam having a first beamwidth may be used by a base station to identify beams to send, for example, during a synchronization process for one or more secondary beams and/or for further refining of a beamwidth during transmission.

[0161] A network may facilitate receive beamforming training at a WTRU, for example, to enable the WTRU to identify receive beams (*e.g.*, the “best” receive beams) for a specific network beam. A network may facilitate receive beamforming training at a WTRU, for example, to use beam repetition for WTRU receive beamforming.

[0162] To facilitate WTRU receive beamforming, a WTRU may sweep its receive beams, for example, based on a periodicity of a transmit beam that the WTRU may have identified as a good beam (*e.g.*, a “best” beam). The WTRU may select the good beam (*e.g.*, the “best” beam) from among the receive beams, for example, once the transmit beam may be identified. This process may be transparent to a base station.

[0163] A WTRU may feed back information to a base station and/or request that the base station switch to a training mode in which the WTRU repeatedly transmits information on a requested beam for an amount of time, *e.g.*, to facilitate a receive beamforming process. Such a WTRU may estimate one or more receive beams to determine a selected receive beam (*e.g.*, a “best” receive beam) for use as a network beam. Such a WTRU may request a selected receive beam (*e.g.*, a “best” receive beam) on a random-access channel. Alternatively, or in addition, the WTRU may send a beam refinement request (*e.g.*, that may include a desired number of receive beams to train) in a scheduling request.

[0164] Feedback provided by a WTRU may be analog or digital. A WTRU may feed back an index indicating a beam location in a periodic beam sweep, for example, where the feedback may be analog. A WTRU may feed back a beam index that may have been estimated during a synchronization process. A WTRU may feed back a beam identifier that may be based on a pre-defined code book.

[0165] Beamformed uplink/downlink control and/or uplink/downlink data transmission may commence once a WTRU has connected to a beam. Multi-layer transmission may be used in systems that may support beamformed transmissions.

[0166] FIG. 20 illustrates exemplary method 2000 that may be used in an example to perform periodic beam synchronization and/or beam-initiated network information acquisition. Method 2000 may include functions that may be similar to those used in, *e.g.*, examples described in reference to FIG. 8. All functions described with regard to method 2000, and any other method described herein, are optional, and implementations may be used that use a subset and/or any combination of any functions described in regard to any method described herein. All such implementations are contemplated as within the scope of this disclosure.

[0167] At block 2005, a periodic beam sweep may be performed, for example, by a base station (*e.g.*, a gNB) at a network reserved time interval that may be interspaced with intervals that may be used for data transmissions. Either, or both, such time intervals may be fixed according to, *e.g.*, a standard. Either, or both, such time intervals may be dynamic and, in some examples, may be determined based on a system load.

[0168] At block 2010, a PBSS may be sent at or by a beam, for example, by a base station. At block 2015, an SBSS may be sent at or by such a beam, for example, by a base station. At block 2020, broadcast information may be sent at or by such a beam, for example, by a base station.

[0169] At block 2025, synchronization and/or network information acquisition may be performed, for example, by a WTRU. At block 2030, such a WTRU may send, to a beam, a random-access signal and/or a grant request to receive beam training. For example, a feedback and/or receive beamforming request may be sent. In some examples, any of the functions of block 2030 and/or 2035 may not be performed. In such examples, method 2000 may proceed to block 2040 from block 2025.

[0170] At block 2035, a beam may be repeated some number (“N”) of times to facilitate receive beam training. For example, a base station may repeat one or more beams a number of times to facilitate training of a WTRU (*e.g.*, receive beam training).

[0171] At block 2040, beam-centric scheduling and/or transmission may be performed, for example, by a base station. Method 2000 may continue by returning to block 2005.

[0172] FIG. 21 illustrates exemplary method 2100 that may be used in an example to perform aperiodic beam synchronization and/or beam-initiated network information acquisition. Method 2100 may include functions that may be similar to those used in, *e.g.*, examples described in reference to FIG. 14. All functions described with regard to method 2100, and any

other method described herein, are optional, and implementations may be used that use a subset and/or any combination of any functions described in regard to any method described herein. All such implementations are contemplated as within the scope of this disclosure.

[0173] At block 2105, data transmission at or by a first beam may be performed, for example, by a base station (*e.g.*, a gNB). At block 2110, a PBSS may be sent at or by such a first beam, for example, by a base station. At block 2115, an SBSS may be sent at or by such a first beam, for example, by a base station. At block 2120, broadcast information may be sent at or by such a first beam, for example, by a base station. As shown at 2181, such a first beam may be scheduled to transmit data.

[0174] At block 2125, data transmission at or by a second beam may be performed, for example, by a base station. At block 2130, a PBSS may be sent at or by such a second beam, for example, by a base station. At block 2135, an SBSS may be sent at or by such a second beam, for example, by a base station. At block 2140, broadcast information may be sent at or by such a second beam, for example, by a base station. As shown at 2182, such a second beam may be scheduled to transmit data.

[0175] At block 2145, synchronization and/or network information acquisition may be performed, for example, by a WTRU. At block 2170, such a WTRU may send, to a beam, a random-access signal and/or a grant request to receive beam training. For example, a feedback and/or receive beamforming request may be sent. In some examples, any of the functions of blocks 2170 and/or 2175 may not be performed. In such examples, method 2100 may proceed to block 2150 from block 2145.

[0176] At block 2175, a beam may be repeated some number (“N”) of times to facilitate receive beam training. For example, a base station may repeat one or more beams a number of times to facilitate training of a WTRU (*e.g.*, receive beam training).

[0177] At block 2150, PBSS may be sent at or by a third beam, for example, by a base station. At block 2155, an SBSS may be sent at or by such a third beam, for example, by a base station. At block 2160, broadcast information may be sent at or by such a third beam, for example, by a base station. As shown at 2183, such a third beam may have no data scheduled for transmission.

[0178] At block 2165, beam-centric scheduling and/or transmission may be performed, for example, by a base station. Note that each of the first beam, second beam, and third beam described in regard to FIG. 21 may be distinct from each of the other beams described in regard to FIG. 21.

[0179] FIG. 22 illustrates exemplary method 2200 that may be used in an example to perform periodic beam synchronization and/or WTRU-initiated network information acquisition. Method 2200 may include functions that may be similar to those described elsewhere herein. All functions described with regard to method 2200, and any other method described herein, are optional, and implementations may be used that use a subset and/or any combination of any functions described in regard to any method described herein. All such implementations are contemplated as within the scope of this disclosure.

[0180] At block 2205, a periodic beam sweep may be performed, for example, by a base station (*e.g.*, a gNB). At block 2210, a PBSS may be sent at or by a beam, for example, by a base station. At block 2215, an SBSS may be sent at or by such a beam, for example, by a base station.

[0181] At block 2220, synchronization and/or network information acquisition may be performed, for example, by a WTRU. At block 2225, such a WTRU may send a random-access signal (*e.g.*, a new and/or different random-access signal) for broadcast to, for example, a beam and/or a base station. At block 2230, a broadcast may be sent, for example, by a beam and/or a base station. At block 2235, such a WTRU may acquire a broadcast channel, for example, the broadcast channel that may be sent at block 2230. In some examples, any of the functions of blocks 2220-2235 may not be performed. In such examples, method 2200 may proceed to block 2240 or block 2250 from block 2235.

[0182] At block 2240, such a WTRU may send, to a beam, a random-access signal and/or a grant request to receive beam training. For example, a feedback and/or receive beamforming request may be sent. In some examples, any of the functions of block 2240 and/or 2245 may not be performed. In such examples, method 2200 may proceed to block 2250 from block 2215 or block 2235.

[0183] At block 2245, a beam may be repeated some number ("N") of times to facilitate receive beam training. For example, a base station may repeat one or more beams a number of times to facilitate training of a WTRU (*e.g.*, receive beam training).

[0184] At block 2250, beam-centric scheduling and/or transmission may be performed, for example, by a base station. Method 2200 may continue by returning to block 2205.

[0185] FIG. 23 illustrates exemplary method 2300 that may be used in an example to perform aperiodic beam synchronization and/or WTRU-initiated network information acquisition. Method 2300 may include functions that may be similar to those described elsewhere herein. All functions described with regard to method 2300, and any other method described herein, are optional, and implementations may be used that use a subset and/or any

combination of any functions described in regard to any method described herein. All such implementations are contemplated as within the scope of this disclosure.

[0186] At block 2305, data transmission at or by a first beam may be performed, for example, by a base station (*e.g.*, a gNB). At block 2310, a PBSS may be sent at or by such a first beam, for example, by a base station. At block 2315, an SBSS may be sent at or by such a first beam, for example, by a base station. As shown at 2381, such a first beam may be scheduled to transmit data.

[0187] At block 2320, data transmission at or by a second beam may be performed, for example, by a base station (*e.g.*, a gNB). At block 2325, a PBSS may be sent at or by such a second beam, for example, by a base station. At block 2330, an SBSS may be sent at or by such a second beam, for example, by a base station. As shown at 2382, such a second beam may be scheduled to transmit data.

[0188] At block 2335, a WTRU may synchronize to a third beam. At block 2340, such a WTRU may send a random-access signal (*e.g.*, a new and/or different random-access signal) for broadcast to, for example, a beam and/or a base station. At block 2345, a broadcast may be sent, for example, by a beam and/or a base station. At block 2350, such a WTRU may acquire a broadcast channel, for example, the broadcast channel that may be sent at block 2345. In some examples, any of the functions of blocks 2335-2350 may not be performed. In such examples, method 2300 may proceed to block 2355 or block 2365 from block 2330.

[0189] At block 2355, such a WTRU may send, to a beam, a random-access signal and/or a grant request to receive beam training. For example, a feedback and/or receive beamforming request may be sent. In some examples, any of the functions of blocks 2355 and/or 2360 may not be performed. In such examples, method 2300 may proceed to block 2365 from block 2350 or 2330.

[0190] At block 2360, a beam may be repeated some number ("N") of times to facilitate receive beam training. For example, a base station may repeat one or more beams a number of times to facilitate training of a WTRU (*e.g.*, receive beam training).

[0191] At block 2365, PBSS may be sent at or by a fourth beam, for example, by a base station. At block 2370, an SBSS may be sent at or by such a fourth beam, for example, by a base station. As shown at 2383, such a fourth beam may have no data scheduled for transmission.

[0192] At block 2375, beam-centric scheduling and/or transmission may be performed, for example, by a base station. Note that each of the first beam, second beam, third beam, and fourth beam described in regard to FIG. 23 may be distinct from each of the other beams described in regard to FIG. 23.

[0193] FIG. 24 illustrates exemplary method 2400 that may be used in an example to perform aperiodic beam synchronization and/or WTRU-initiated network information acquisition. Method 2400 may include functions that may be similar to those described elsewhere herein. All functions described with regard to method 2400, and any other method described herein, are optional, and implementations may be used that use a subset and/or any combination of any functions described in regard to any method described herein. All such implementations are contemplated as within the scope of this disclosure.

[0194] At block 2405, data transmission at or by a first beam may be performed, for example, by a base station (*e.g.*, a gNB). At block 2410, a PBSS may be sent at or by such a first beam, for example, by a base station. At block 2415, an SBSS may be sent at or by such a first beam, for example, by a base station. As shown at 2481, such a first beam may be scheduled to transmit data.

