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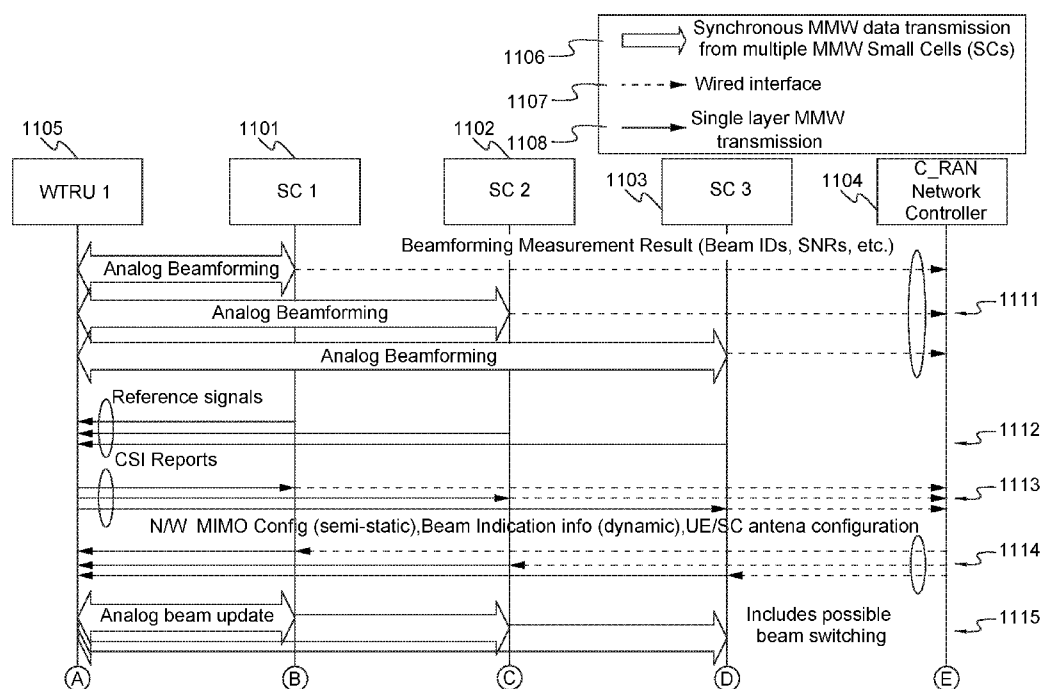


FIG. 11A

(57) **Abstract:** A system, method, and apparatus for hybrid beamforming based network multiple input and multiple output (MIMO) is disclosed. At least one wireless transmit/receive unit (WTRU) may measure channel state information (CSI) and send the information to a next generation NodeB (gNB) of a small cell. The gNB may receive CSI from the at least one WTRU and may aggregate the CSI when received from more than one WTRU. The gNB may compute a precoding matrix for each of the WTRUs or the gNB may receive a computed precoding matrix from a network controller. The gNB may also compute postcoding matrices for each of the WTRUs. The at least one WTRU may receive data from the gNB or may receive data simultaneously from more than one gNB that has been individually encoded for each of the at least one WTRU.

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HYBRID BEAMFORMING BASED NETWORK MIMO IN MILLIMETER WAVE ULTRA DENSE NETWORK

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/358,375 filed on July 5, 2016, the contents of which are hereby incorporated by reference herein.

SUMMARY

[0002] A system, method, and apparatus for hybrid beamforming based network multiple input and multiple output (MIMO) is disclosed. At least one wireless transmit/receive unit (WTRU) may measure channel state information (CSI) and send the information to a next generation NodeB (gNB) of a small cell. The gNB may receive CSI from the at least one WTRU and may aggregate the CSI when received from more than one WTRU. The gNB may compute a precoding matrix for each of the WTRUs or the gNB may receive a computed precoding matrix from a network controller. The gNB may also compute postcoding matrices for each of the WTRUs. The at least one WTRU may receive data from the gNB or may receive data simultaneously from more than one gNB that has been individually encoded for each of the at least one WTRU.

BACKGROUND

[0003] There may be many uses cases for emerging wireless communication systems such as Enhanced Mobile Broadband (eMBB), Massive Machine Type Communications (mMTC), and Ultra Reliable and Low latency Communications (URLLC). Different use cases may focus on different requirements such as higher data rate, higher spectrum efficiency, low power and higher energy efficiency, lower latency, and higher reliability.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings wherein:

[0005] FIG. 1A is a system diagram of an example communications system in which one or more disclosed embodiments may be implemented;

[0006] FIG. 1B is a system diagram of an example wireless transmit/receive unit (WTRU) that may be used within the communications system illustrated in FIG. 1A;

[0007] FIG. 1C is a system diagram of an example radio access network and an example core network that may be used within the communications system illustrated in FIG. 1A;

[0008] FIG. 2 is an example network architecture of a millimeter wave (mmW) system;

[0009] FIG. 3 shows hybrid beamforming based network multiple-input and multiple-output (MIMO) for a millimeter wave (mmW) ultra dense network (UDN);

[0010] FIG. 4 shows an example of hybrid beamforming based network MIMO in a single-user (SU) MIMO network;

[0011] FIG. 5A shows an example of hybrid beamforming based network MIMO in a multi-user (MU) MIMO network;

[0012] FIG. 5B shows an example of a procedure of hybrid beamforming based network MIMO;

[0013] FIG. 6 shows an example network topology for SU-MIMO support from multiple gNBs;

[0014] FIG. 7 shows an example single gNB serving multiple wireless transmit/receive units (WTRUs) via network MIMO;

[0015] FIG. 8 shows an example using multiple gNBs to serve multiple WTRUs using network MIMO;

[0016] FIG. 9 shows an example resource grid showing reference signals for CSI estimation;

[0017] FIG. 10 shows an example resource grid using reference samples transmitted by each WTRU for CSI estimation;

[0018] FIG. 11A shows an example of gNB signaling and WTRU procedures to enable network MIMO; and

[0019] FIG. 11B shows an example of gNB signaling and WTRU procedures to enable network MIMO.