[0195] At block 2420, data transmission at or by a second beam may be performed, for example, by a base station (*e.g.*, a gNB). At block 2425, a PBSS may be sent at or by such a second beam, for example, by a base station. At 2430, an SBSS may be sent at or by such a second beam, for example, by a base station. As shown at 2482, such a second beam may be scheduled to transmit data.

[0196] At block 2435, a WTRU may synchronize to a third beam. At block 2440, such a WTRU may send a random-access signal (*e.g.*, a new and/or different random-access signal) for broadcast to, for example, a beam and/or a base station. At block 2445, a broadcast channel may be sent, for example, by a beam and/or a base station. At block 2450, such a WTRU may acquire a broadcast channel, for example, the broadcast channel that may be sent at block 2445. In some examples, any of the functions of blocks 2435-2450 may not be performed. In such examples, method 2300 may proceed to block 2455 or block 2465 from block 2430.

[0197] At block 2455, such a WTRU may send, to a beam, a random-access signal and/or a grant request to receive beam training. For example, a feedback and/or receive beamforming request may be sent. In some examples, any of the functions of blocks 2455 and/or 2460 may not be performed. In such examples, method 2400 may proceed to block 2465 from block 2430 or block 2450.

[0198] At block 2460, a beam may be repeated some number ("N") of times to facilitate receive beam training. For example, a base station may repeat one or more beams a number of times to facilitate training of a WTRU (*e.g.*, receive beam training).

[0199] At block 2465, a fourth beam may be transmitted, for example by a base station. Such a fourth beam may be in “dummy” mode. As shown at 2483, such a fourth beam may not be scheduled to transmit data.

[0200] At block 2470, a WTRU may transmit a signal on a BBRACH. At block 2475, a PBSS and/or an SBSS may be sent at or by a fourth beam, for example, by a base station. At block 2490, such a fourth beam may transmit a broadcast channel. At block 2493, a WTRU may acquire a broadcast channel, for example, the broadcast channel that may be sent at block 2490. In some examples, any of the functions of blocks 2470-2493 may not be performed. In such examples, method 2400 may proceed to block 2495 from block 2465.

[0201] At block 2495, beam-centric scheduling and/or transmission may be performed, for example, by a base station. Note that each of the first beam, second beam, third beam, and fourth beam described in regard to FIG. 24 may be distinct from each of the other beams described in regard to FIG. 24.

[0202] Multi-beam and/or multi-stream transmission may be facilitated by enabling beam separation at a WTRU in downlink transmission and/or by enabling separate transmission for beam decoding in uplink transmission. In an example, beams may be independent (*e.g.*, entirely independent) and/or self-contained. Where a backhaul and/or a centralized RAN may be used, beams may or may not be independent (*e.g.*, entirely independent) and/or self-contained.

[0203] Beam acquisition and/or synchronization processes and systems may include aspects such as a WTRU that may identify and/or synchronize to multiple beams (*e.g.*, using one or more of the sync techniques set forth herein). A WTRU may send a scheduling request associated with a first beam for receive beamforming training. This first beam may repeat and/or be repeatedly transmitted (*e.g.*, by a base station) a first number (“N”) of times to facilitate receive beam training of a WTRU. A WTRU may send a scheduling request associated with a second beam for receive beamforming training. This second beam may repeat and/or be repeatedly transmitted (*e.g.*, by a base station) a second number (*e.g.*, “N-1”) of times to facilitate receive beam training of a WTRU. The first receive beam and the second receive beam may be self-contained beams, and may be distinct (*e.g.*, different) beams.

[0204] A WTRU may create multiple independent streams, for example, where such streams may be from or associated with distinct beams. Such a WTRU may generate one or more traffic requests that may be sent to each of a first beam and a second beam. Such a WTRU may also, or instead, send feedback that may indicate an availability and/or an identity of the first beam to the second beam, and/or vice versa.

[0205] Beams (*e.g.*, a base station using beams) may schedule traffic to and/or from a WTRU, in an example independently and/or simultaneously. A transmission to a beam (*e.g.*, a single beam) may include multiple layers. A beam (*e.g.*, a base station using beams) and/or a WTRU may initiate multi-beam and/or multi-layer transmission.

[0206] FIG. 25 illustrates exemplary method 2500 that may be used in an example to perform multi-beam and/or multi-stream transmission. Method 2500 may include functions that may be similar to those described elsewhere herein. All functions described with regard to method 2500, and any other method described herein, are optional, and implementations may be used that use a subset and/or any combination of any functions described in regard to any method described herein. All such implementations are contemplated as within the scope of this disclosure.

[0207] At block 2505, a WTRU may identify synchronization and/or broadcast information associated with a first beam. At block 2510, such a WTRU may transmit a receive beam training request to the first beam (*e.g.*, a base station associated with the first beam). At block 2515, the WTRU may determine a preferred, or “best”, beam for the first beam.

[0208] At block 2520, a WTRU may identify synchronization and/or broadcast information associated with a second beam. At block 2525, such a WTRU may transmit a receive beam training request to the second beam (*e.g.*, a base station associated with the second beam). At block 2530, the WTRU may determine a preferred, or “best”, beam for the second beam.

[0209] At block 2535, the WTRU may create multiple independent streams from or at each of multiple beams. For example, the WTRU may create an independent stream at each of the first beam and the second beam.

[0210] At block 2540, the WTRU may feed back presence and/or identity information that may be associated with one or more beams. For example, the WTRU may feed back presence and/or identity information that may be associated with one or more beams other than the first and the second beam. Alternatively, or in addition, the WTRU may feed back presence and/or identity information that may be associated with the first and/or the second beam.

[0211] At block 2545, the WTRU may transmit such beams independently and/or simultaneously.

[0212] WTRU to WTRU communication (*e.g.*, device-to-device communication (D2D), such as 3GPP D2D communication) may be performed. A WTRU, *e.g.*, that may perform WTRU to WTRU communications, may perform one or more functions that may be similar to one or more functions that may be performed by a base station, *e.g.*, performed using a beam.

For example, periodic beam synchronization and/or network information acquisition may be initiated by one or more WTRUs. Aperiodic beam synchronization and/or network information acquisition may be initiated by one or more WTRUs.

[0213] Although features and elements of the present disclosure may be described in particular combinations, features and/or elements set forth in the present disclosure may be used alone without other features and/or elements described in this disclosure and/or in various combinations that may or may not include any other features and/or elements, disclosed herein or otherwise. Although the features and/or elements described herein may be contemplated in regard to New Radio (NR) and/or other examples, it is understood that the features and/or elements described herein are not restricted to such scenarios and may be applicable to other technologies and wireless systems as well.

[0214] The example processes described above may be implemented in a computer program, software, and/or firmware that may be incorporated in a computer-readable medium for execution by a computer and/or processor. Examples of computer-readable media include, but are not limited to, electronic signals (transmitted over wired and/or wireless connections) and/or computer-readable storage media. Examples of computer-readable storage media include, but are not limited to, a read-only memory (ROM), a random-access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as, but not limited to, internal hard disks and/or removable disks, magneto-optical media, and/or optical media such as CD-ROM disks, and/or digital versatile disks (DVDs). A processor in association with software may be used to implement a radio frequency transceiver for use in a WTRU, terminal, base station, gNB, RNC, and/or any host computer.

CLAIMS

What is claimed is:

1. A method of beam synchronization performed by a wireless transmit/receive unit (WTRU), the method comprising:
 - receiving a beam,
 - determining whether a signal is in the beam,
 - transmitting a request for the signal to a base station, wherein the request comprises an indication of the beam and an indication of a signal characteristic.
2. The method of claim 1, wherein determining whether the signal is in the beam comprises determining that a beam component of the beam is signaled to the WTRU.
3. The method of claim 2, wherein the beam component comprises at least one of a synchronization component, a broadcast component, or a reference component.
4. The method of claim 1, wherein determining whether the signal is in the beam comprises determining a beam component of the beam.
5. The method of claim 4, wherein the beam component comprises at least one of a synchronization component, a broadcast component, or a reference component.
6. The method of claim 1, wherein the signal characteristic is one of synchronization, broadcast, measurement reference signal (MRS), and any combination thereof.
7. The method of claim 1, wherein determining whether the signal is in the beam comprises determining a beam type of the beam.
8. The method of claim 1, wherein the base station is a next generation Node B (gNB).

9. A wireless transmit/receive unit (WTRU) comprising:
a transceiver configured to:
 receive a beam, and
 transmit a request for a signal to a base station; and
a processor configured to:
 determining whether the signal is in the beam, and
 generate the request for the signal, wherein the request comprises an indication of the beam and an indication of a signal characteristic.
10. The WTRU of claim 9, wherein the processor is configured to determine whether the signal is in the beam by determining that a beam component of the beam is signaled.
11. The WTRU of claim 10, wherein the beam component comprises at least one of a synchronization component, a broadcast component, or a reference component.
12. The WTRU of claim 9, wherein the processor is configured to determine whether the signal is in the beam by determining a beam component of the beam.
13. The WTRU of claim 12, wherein the beam component comprises at least one of a synchronization component, a broadcast component, or a reference component.
14. The WTRU of claim 9, wherein the signal characteristic is one of synchronization, broadcast, measurement reference signal (MRS), and any combination thereof.
15. The WTRU of claim 9, wherein the base station is a next generation Node B (gNB).