DETAILED DESCRIPTION

[0020] FIG. 1A is a diagram of an example communications system 100 in which one or more disclosed embodiments may be implemented. The communications system 100 may be a multiple access system that provides content, such as voice, data, video, messaging, broadcast, etc., to multiple wireless users. The communications system 100 may enable multiple wireless users to access such content through the sharing of system resources, including wireless bandwidth. For example, the communications systems 100 may employ one or more channel access methods, such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), single-carrier FDMA (SC-FDMA), and the like.

[0021] As shown in FIG. 1A, the communications system 100 may include wireless transmit/receive units (WTRUs) 102a, 102b, 102c, 102d, a radio access network (RAN) 104, a core network 106, a public switched telephone network (PSTN) 108, the Internet 110, and other networks 112, though it will be appreciated that the disclosed embodiments contemplate any number of WTRUs, base stations, networks, and/or network elements. Each of the WTRUs 102a, 102b, 102c, 102d may be any type of device configured to operate and/or communicate in a wireless environment. By way of example, the WTRUs 102a, 102b, 102c, 102d 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.

[0022] The communications systems 100 may also include a base station 114a and a base station 114b. Each of the base stations 114a, 114b may be any type of device configured to wirelessly interface with at least one of the WTRUs 102a, 102b, 102c, 102d to facilitate access to one or more communication networks, such as the core network 106, the Internet 110, and/or the other networks 112. By way of example, the base stations 114a, 114b may be a base transceiver station (BTS), a Node-B, an eNode B, a Home Node B, a Home eNode B, a site controller, an access point (AP), a wireless router, and the like. While the base stations 114a, 114b are each depicted as a single element, it will be appreciated that the base stations 114a, 114b may include any number of interconnected base stations and/or network elements.

[0023] The base station 114a may be part of the RAN 104, which may also include other base stations and/or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, 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 one embodiment, the base station 114a may include three transceivers, i.e., one for each sector of the cell. In another embodiment, the base station 114a may employ multiple-input multiple-output (MIMO) technology and, therefore, may utilize multiple transceivers for each sector of the cell.

[0024] The base stations 114a, 114b may communicate with one or more of the WTRUs 102a, 102b, 102c, 102d over an air interface 116, which may be any suitable wireless communication link (e.g., radio frequency (RF), microwave, infrared (IR), ultraviolet (UV), visible light, etc.). The air interface 116 may be established using any suitable radio access technology (RAT).

[0025] More specifically, as noted above, the communications system 100 may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and the like. For example, the base station 114a in the RAN 104 and the WTRUs

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

[0026] In another embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as Evolved UMTS Terrestrial Radio Access (E-UTRA), which may establish the air interface 116 using Long Term Evolution (LTE) and/or LTE-Advanced (LTE-A).

[0027] In other embodiments, the base station 114a and the WTRUs 102a, 102b, 102c may implement radio technologies such as IEEE 802.16 (i.e., Worldwide Interoperability for Microwave Access (WiMAX)), CDMA2000, CDMA2000 1X, CDMA2000 EV-DO, Interim Standard 2000 (IS-2000), Interim Standard 95 (IS-95), Interim Standard 856 (IS-856), Global System for Mobile communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), GSM EDGE (GERAN), and the like.

[0028] 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 one embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In another embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). In yet another embodiment, the base station 114b and the WTRUs 102c, 102d may utilize a cellular-based RAT (e.g., WCDMA, CDMA2000, GSM, LTE, LTE-A, 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.

[0029] The RAN 104 may be in communication with the core network 106, which may be any type of network configured to provide voice, data, applications, and/or voice over internet protocol (VoIP) services to one or more of the WTRUs 102a, 102b, 102c, 102d. For example, the core network 106 may provide call control, billing services, mobile location-based services, pre-paid calling, Internet connectivity, video distribution, etc., and/or perform high-level security functions, such as user authentication. Although not shown in FIG. 1A, it will be appreciated that the RAN 104 and/or the core network 106 may be in direct or indirect communication with other RANs that employ the same RAT as the RAN 104 or a different RAT. For example, in addition to being connected to the RAN 104, which may be utilizing an E-UTRA radio technology, the core network 106 may also be in communication with another RAN (not shown) employing a GSM radio technology.

[0030] The core network 106 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 104 or a different RAT.

[0031] Some or all of the WTRUs 102a, 102b, 102c, 102d in the communications system 100 may include multi-mode capabilities, i.e., 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.

[0032] 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 embodiment.

[0033] 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.

[0034] The transmit/receive element 122 may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station 114a) over the air interface 116. For example, in one embodiment, the transmit/receive element 122 may be an antenna configured to transmit and/or receive RF signals. In another embodiment, the transmit/receive element 122 may be an emitter/detector configured to transmit and/or receive IR, UV, or visible light signals, for example. In yet another embodiment, the transmit/receive element 122 may be configured to transmit and 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.