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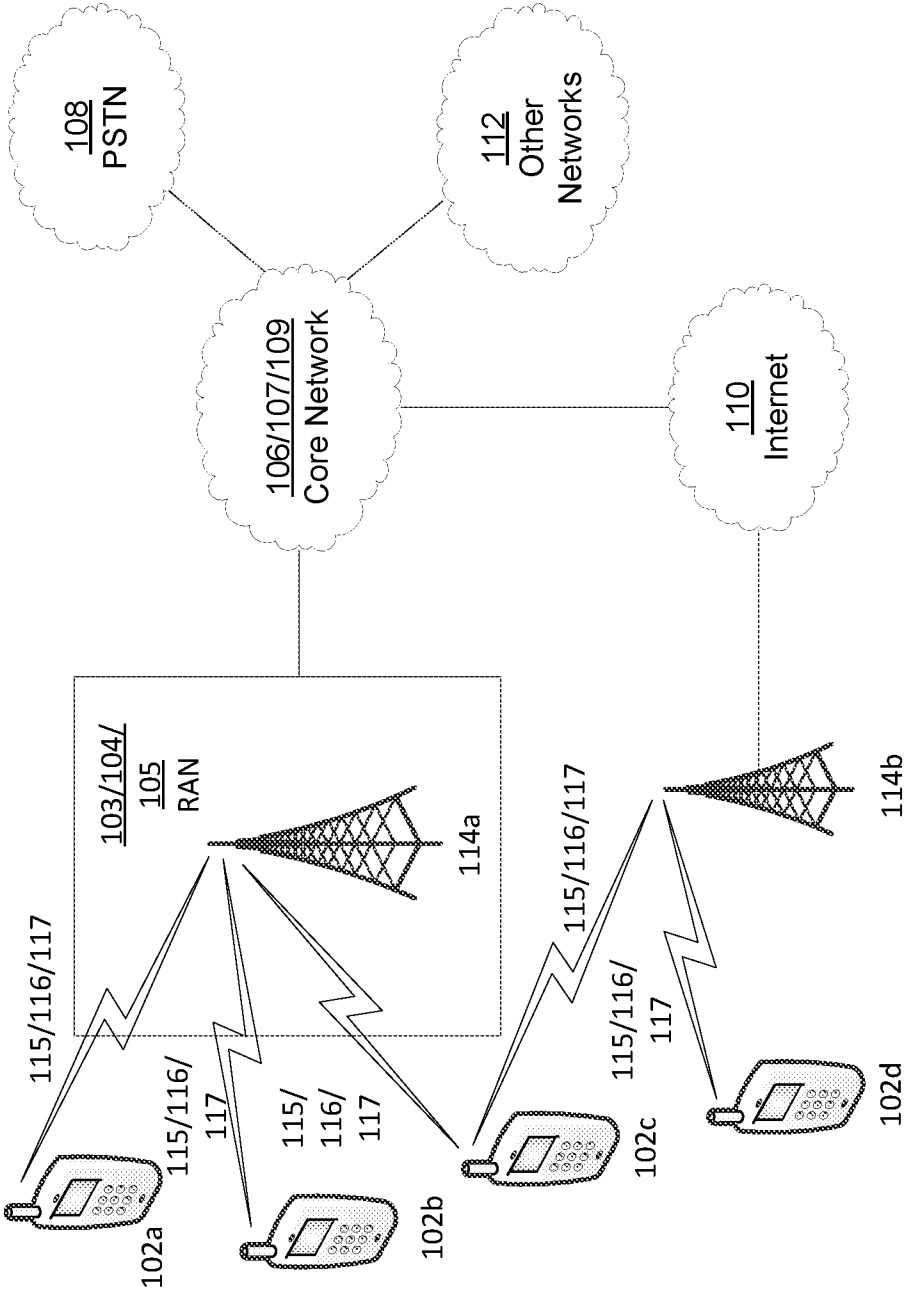
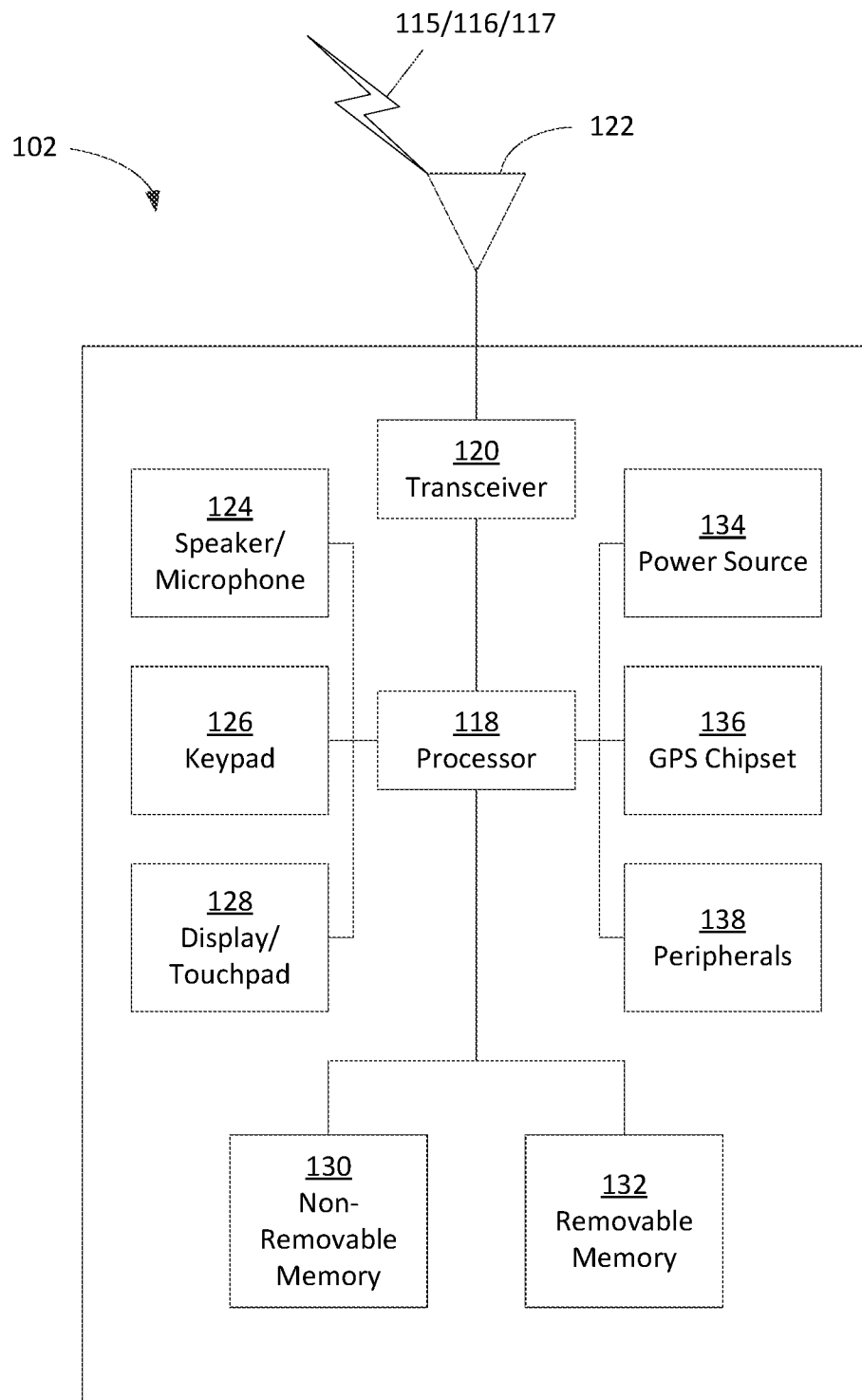