[0035] 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 one embodiment, the WTRU 102 may include two or more transmit/receive elements 122 (e.g., multiple antennas) for transmitting and receiving wireless signals over the air interface 116.

[0036] The transceiver 120 may be configured to modulate the signals that are to be transmitted by the transmit/receive element 122 and to demodulate the signals that are received by the transmit/receive element 122. As noted above, the WTRU 102 may have multi-mode capabilities. Thus, the transceiver 120 may include multiple transceivers for enabling the WTRU 102 to communicate via multiple RATs, such as UTRA and IEEE 802.11, for example.

[0037] The processor 118 of the WTRU 102 may be coupled to, and may receive user input data from, the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128 (e.g., a liquid crystal display (LCD) display unit or organic light-emitting diode (OLED) display unit). The processor 118 may also output user data to the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128. In addition, the processor 118 may access information from, and store data in, any type of suitable memory, such as the non-removable memory 130 and/or the removable memory 132. The non-removable memory 130 may include random-access memory (RAM), read-only memory (ROM), a hard disk, or any other type of memory storage device. The removable memory 132 may include a subscriber identity module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. In other embodiments, the processor 118 may access information from, and store data in, memory that is not physically located on the WTRU 102, such as on a server or a home computer (not shown).

[0038] 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.

[0039] The processor 118 may also be coupled to the GPS chipset 136, which may be configured to provide location information (e.g., longitude and latitude) regarding the current location of the WTRU 102. In addition to, or in lieu of, the information from the GPS chipset 136, the WTRU 102 may receive location information over the air interface 116 from a base station (e.g., base stations 114a, 114b) and/or determine its location based on the timing of the signals being received from two or more nearby base stations. It will be appreciated that the WTRU 102 may acquire location information by way of any suitable location-determination method while remaining consistent with an embodiment.

[0040] 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.

[0041] FIG. 1C is a system diagram of the RAN 104 and the core network 106 according to an embodiment. As noted above, the RAN 104 may employ an E-UTRA radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 104 may also be in communication with the core network 106.

[0042] The RAN 104 may include eNode-Bs 140a, 140b, 140c, though it will be appreciated that the RAN 104 may include any number of eNode-Bs while remaining consistent with an embodiment. The eNode-Bs 140a, 140b, 140c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In one embodiment, the eNode-Bs 140a, 140b, 140c may implement MIMO technology. Thus, the eNode-B 140a, for example, may use multiple antennas to transmit wireless signals to, and receive wireless signals from, the WTRU 102a.

[0043] Each of the eNode-Bs 140a, 140b, 140c 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 and/or downlink, and the like. As shown in FIG. 1C, the eNode-Bs 140a, 140b, 140c may communicate with one another over an X2 interface.

[0044] The core network 106 shown in FIG. 1C may include a mobility management entity gateway (MME) 142, a serving gateway 144, and a packet data network (PDN) gateway 146. 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.

[0045] The MME 142 may be connected to each of the eNode-Bs 140a, 140b, 140c in the RAN 104 via an S1 interface and may serve as a control node. For example, the MME 142 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 142 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.

[0046] The serving gateway 144 may be connected to each of the eNode Bs 140a, 140b, 140c in the RAN 104 via the S1 interface. The serving gateway 144 may generally route and forward user data packets to/from the WTRUs 102a, 102b, 102c. The serving gateway 144 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.

[0047] The serving gateway 144 may also be connected to the PDN gateway 146, 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.

[0048] The core network 106 may facilitate communications with other networks. For example, the core network 106 may provide the WTRUs 102a, 102b, 102c with access to circuit-switched networks, such as the PSTN 108, to facilitate communications between the WTRUs 102a, 102b, 102c and traditional land-line communications devices. For example, the core network 106 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the core network 106 and the PSTN 108. In addition, the core network 106 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.

[0049] Other network 112 may further be connected to an IEEE 802.11 based wireless local area network (WLAN) 160. The WLAN 160 may include an access router 165. The access router may contain gateway functionality. The access router 165 may be in communication with a plurality of access points (APs) 170a, 170b. The communication between access router 165 and APs 170a, 170b may be via wired Ethernet (IEEE 802.3 standards), or any type of wireless communication protocol. AP 170a is in wireless communication over an air interface with WTRU 102d.

[0050] Based on the general requirements set out by the International Telecommunication Union (ITU) Radio Communications Sector (ITU-R), the Next Generation Mobile Networks (NGMN), and the Third Generation Partnership Project (3GPP), a broad classification of use cases for emerging 5G systems may be: Enhanced Mobile Broadband (eMBB), Massive Machine Type Communications (mMTC), and/or Ultra Reliable and Low latency

Communications (URLLC). Different use cases may focus on different requirements such as higher data rates, higher spectrum efficiency, lower power and higher energy efficiency, lower latency and higher reliability.

[0051] FIG. 2 shows an example network architecture of a millimeter wave (mmW) system. A mmW network 200 of macro sub-6GHz may have mmW base stations (mBs) 203a, 203b, and 203c that may serve mmW mUEs 204a, 204b, and 204c (e.g. UEs or WTRUs) through mmW links 205a, 205b, and 206c, respectively. As discussed herein, mBs may be interchangeable with gNBs for New Radio (NR). The gNBs or mBs may be a small cell (SC) aggregation point for LTE, LTE-A, or 5G traffic. The gNBs or mBs 203a-c may be connected to each other wirelessly through mmW links 206a and 206b. Each mB 203a-c may reach a gateway mB such as 208c through one or more wireless hops. A gateway mB may be a node such as a cloud radio access network (C-RAN) point of presence (PoP) 208c that has a wired fiber connection 209 access to a core network 211, local IP access (LIPA) 208d connected 217 to an IP cloud such as the internet 214, or 208b mobile edge computing (MEC). The mmW nodes, including the mBs 203a-c and gateway mBs 207b, 207c, and 207d, in the network 200 may have a sub-6 GHz connection to a macro cell. The control plane 202 overlay may be used to provide fast and reliable control to the systems. In FIG. 2 MEC 208b is shown with a mmW small cell but may be deployed at the Macro. In one scenario, mmW SDN controller may be deployed within the operator core or optionally in the Internet cloud. SIPTO/LIPA options. It should be noted that the framework here also supports network architectures such as Local IP Access (LIPA) and Selected IP Traffic Offload (SIPTO), which could allow IP traffic from mUE to be routed directly to the Internet or IP cloud, bypassing the mobile network operator's core network.

[0052] Still looking at the example system shown in FIG. 2, a WTRU 204a that accesses the Internet 214 via one access link 205a and mB 203a may be called a single-hop scenario. A WTRU 204c that accesses the C-RAN baseband unit (BBU) via both an access link and a fronthaul link 206a-b is called a single-hop extension or two-hop scenario. Latency for data

communications should be minimized for either an access link 205a-c, a fronthaul link 206a-b, or both. A gNB, eNB or mB that reaches the gateway gNB, eNB or mB through one or more wireless hops in a wireless mesh topology is called a multi-hop scenario. Use cases may include data transmission and reception in an access link 205a-c, joint access and fronthaul 206a-b, or multi-hop network for 5G.

[0053] Hybrid beamforming (HB) based network MIMO (NW-MIMO) designs for next generation NR or 5G and beyond for an ultra dense network (UDN) may include: hybrid beamforming from multiple sites with multiple connections; hybrid beamforming to enable network MIMO for interference mitigation, throughput enhancement, resource optimization, and performance improvement; and signaling design to enable HB-NW-MIMO. A gNB may be a Node-B, eNB, next generation Node-B, or Access Node (AN) and will be referred to herein as gNB.

[0054] FIG. 3 shows an example of a method of hybrid beamforming (BF) based network MIMO for mmW UDN. Multiple gNBs, such as 301 and 302, may transmit data to multiple WTRUs 303 simultaneously. Each gNB 301 and 302 may be aware of and obtain a copy of the data 312 destined to one or more of the WTRUs 303. Data exchange between gNBs 301, 302, may be needed for joint transmission. Channel state information (CSI) may also be exchanged, not shown, between gNBs 301 and 302. Multi-layer precoding that is used to support multiple data streams for multiple WTRUs 303 may be performed such as layer mapping 304a and 304b.

[0055] Each gNB 301, 302, may form multiple analog beams to multiple WTRUs in different directions at 313a and 313b respectively. The analog beam forming 313a and 313b may include a digital to analog converter (DAC) 307a and 307b, an radio frequency module 308a and 308b, and a phased array antenna (PAA) 309a and 309b.

[0056] Multiple gNBs 301, 302, may also form multiple layer digital beams to multiple WTRUs simultaneously as part of a network (NW) virtual digital beam forming (BF) such as at 305a and 305b. After the digital BF there may be further baseband (BB) processing 306a and 306b. Each digital beam

may be sent over multiple analog beams for one data stream for a given WTRU. For more than one data stream per WTRU, N digital beams may be aligned with K multiple analog beams (not shown in FIG. 3). K may be 2 and N may be 1 or 2, however, N and K may be a wide range of values and should not be considered limited to the examples provided.

[0057] FIG. 4 shows an example of hybrid beamforming based network MIMO in a single user (SU) MIMO network. Multiple mmW small cells 401 and 402 may communicate with a SU-MIMO WTRU 403.

[0058] FIG. 5A shows an example of hybrid beamforming based network MIMO in a multi user (MU) MIMO network. Multiple mmW small cells 501 and 502 communicate with multiple users such as MIMO WTRU 503 and 504.

[0059] Using an example such as a MU-MIMO mmW NW as shown in FIG. 5A, FIG. 5B shows a procedure of hybrid beamforming based network MIMO that may be described as follows: at 510 CSI information may be transmitted from WTRU 503 and WTRU 504 to a SC gNB 501 where the SC 501 with a gNB aggregates the CSI information across each WTRU 503 and 504; at 511 the SC gNB 501 computes optimal precoding matrices for each WTRU 503 and WTRU 504 and the SC gNB 501 also computes optimal postcoding matrices for each WTRU 503 and WTRU 504; the computations from one SC gNB 501 may be shared with other SCs, such as SC gNB 502; at 512 data is transmitted from the SCs 501 and 502 in a physical downlink shared channel (PDSCH) and a pre-coding matrix indicator (PMI) is transmitted in a physical downlink control channel (PDCCH) to WTRU 503 and WTRU 504; at 513 each WTRU 503 and WTRU 504 cancels interference using the PMI and recovers a signal; at 514 each WTRU 503 and WTRU 504 computes its own precoding matrix from the PMI and synchronizes with other WTRUs using synchronization methods such as a primary synchronization signal (PSS), a secondary synchronization signal (SSS), timing advance (TA), or the like or combination; and the gNB recovers signals in aggregate and resolves each WTRU message using transformation of its global PMI.