FIG. 1A

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**FIG. 1B**

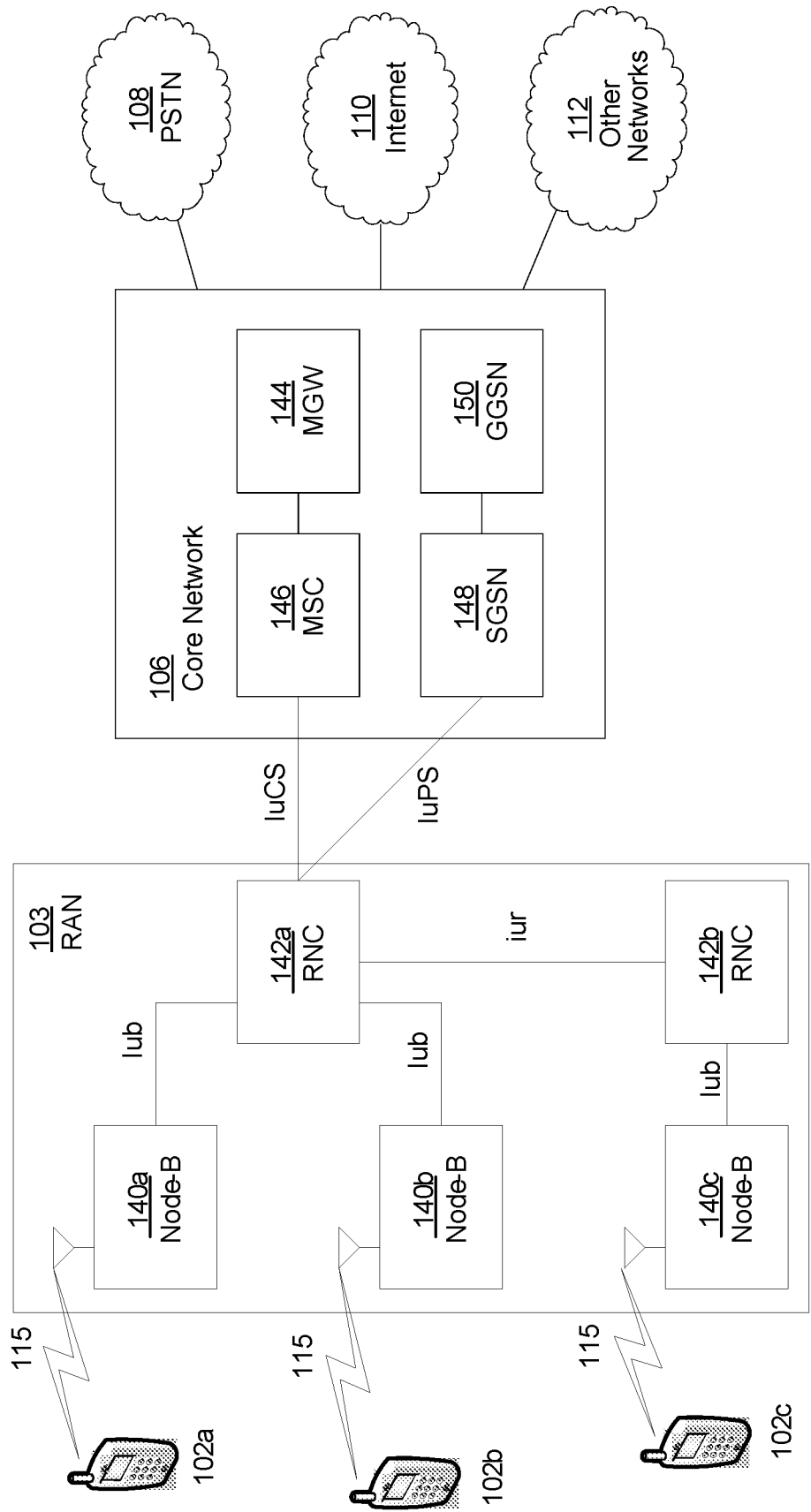


FIG. 1C

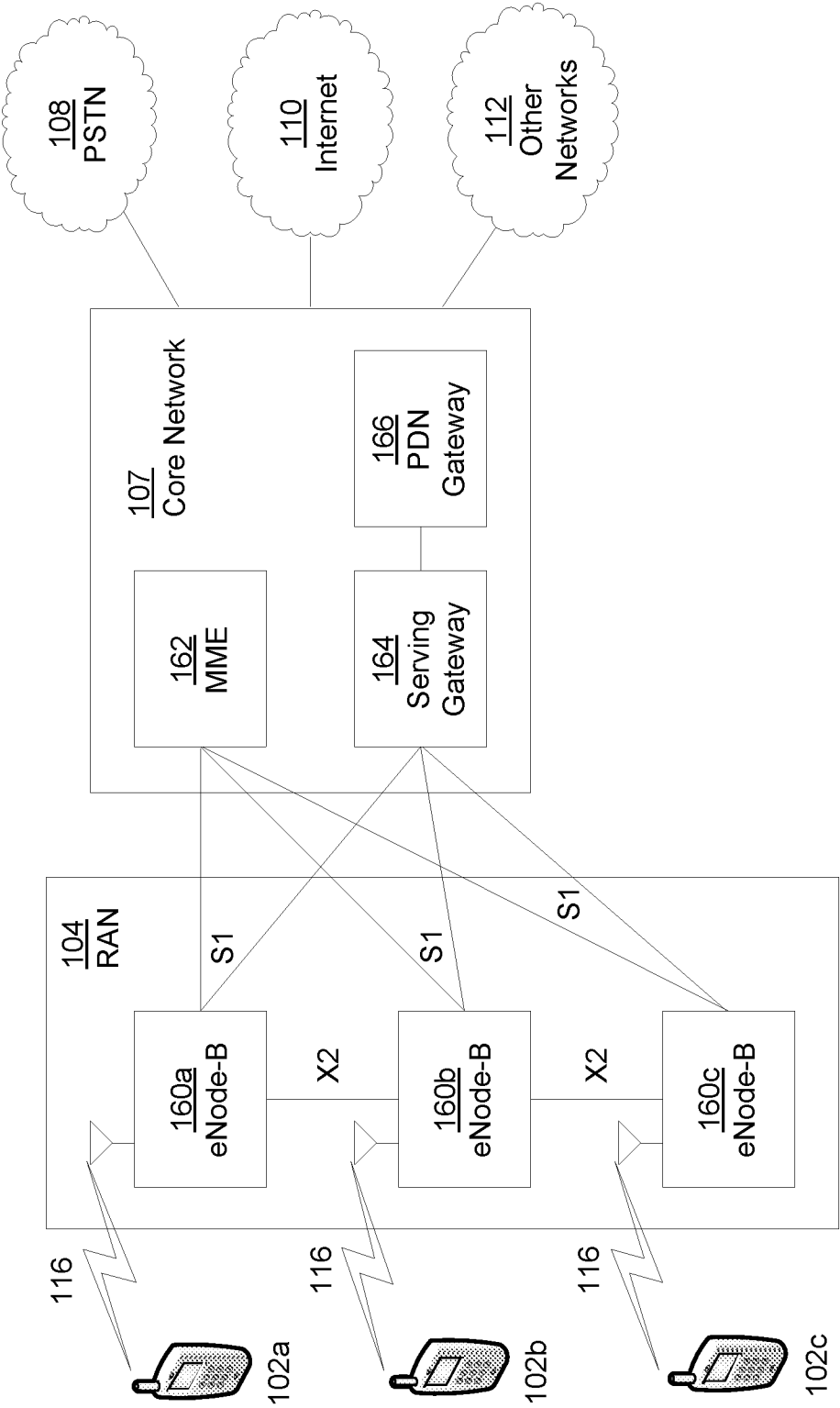


FIG. 1D

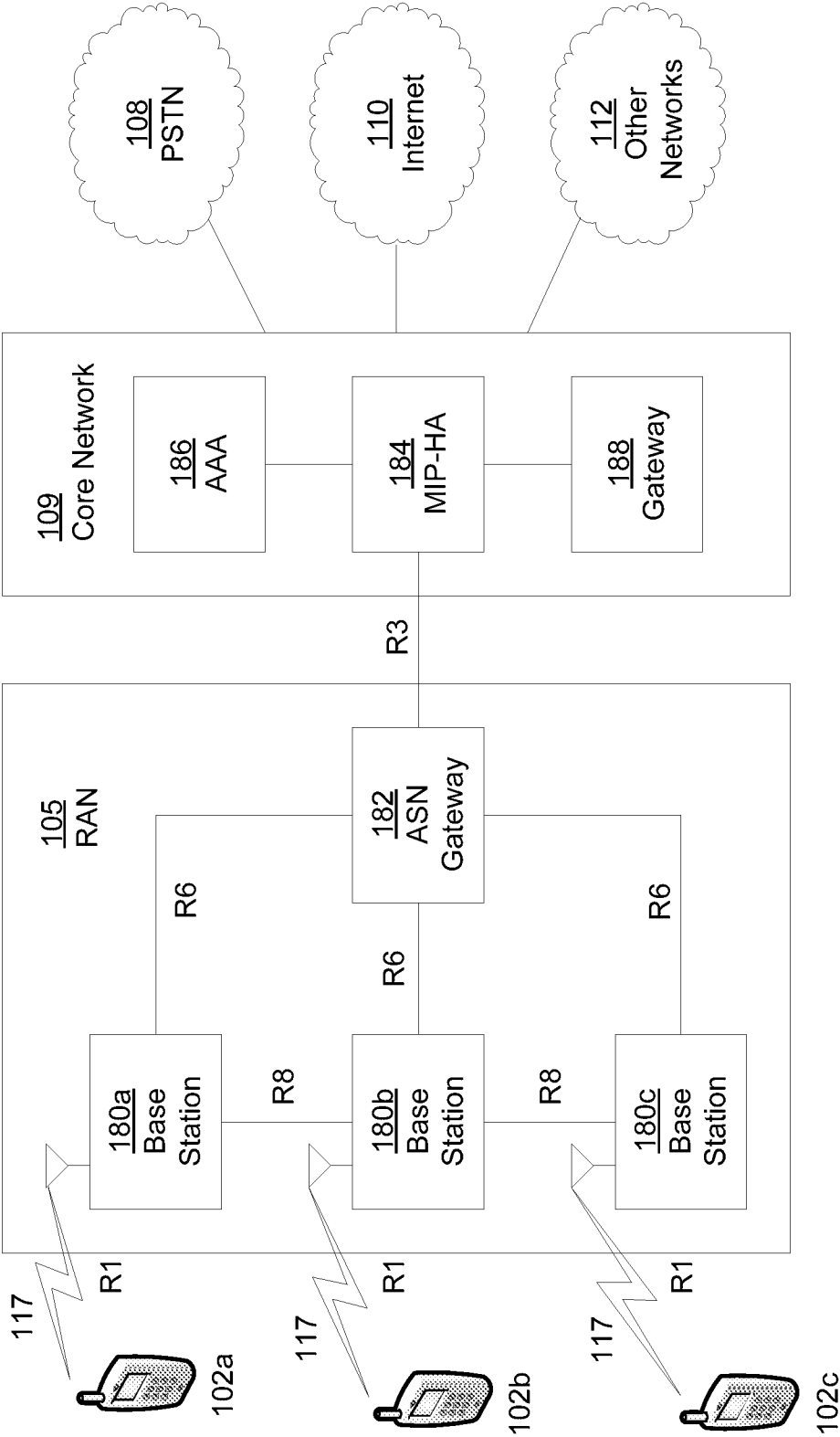


FIG. 1E

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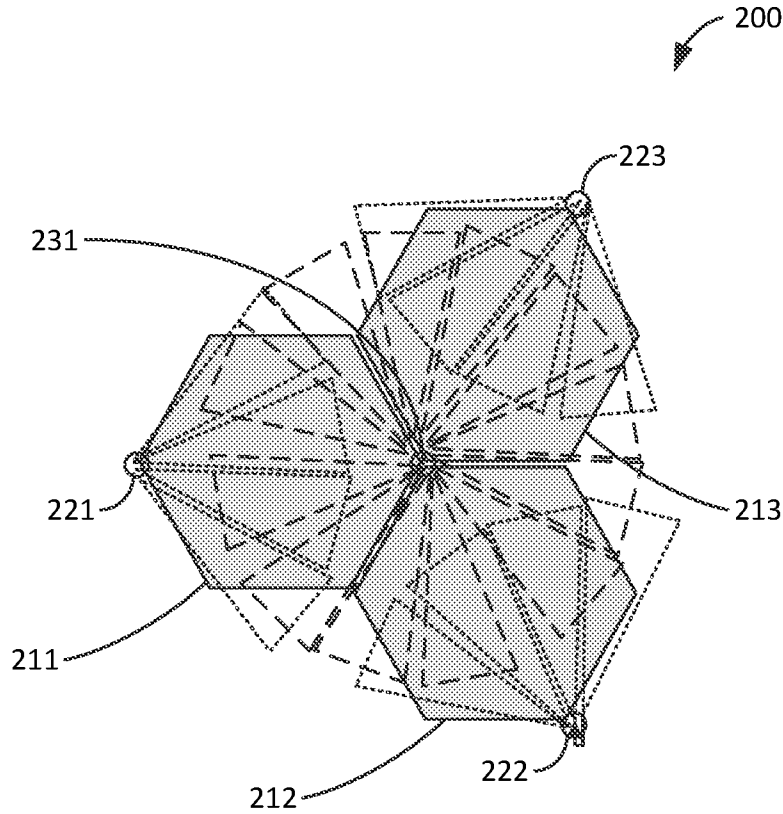


FIG. 2

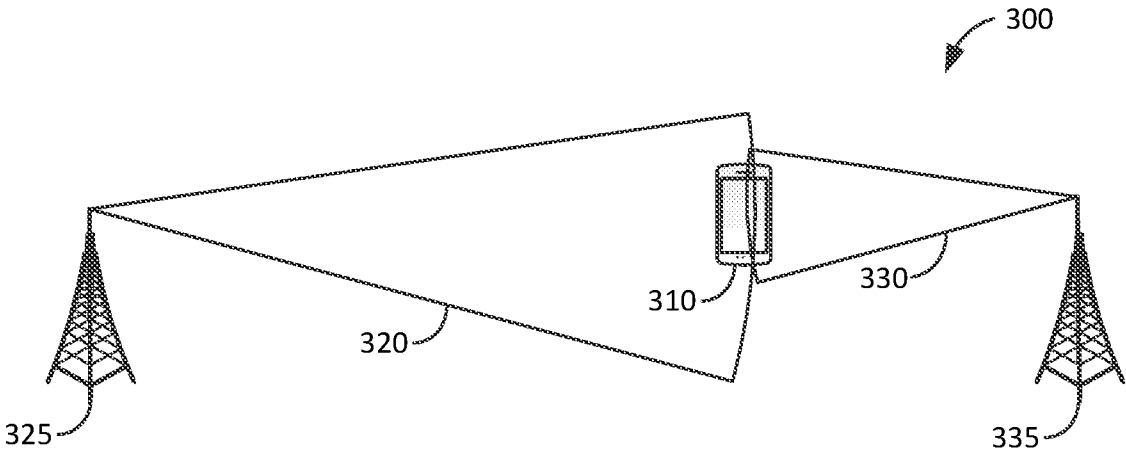


FIG. 3

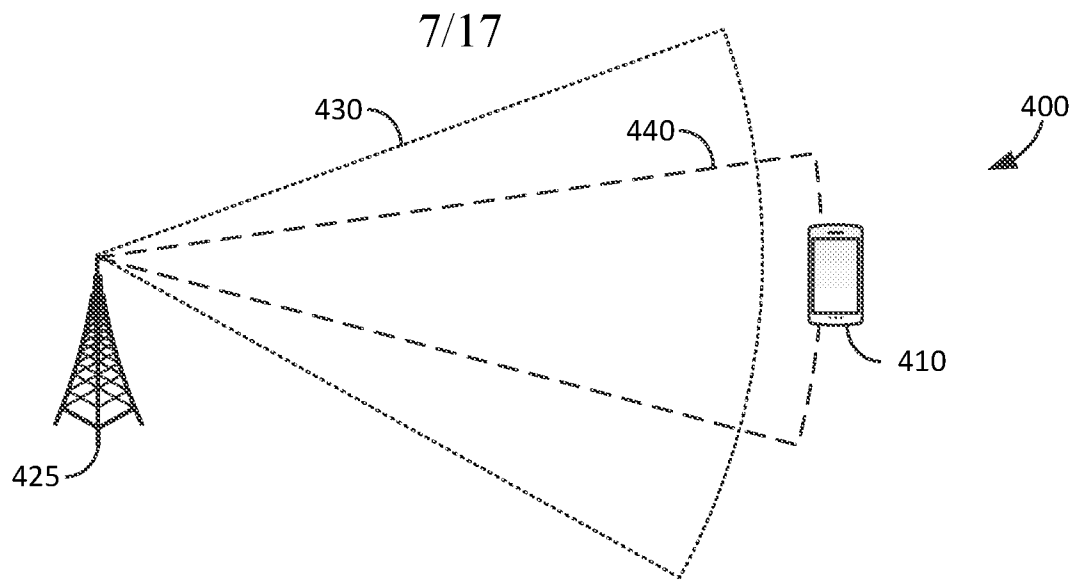


FIG. 4

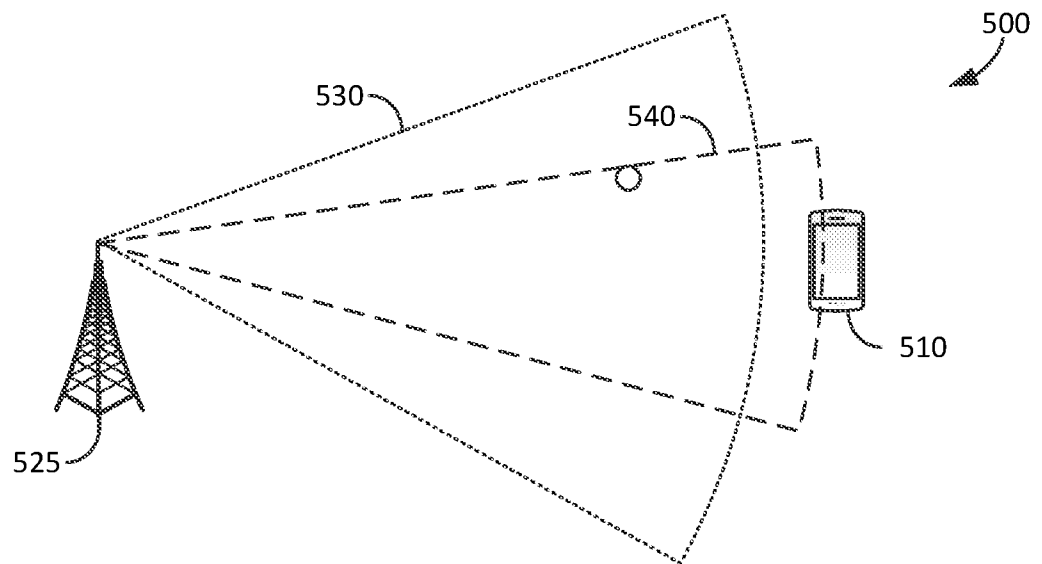


FIG. 5

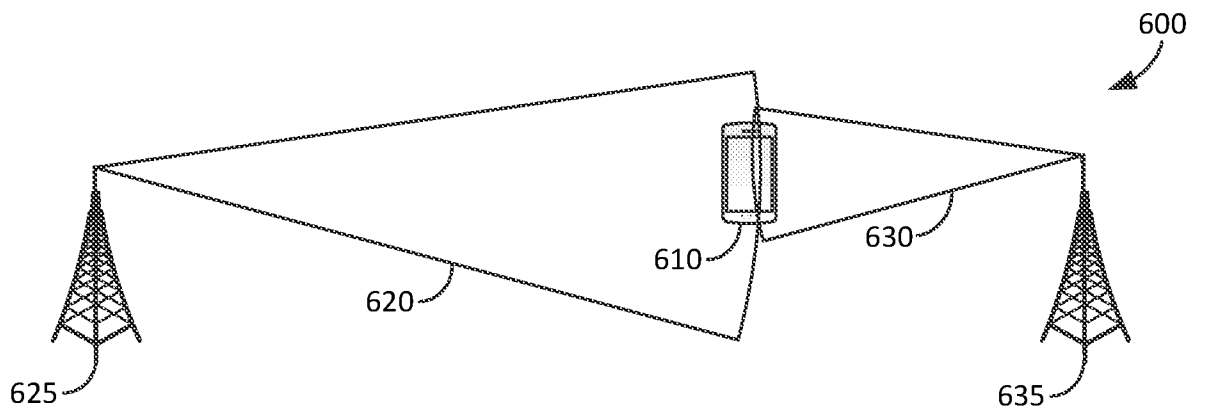


FIG. 6

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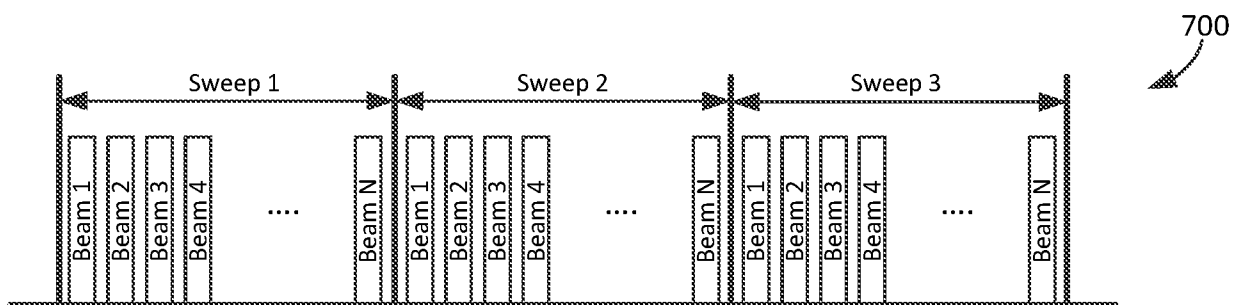


FIG. 7

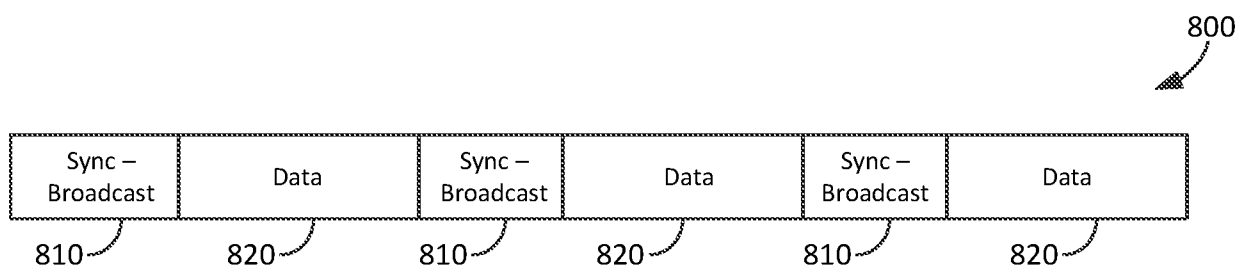


FIG. 8

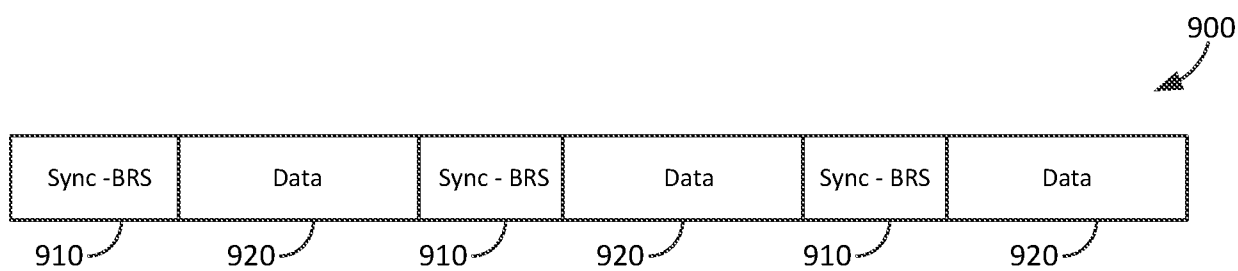


FIG. 9

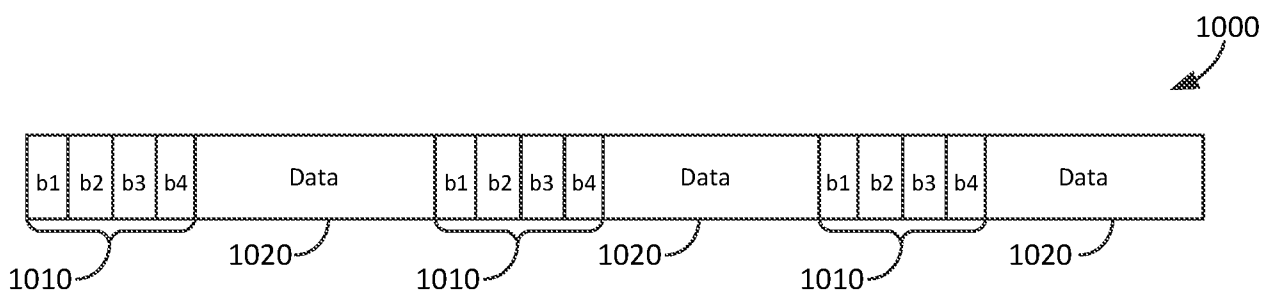


FIG. 10

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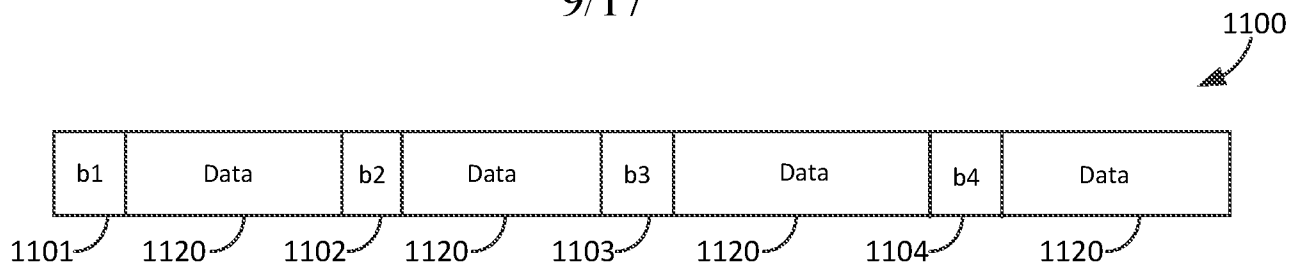