[0060] FIG. 6 shows an example of SU-MIMO scenarios for a next generation mmW network. Coordination with multiple gNBs in next

generation networks may require a coordinated selection of pre-coding matrices for each gNB. In order to configure each gNB 602a, 602b, and 602c for proper communication 603a, 603b, and 603c with the WTRU 601, the WTRU 601 estimates the channel state information (CSI), $\hat{H}^r$, from each gNB, r , where r is an index number indicating a specific gNB, using orthogonal reference signals (RS) and computes the optimal analog beamforming weight, Φ_r , the optimal pre-coding matrix, P_r^* , for each gNB, r , and its own post-coding matrix, $P^\dagger$. The precoding matrix may be selected from an indexed list and an optimal configuration may be sent as the pre-coding matrix indicator (PMI) via a control channel such as a physical uplink control channel (PUCCH) or embedded in a data channel such as a physical uplink shared channel (PUSCH) to each of the gNBs. Similarly, the analog beamforming weights, Φ_r , may be selected from an indexed list and transmitted to a gNB such as 602a-c via a PUCCH or a PUSCH. The number of digital layers that may be supported via spatial multiplexing is indicated via the rank indicator (RI) which may also be transmitted 603a-c via a PUCCH or a PUSCH to each gNB 602a-c. The gNBs 602a-c may coordinate downlink transmission using this control information.

[0061] A message, x_v , transmitted over digital layer, v , may be sent to each gNB 602a-c via the core network. The maximum number of layers, V , that may be supported are a function of the RI. The message, x , may be indicated as $x = [x_1, x_2, \dots, x_V]^T$. Each gNB 602a-c may generate the signal, x_r , to be transmitted 603a-c to the WTRU as $x_r = \Phi_r P_r^* x$. The messages may propagate over an uncorrelated wireless channel and may be received at a WTRU 601 in the aggregate from each gNB, r , so that the received signal, y , may be indicated as $y = \sum_{r=1}^R H^r * x_r$, where, H^r , is the wireless propagation channel between a gNB, r , such as 602a-c and the WTRU 601. The WTRU 601 may then resolve the individual digital layers using its calculated post-coding matrix as, $\hat{x} = P^\dagger y$.

[0062] As shown in the example of FIG. 6, multiple gNBs 601a-c may transmit 603a-c data to a single WTRU 601 simultaneously. Each gNB 602a-c may be aware of and obtain a copy of the WTRU's data. Data exchange

between gNBs may be needed for joint transmission (not shown). CSI may also be exchanged between gNBs when coordinated beamforming is performed. Each gNB 602a-c may perform analog beamforming. Analog beamforming of each gNB 602a-c may be directed to the desired WTRU, such as 601, that is scheduled for hybrid beamforming. Each gNB 602a-c may perform precoding for data. The overall precoding matrix may be derived by an individual precoding matrix of multiple gNBs by joint processing of multiple individual precoding matrices. A set of gNBs, such as only 602a and 602b, or some other group of available gNBs, may be scheduled to perform network (NW) MIMO hybrid beamforming for the scheduled WTRU 601. Multiple gNBs 602a-c may form a virtual digital or hybrid beamforming. The same WTRU data may go to all scheduled gNBs. Scheduling may be performed in either a centralized or a distributed manner. In general scheduling for network hybrid beamforming may be done for the WTRU and gNBs that are scheduled to participate in the hybrid beamforming by an entity other than the WTRU and gNBs involved. However, when a gNB is capable of connecting to multiple other gNB, this gNB may also be used to schedule or configure which WTRU and/or gNB to participate network MIMO based hybrid beamforming.

[0063] FIG. 7 shows an example of multiple users and one gNB. The gNB 701, or each gNB when there is more than one, may compute its analog beamforming weights independently and may compute and share the precoding and post-coding matrices via a connection 703, 705, 705, 709, 711, and 713 for each of the J WTRUs 702, 704, 706, 708, 710, and 712, respectively, without the coordination of the core network, as shown in FIG. 7. In an embodiment, a gNB, m , such as 701 may aggregate all channel estimates for each of the J WTRUs within its coverage, and may compute an optimal set of analog beamforming weights $\Phi = g(\hat{H}_1, \hat{H}_2, \dots, \hat{H}_J)$. The gNB, m , 701 may then compute a pre-coding matrix, P_j^* , and post-coding matrix, $P_j^\dagger$, for WTRU, j $[P_j^*, P_j^\dagger] = p(\Phi, \hat{H}_1, \hat{H}_2, \dots, \hat{H}_J) | \forall j \in J$. The precoding matrix, P_j^* , may be used for the transmission 703, 705, 707, 709, 711, and 713 of messages, x_j , such that the message, y_j , received at WTRU, j , is $y_j = H_j * \Phi \sum_{j=1}^J (P_j x_j)$. The post-coding matrix, $P_j^\dagger$, for WTRU, j , may be transmitted 703, 705, 707, 709,

711, and 713 via a PDCCH or PDSCH and used by WTRU j to recover the message $\hat{x}_j = P_j^\dagger y_j$. Uplink messages may be generated using transposed forms of the post-coding matrix, $T_j^* = P_j^{\dagger T}$ as a precoding matrix so that the signal received at the gNB is $y = \Phi \sum_{j=1}^J (H_j * T_j^* x_j)$. The received uplink message, x_j , from WTRU, j , may be recovered using a transposed form of the pre-coding matrix, $T_j^\dagger = P_j^{*T}$, such that $\hat{x}_j = T_j^\dagger y$.