FIG. 11

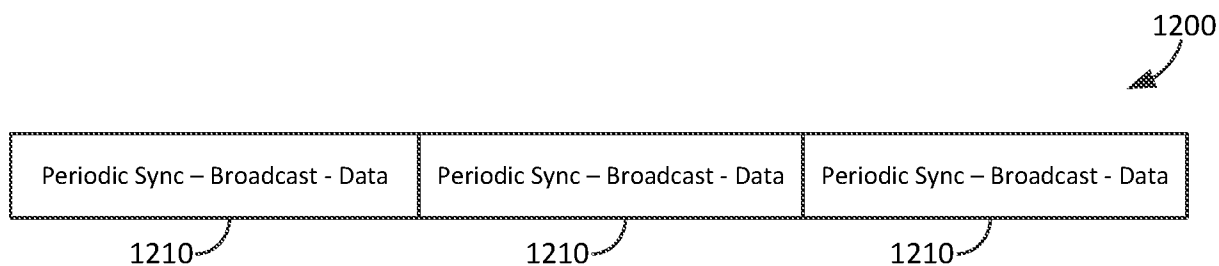


FIG. 12

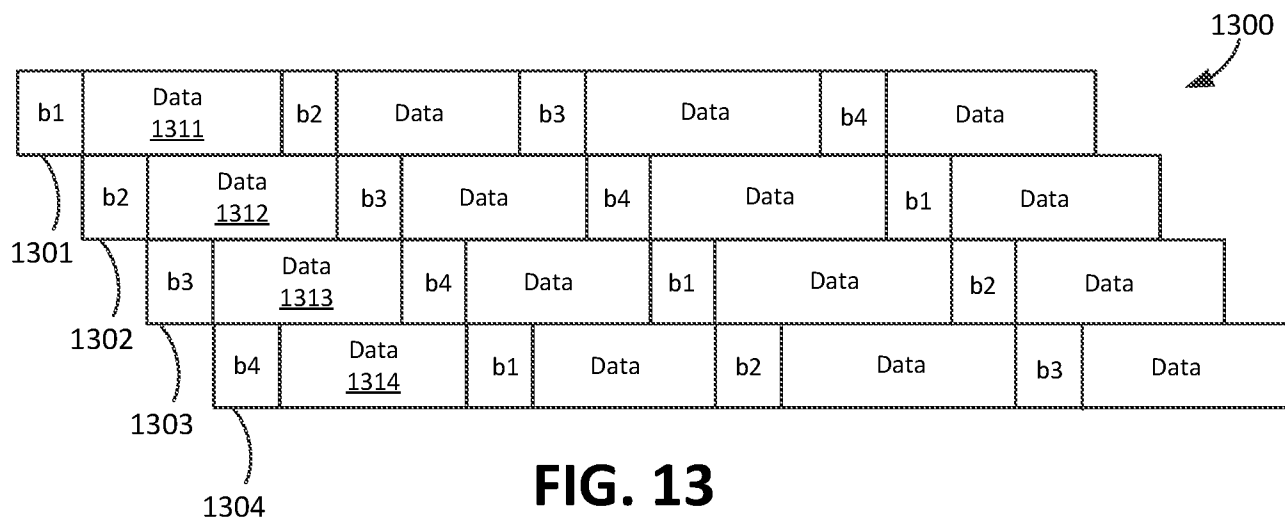


FIG. 13

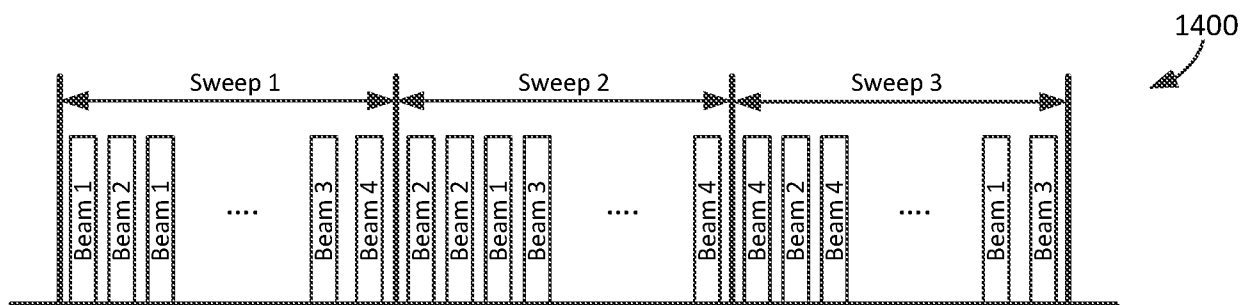


FIG. 14

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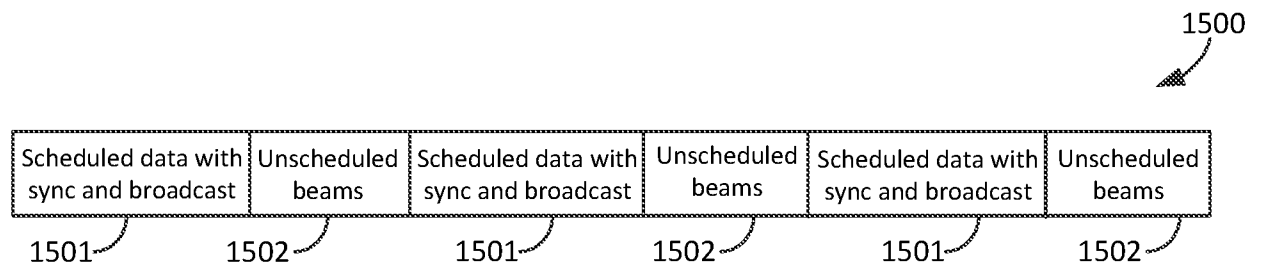


FIG. 15

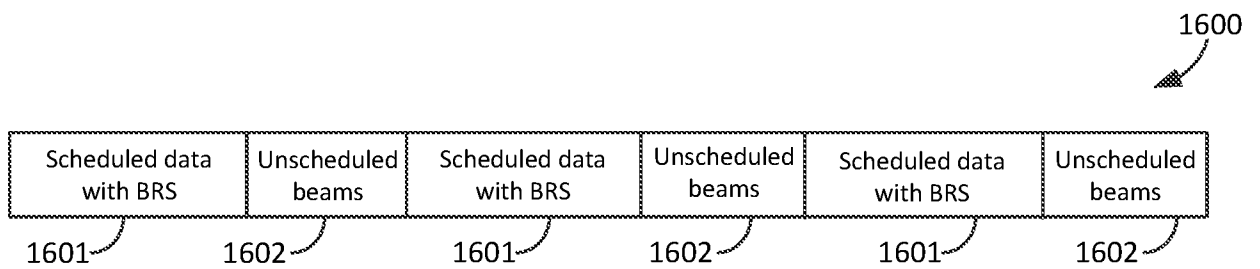


FIG. 16

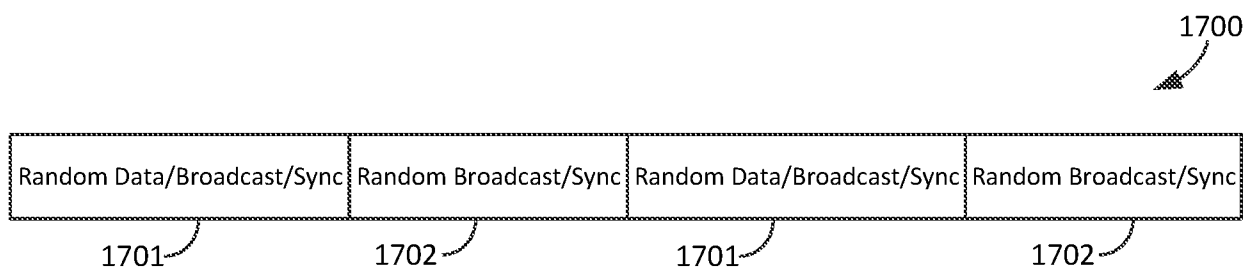


FIG. 17

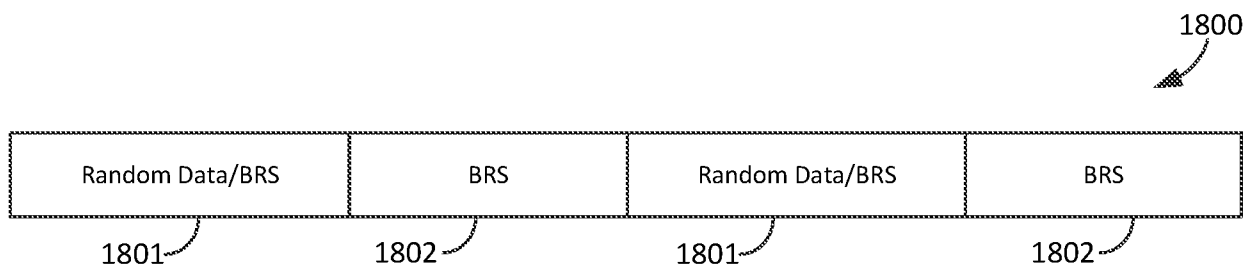


FIG. 18

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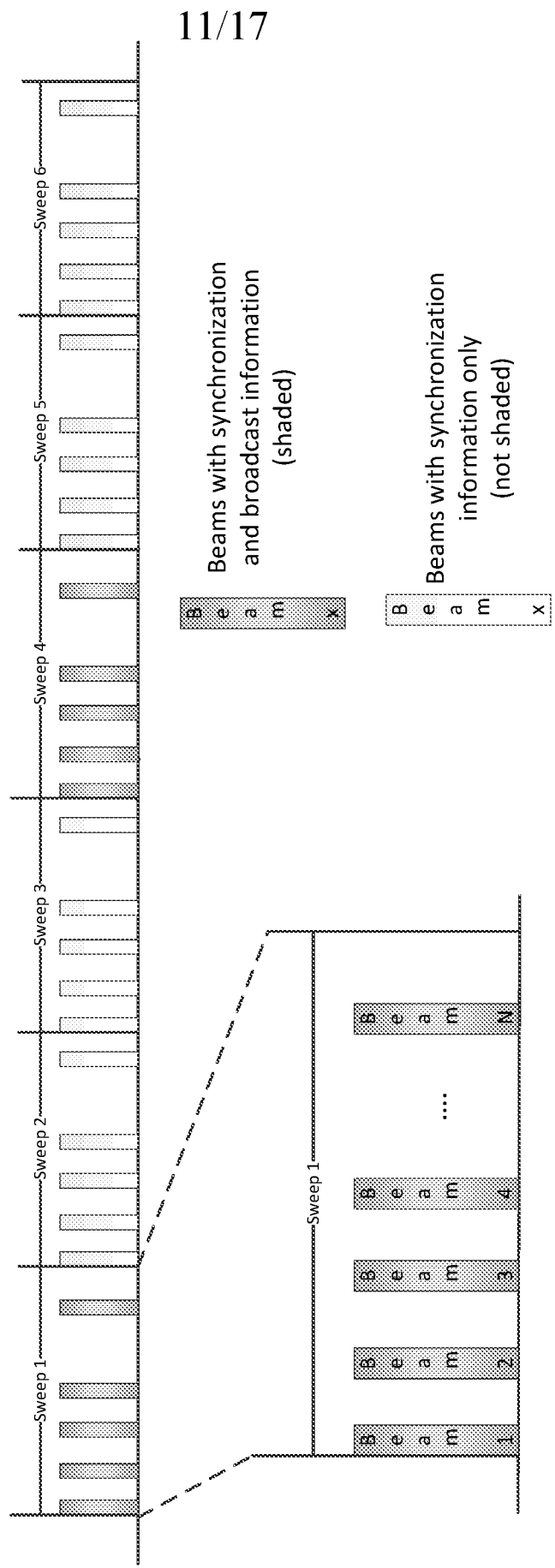