[0064] FIG. 8 shows an example of multiple gNBs and multiple WTRUs. Multiple gNBs 801, 802, and 803 may coordinate their signaling to multiple WTRUs 804, 805, 806 to improve a signal-to-interference-plus-noise-ratio (SINR) at the cell edge, increase network capacity, and ease handover, as shown in FIG. 8. The gNB 801 may have signaling 801a-801c to WTRUs 804-806 respectively. Similarly, gNB 802 may have signaling 802a-802c to WTRUs 804-806 respectively, and gNB 803 may have signaling 803a-803c to WTRUs 804-806 respectively. The gNBs 801-803 may communicate amongst themselves (not shown).

[0065] In order to coordinate communications across multiple gNBs, R , 801-803, the CSI for gNB, r , as given by $\hat{H}^r = \{H_1^r, H_2^r, \dots, H_J^r\}$, may be relayed to a software defined network (SDN), not shown, so that an optimal set of analog beamforming weights, $\Phi_r | \forall r \in R$, may be computed for each of the R gNBs. Additionally a pre-coding matrix, $P_{r,j}^*$, for each gNB, r , and each WTRU, j , and a post-coding matrix, $P_j^\dagger$, for each WTRU, j , may be computed. The pre-coding matrices, $P_{r,j}^*$, may be relayed to each gNB, r , via the core network, and the post-coding matrix, $P_j^\dagger$, may be relay to each WTRU, j , via a PDCCH or a PDSCH.

[0066] The signals transmitted from each gNB, x_r , may be $x_r = \Phi_r (P_{r,1}^* x_1 + P_{r,2}^* x_2 + \dots + P_{r,J}^* x_J)$. These signals may be sent synchronously from each of the R gNB's such the signal, y_j , seen as WTRU j is seen as $y_j = \sum_{r=1}^R H_j^r * x_r$. WTRU j may then recover its intended message, $\hat{x}_j$, using the post-coding matrix, $P_j^\dagger$, such that $\hat{x}_j = P_j^\dagger y_j$.

[0067] Uplink messages, x_j , may be sent from WTRU, j , using a transposed form of the post-coding matrix, $T_j^* = P_j^{\dagger T}$, so that the signal, y_r , received at gNB, r , may be seen as $y_r = \Phi_r \sum_{j=1}^J H_j^r * T_j^* x_j$. These messages may be post coded using a transposed form of the pre-coding matrix, $T_{r,j}^\dagger = P_{r,j}^*$, and the recovered message, $x_{r,j}$, may be sent to the SDN so the message, x_j , may be estimated in the aggregate as $x_j = \sum_{r=1}^R x_{r,j} = \sum_{r=1}^R T_{r,j}^\dagger y_r$.

[0068] A WTRU may estimate CSI from reference signals (RSs) embedded in a PDCCH or a PDSCH. In open loop spatial multiplexing, the CSI may be used for interference cancellation, allowing the WTRU to recover multiple layers of transmitted data. In closed loop spatial multiplexing, the CSI may be used to compute the PMI, which may be relayed back to a gNB to pre-code the data prior to transmission. In network MIMO, CSI may be aggregated by the gNB, since message pre-coding matrices may be designed to maximize capacity to all users globally.

[0069] FIG. 9 shows an example resource allocation of reference signals in a downlink transmission from a gNB. Subcarriers 902 are indicated on the vertical axis. Time 901 is indicated on the horizontal axis. The RSs for antenna port 1, 904, are indicated by blocks with a “1” inside. The reference signals (RS) for antenna port 2, 905, are indicated by blocks with a “2” inside. The blocks that are shaded represent the control 903 signals. The data 906 signals are represented by blank boxes. The RSs 904 and 905 may be used for the estimation of CSI that are used to compute the rank indication (RI), pre-coding matrix, and post-coding matrix that are used for multiple antenna signaling.

[0070] The RI and pre-coding matrix may be measured and computed at the WTRU and transmitted back to the gNB for beamforming and closed-loop MIMO spatial multiplexing. In an embodiment, the RI and pre-coding matrix may be measured and computed elsewhere, such as when network MIMO involves mixed WTRU, transmit and receive point (TRP) and gNB, then RI and pre-coding matrix may be measured and computed at the other TRP and gNB and transmitted back to the TRP or gNB for beamforming and closed-

loop MIMO spatial multiplexing. In this embodiment, the TRP and/or gNB that perform the measurement, compute, and send back the RI and pre-coding matrix may be treated as a “special” WTRU without mobility. In another embodiment, (i.e., in TDD), RI and a pre-coding matrix may be measured and computed at the TRP and gNB when channel reciprocity between DL and UL is available.

[0071] As shown by the example in FIG. 9, RSs from separate antenna ports 904 and 905, or generically indicated by RS_i , may be transmitted orthogonally in time 901 and frequency/subcarrier 902. The received pilot tones, $x_{RS_i}(k, n)$, at sub carrier, k , in time slot, n , enable estimation of the channel at the WTRU through the channel estimation operation, f , such that

$$\begin{aligned} &f(x_{RS_1}(k_{RS_1(1)}, n_{RS_1(1)}), x_{RS_1}(k_{RS_1(2)}, n_{RS_1(2)}), \dots, x_{RS_1}(k_{RS_1(l_1)}, n_{RS_1(l_1)}), \\ &x_{RS_2}(k_{RS_2(1)}, n_{RS_2(1)}), x_{RS_2}(k_{RS_2(2)}, n_{RS_2(2)}), \dots, x_{RS_2}(k_{RS_2(l_2)}, n_{RS_2(l_2)}), \dots, \\ &x_{RS_w}(k_{RS_w(1)}, n_{RS_w(1)}), x_{RS_w}(k_{RS_w(2)}, n_{RS_w(2)}), \dots, x_{RS_w}(k_{RS_w(l_w)}, n_{RS_w(l_w)})) = \hat{H}. \end{aligned}$$

[0072] The channel estimate, $\hat{H}_j$, for user, j , may be transmitted via a PUCCH or a PUSCH back to the gNB.

[0073] FIG. 10 shows an example resource allocation of reference signals in a downlink transmission from a gNB involving multiple WTRUs. Time 1001 is indicated on the horizontal axis. Subcarriers 1002 are indicated on the vertical axis. The full transmission of CSI for each WTRU 1004-1007 may require significant overhead which may reduce the total network capacity. Control overhead for CSI reporting may be reduced if unique RSs are transmitted orthogonally in the uplink channel. The RSs for each WTRU 1004-1007 are represented by blocks with 1, 2, 3, and 4, respectively. The control 1003 signal is represented by shaded blocks. The data 1008 signal is represented by the blank blocks. At initiation, each WTRU 1004-1007 may be provided a resource element via the PDCCH. The resource element may be used for the transmission of a unique pilot in a PUSCH for the purpose of estimating the channel at the gNB. The gNB may be capable of computing the channel estimate, $\hat{H}_j$, for WTRU, j , and may aggregate the channel estimates for all of the J WTRUs; in the example of FIG. 10 J WTRUs are 1004-1007. The collection of CSI may either be used at the gNB to compute the optimal

analog beamforming weights, Φ_r , and pre-coding matrix, $P_{r,j}^*$, and post-coding matrix, $P_j^\dagger$ locally, or relay the CSI set, $\hat{H}^r$, to compute the weights globally. The post-coding matrices may again be sent to the destination WTRUs via a PDCCH or a PDSCH.

[0074] In an embodiment, the PDCCH may be transmitted from a serving gNB or TRP. Alternatively each gNB or TRP participating network MIMO may transmit PDCCH to the desired WTRU. In case that PDCCH is transmitted from a serving gNB or TRP, the control information 1003 may be carried by this PDCCH. In case that PDCCH is transmitted from multiple gNBs or TRPs, same control information 1003 may be carried by different PDCCHs. Alternatively, different control information 1003 may be carried by multiple PDCCHs transmitted from multiple gNBs or TRPs.

[0075] FIG. 11A and 11B shows an example of gNB signaling and WTRU procedures to enable network MIMO. In a signaling procedure there may be one or more WTRUs 1105, a plurality of small cells (SCs) 1101, 1102, and 1103 that each may have a serving gNB. There may also be a gNB or C-RAN network controller 1104. Synchronous MMW data transmission from multiple MMW may be shown by a shaded arrow. A wired interface 1107 may be shown by a dotted arrow. Single layer MMW transmission 1108 may be shown by a non-dotted arrow.

[0076] The periodicity and frequency resolution to be used by a WTRU 1105 to report channel quality information (CQI) may both be controlled by a gNB. In the time domain, both periodic and aperiodic CQI reporting may be supported. Additionally, in a case where there are multiple antennas in use, CQI values may be reported for more than one codeword. The CQI report corresponding to all gNBs for which measurements are available may be sent to the serving gNB of a SC 1101-1103.

[0077] In periodic CQI report configuration, CQI/PMI/RI may be transmitted periodically with a certain interval specified by higher layer message (e.g., radio resource control (RRC) Connection Reconfiguration, RRC Connection Setup). At 1111, the analog beamforming weights or beam ID may be exchanged during WTRU 1105 attachment and may be refreshed

periodically with the rate depending on WTRU 1105 mobility or speed. Digital beamforming attributes (e.g., channel measurements or precoder matrix index) may be reported with a different frequency depending on WTRU 1105 mobility or speeds. In one embodiment, a prioritized list of beams may be reported in the analog beamforming weights feedback procedure.

[0078] At 1112 the gNB of each SCs 1101-1103 may then send reference signals or pilots using some or all of the reported beams. At 1113 the WTRUs 1105 may report a CSI or local estimates of the precoding matrix to one or more of the gNB of each SCs 1101-1103 which then send it to the Network Controller 1104. Once the measurements or feedback from WTRU 1105 are received, the gNB of each SCs 1101-1103 or central network controller 1104, may then choose the optimum set of beams (transmit and receive) to communicate with the WTRU 1105 from all of the gNBs of each SCs 1101-1103. The CSIs reported by the WTRUs may be distributed by the serving gNB of each SCs 1101-1103 to other gNBs in the cluster via an X2 interface or the like. The cluster may consist of gNBs that the WTRU 1105 communicates with using network MIMO. The cluster of gNBs may change based on WTRU 1105 mobility.

[0079] At 1114, based on the CSI reported for each WTRU 1105 served by the network, a global precoding matrix may be computed by a central network controller 1104 that may contain individual precoding matrices to be used by the gNB of each SCs 1101-1103 to communicate with the WTRUs 1105 associated with it. The precoding matrix may be computed and maintained by a single centralized entity, such as the central network controller 1104. Portions of the matrix relevant to individual gNBs may be sent to the gNB of each SCs 1101-1103 by the central network controller 1104, whenever they are updated. The periodicity of the precoding matrix updates may be linked to the CSI feedback rate from the WTRU 1105, which may in turn be linked to the WTRU mobility speed. Different portions of the precoding matrix may be updated with different frequencies.