FIG. 19

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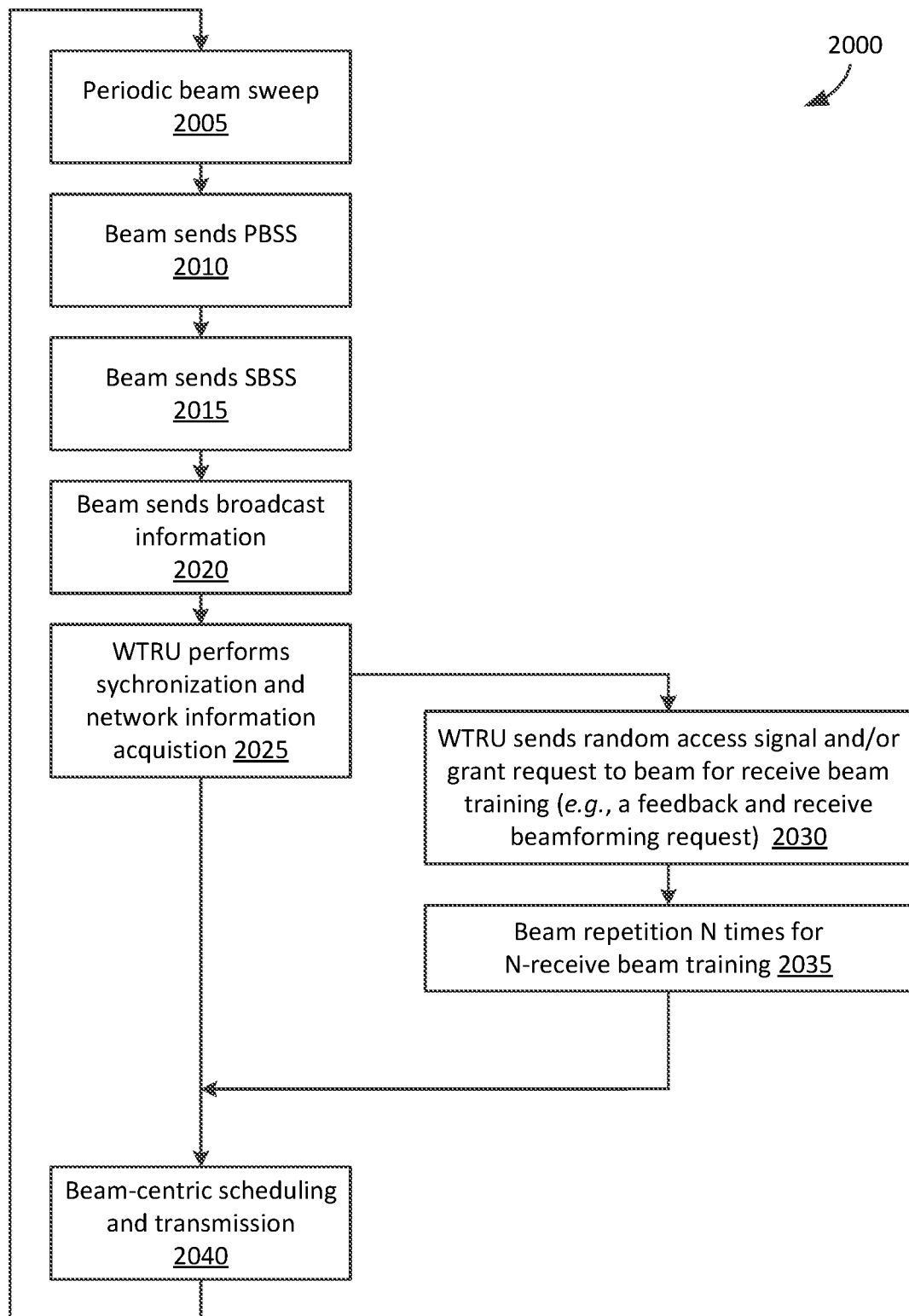


FIG. 20

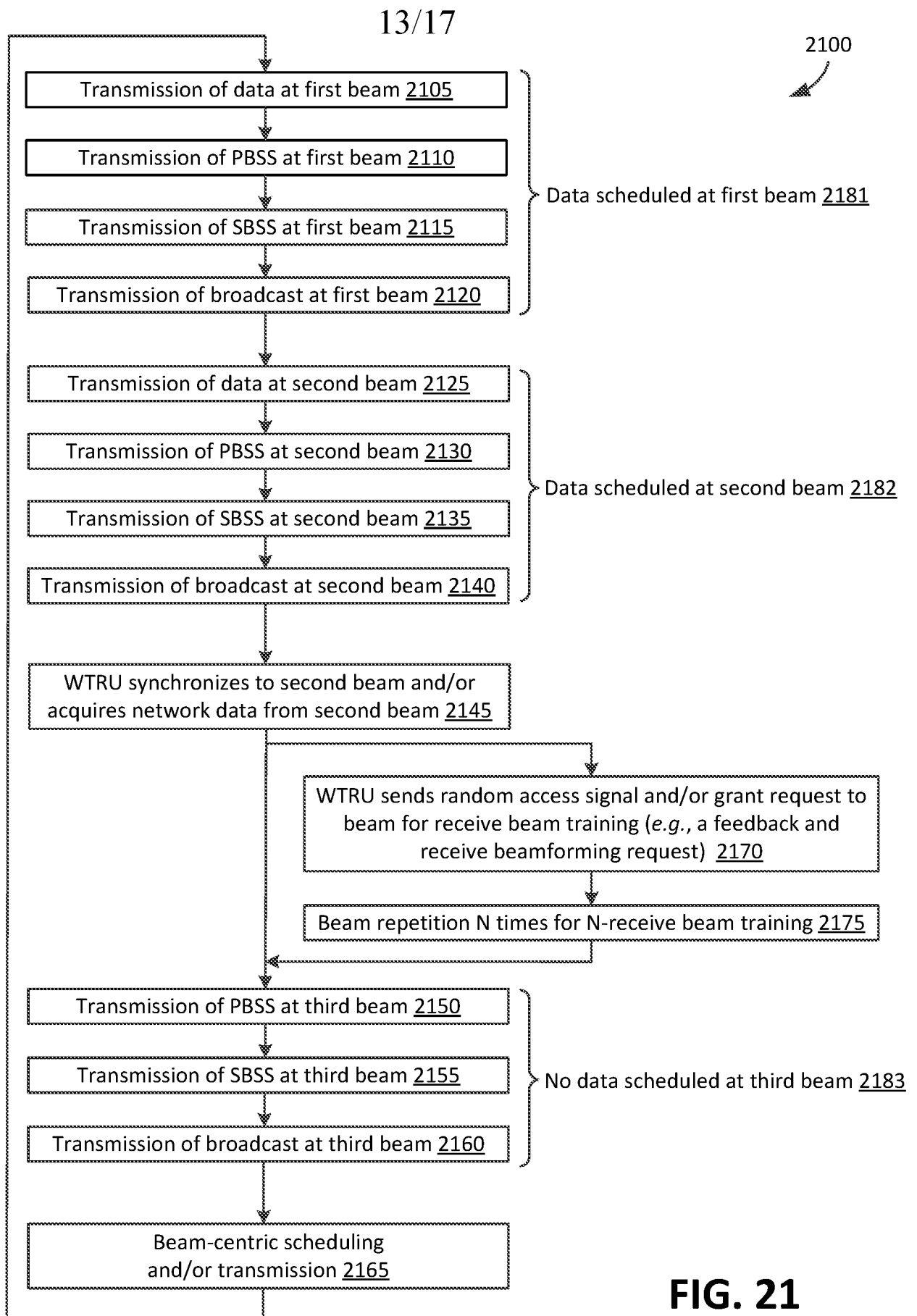


FIG. 21

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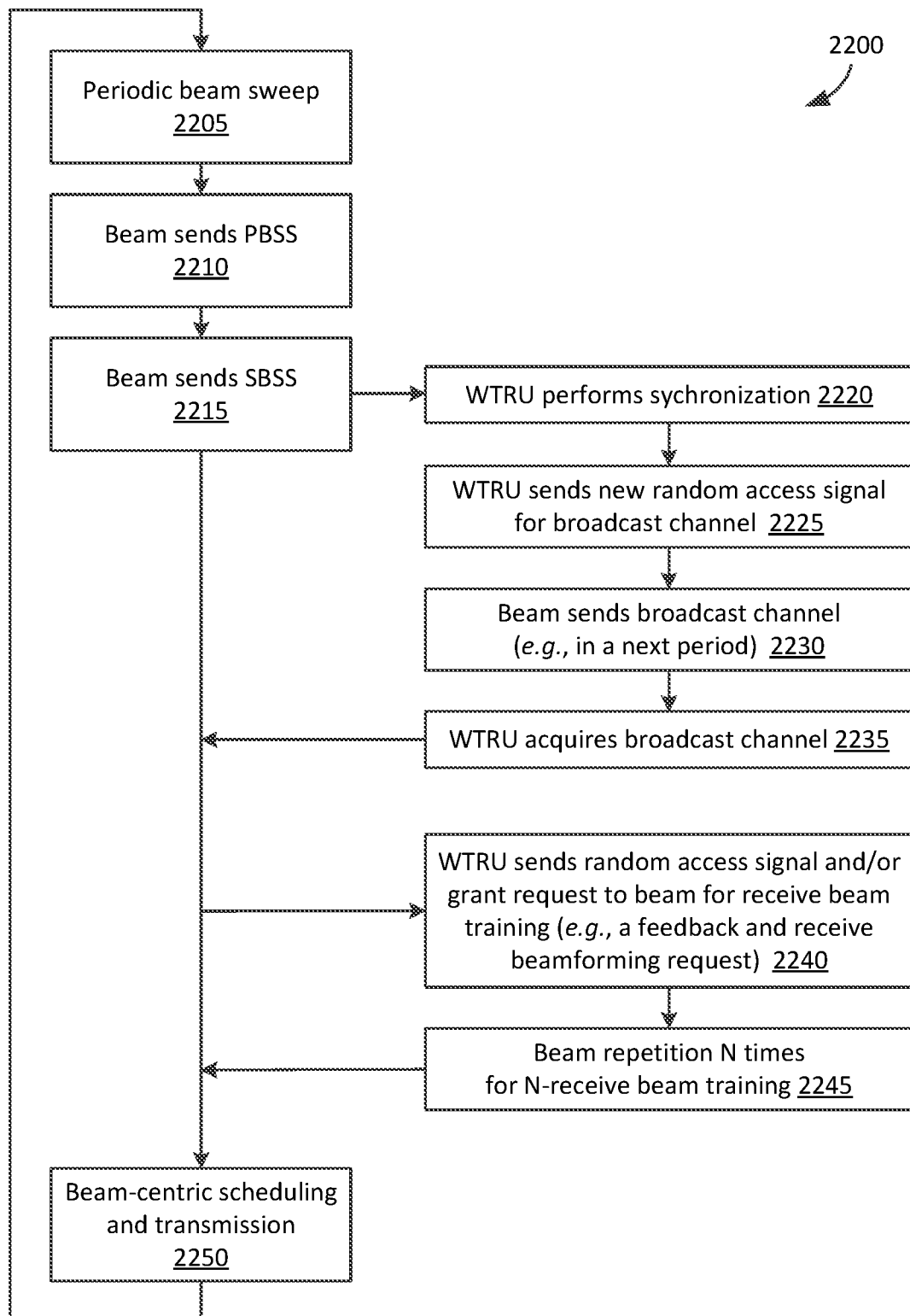


FIG. 22

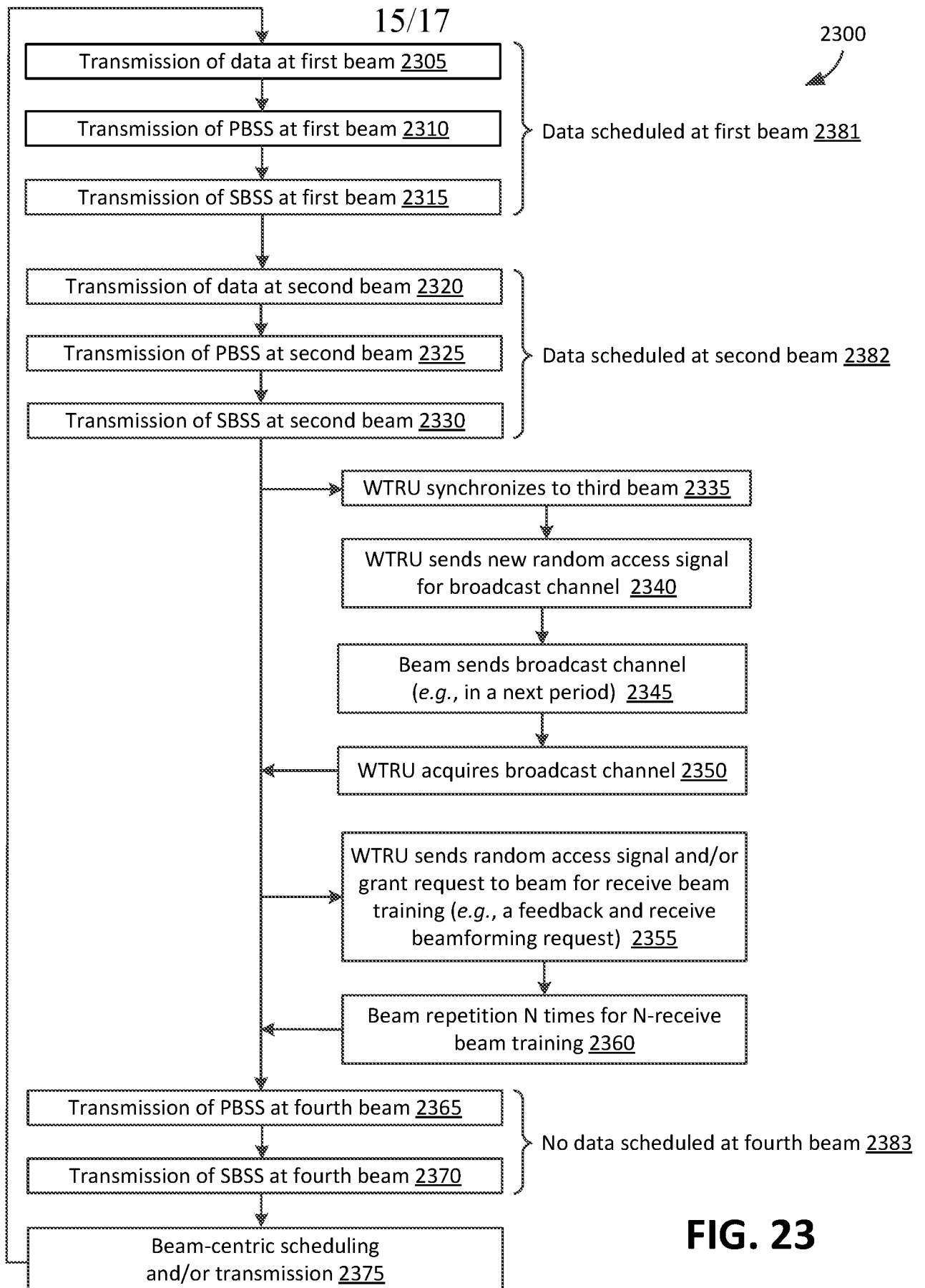


FIG. 23

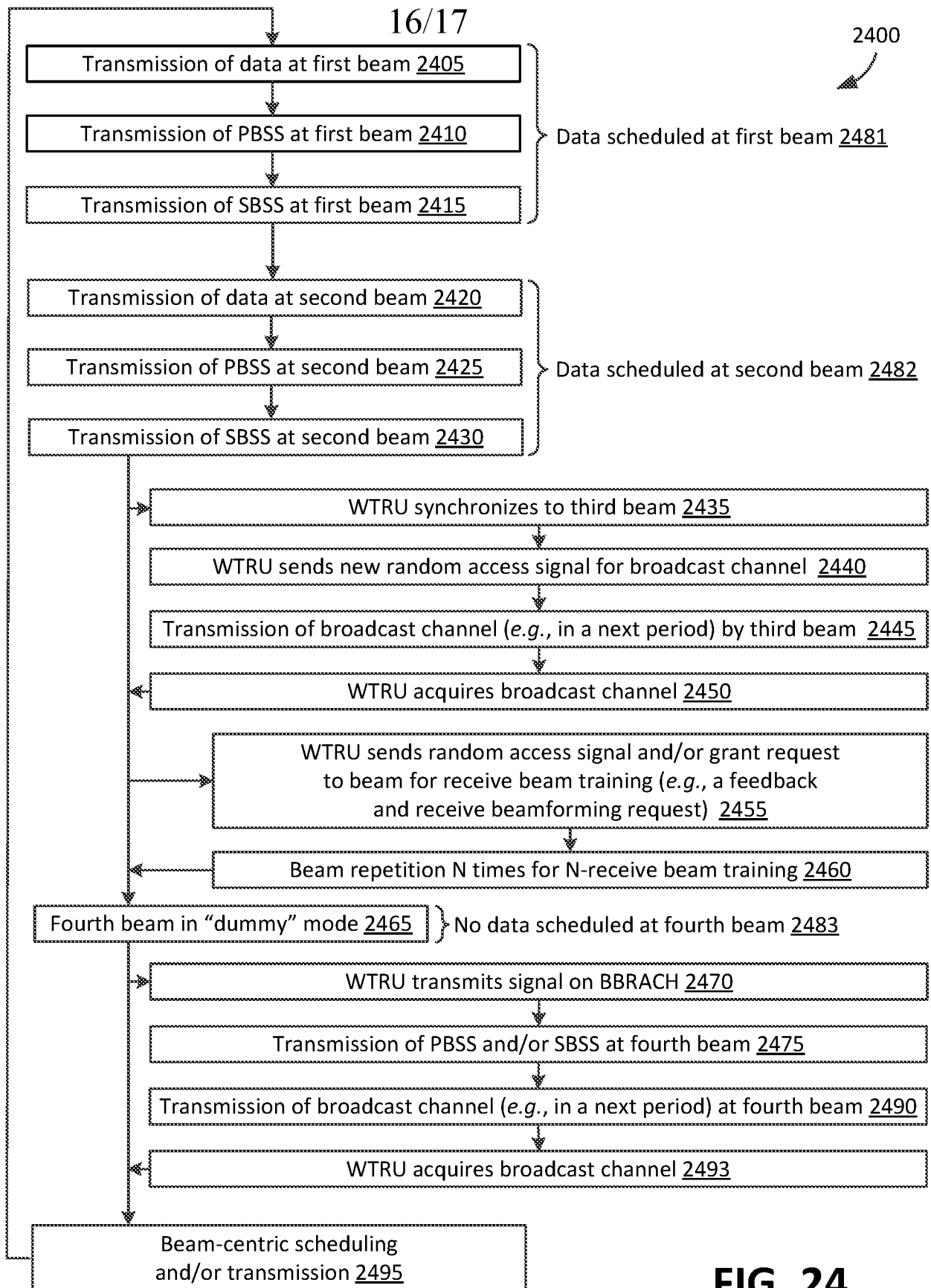


FIG. 24

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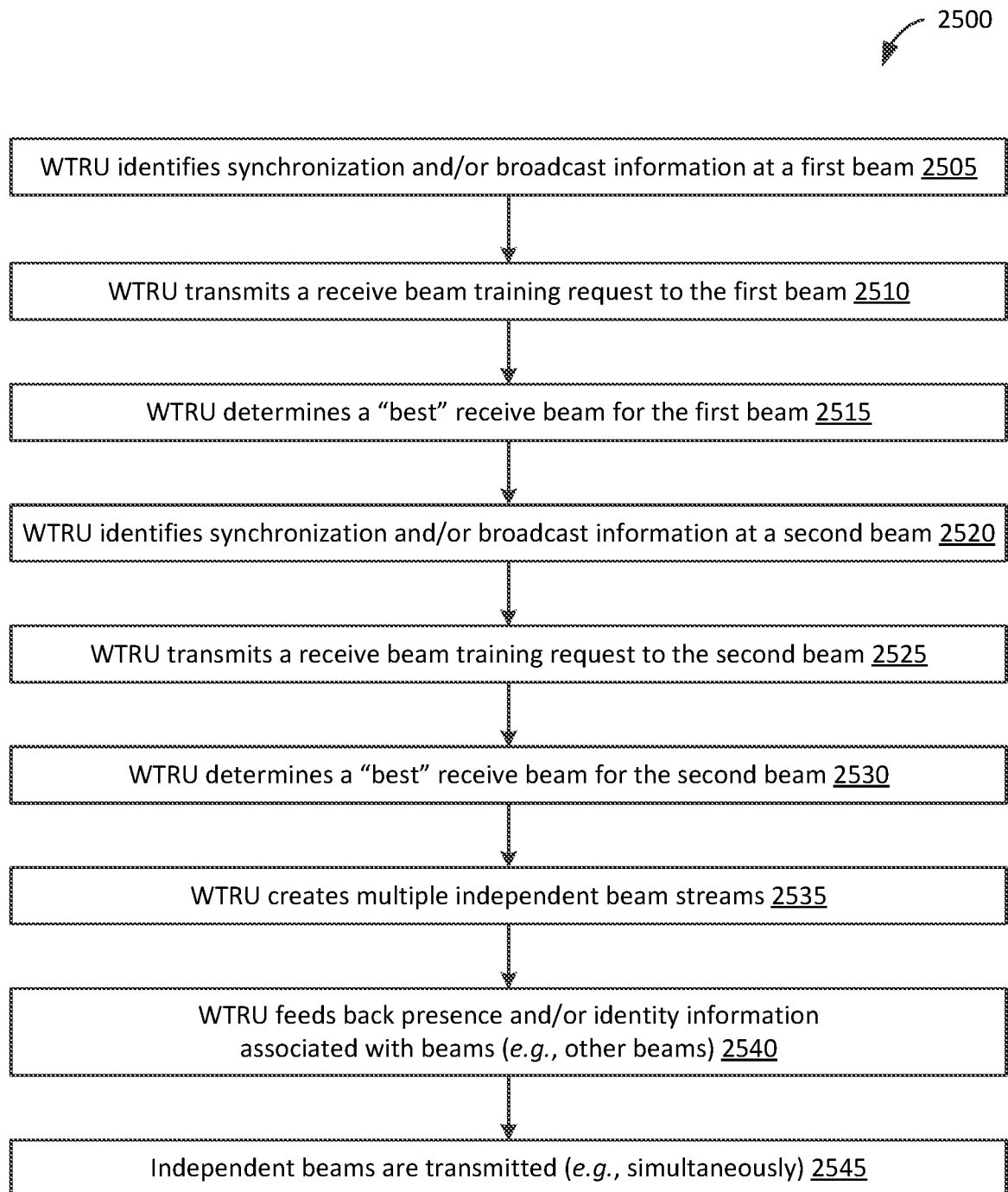


FIG. 25

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2017/032146

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04B7/06
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)
H04B

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2015/184630 A1 (ERICSSON TELEFON AB L M [SE]; LI GEN [CN]) 10 December 2015 (2015-12-10) page 1, line 11 - line 15 page 7, line 4 - line 8 page 8, line 18 - line 22 page 12, line 3 - line 4 page 12, line 16 - line 19 page 12, line 23 - line 32 page 13, line 1 - line 2 page 13, line 15 - line 17 page 14, line 1 - line 5 figures 4-7 -----	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

30 June 2017

Date of mailing of the international search report

10/07/2017

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

Cehade, Thomas

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2017/032146

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2015184630 A1	10-12-2015	AU 2014396695 A1	22-12-2016
		CA 2951298 A1	10-12-2015
		CN 106465232 A	22-02-2017
		EP 3152960 A1	12-04-2017
		KR 20170003633 A	09-01-2017
		PH 12016502245 A1	09-01-2017
		SG 11201609504Y A	29-12-2016
		US 2017150419 A1	25-05-2017
		WO 2015184630 A1	10-12-2015