[0080] For example, a WTRU, WTRU1, may be associated with two gNBs, gNB1 and gNB2. Additionally, gNB1 and gNB2 may be associated with

another WTRU, WTRU2. Therefore, both gNB1 and gNB2 may have portions of the global precoding matrix corresponding to WTRU1 and WTRU2.

[0081] Different analog beams at a WTRU may have asymmetric capacities and unequal number of digital layers that they may support. A scheduler at any one the gNBs of each SCs 1101-1103 may map different data streams to the different digital layers/streams depending on the required parameters such as throughput, reliability, etc. The gNB may trade extra capacity over multiple spatial layers/streams with higher reliability via spatial diversity. An analog beam with two digital layers may be used for URLLC traffic, with spatial diversity configuration, whereas another analog beam with a single, high quality digital layer may be used for eMBB traffic. Additional signaling may be required between a gNB of a SC 1101-1103 and WTRU 1105 to coordinate the various transmission modes.

[0082] At 1116, a hierarchical method of feedback may be considered where CSI or estimated precoding matrix values may be reported by the WTRU 1105 more frequently than analog beam identifiers. Additionally, the analog beam identifier feedback may be configured for triggered updates whereas the digital beamforming parameters (e.g., CSI, precoding matrix values, etc.) may be configured to be updated periodically. When the digital beamforming feedback values change significantly (e.g., greater than a pre-defined or pre-determined threshold) an analog beam quality update procedure may be triggered, such as at 1115. As a note, the precoding matrix and postcoding matrix may be sent depending on the directions; CSI reports including precoding matrix may be sent in the UL direction (e.g., reported from WTRU) while postcoding matrix may be sent in the DL direction (e.g., send by gNB).

[0083] For example, digital beamforming parameters may be fed back by the WTRU 1105 every transmission time interval (TTI), and when a gNB, such as the gNB of SC 1101, finds that the reported digital beamforming values have changed considerably from previously reported values, the analog beamforming weight update procedure is triggered. The gNB of SC 1101 may then schedule an analog (or truncated analog) beamforming weight estimation

procedure in the current or next TTI, where the gNB of SC 1101 and WTRU 1105 test one or more candidate beams to find the optimum transmit-receive pair. Since the gNB at SC 1101 and WTRU 1105 may have a working reference beam pair that was used previously, the gNB at SC 1101 and WTRU 1105 may test a few nearby beams for optimality in a truncated procedure.

[0084] In the hierarchical feedback method, an update 1115 to the analog beamforming weights or analog beams, may require channel measurements to update the digital beamforming values (e.g., CSI, precoding weights, etc.).

[0085] The WTRU 1105 may make periodic channel measurements based on a schedule sent by one of the gNB of SCs 1101-1103 or network controller 1104. The measurements may include signal strength measurements using multiple alternate analog beam identifiers and channel measurements using previously adopted analog beams to determine digital beamforming weights. The WTRU 1105 may send back either the raw channel measurements (CSI) or locally computed precoding matrix values at 1116. Once the measurements and an acknowledgement is made by the gNBs of SCs 1101-1103, the precoding matrix is updated at 1117. At this point 1118, data may be sent originating from the core network/gateway (not shown) to the gNBs of SCs 1101-1103 destined for the WTRU 1105. The data may be sent from the gNBs of each SCs 1101-1103 to the WTRU 1105 by synchronous MMW transmission. The WTRU 1105 may send back an ACK depending on the success of receiving the data from the core network/gateway (not shown) at 1119.

[0086] The analog antenna weights and digital antenna weight updates may repeat as necessary as indicated in 1120-1122. The digital antenna weights may be updated more frequently than analog antenna weights.

[0087] In another embodiment, there may be more than one WTRU and each WTRU may perform a full analog beam sweep at start up to identify an optimum transmit-receive beam pair for a particular gNB. The WTRUs may perform signal strength measurements using each of its available receive beams for each transmit beam used by a gNB to transmit reference signals.

The WTRU may report the best gNB transmit beam that it observes. The transmit beam identifier may be known to the WTRUs, either via a transmission schedule shared earlier by the gNB or via L1/L2 control signaling sent in a PDCCH or higher layer message. Additionally, the WTRUs may also report the local receive beam that results in optimum signal strength measurement. The WTRUs may be configured to report the first N ($N \geq 1$) gNB transmit beams and WTRU receive beams.

[0088] Next, the WTRUs may be directed by the gNB to make channel estimates using previously identified analog beams. The CSI values may be used to locally estimate the precoding matrix entries. The results (CSI or precoding matrix values) may be reported to the gNB via an uplink control message or signaling such as PUCCH, control-based PUSCH or the like.

[0089] Next, the beamwidth to be used for analog beamforming beam estimation may be supplied by the gNB. The gNB may vary the beamwidth to support different WTRU mobility speeds. For example, the gNB may increase beamwidth to accommodate higher speed or higher mobility WTRUs. Furthermore the gNB may adjust beamwidth properly to accommodate a group of WTRUs.

[0090] In another embodiment, the WTRU may be directed to perform digital beamforming weight estimation with the widest possible analog beam that allows successful signal reception. Thereafter, a gNB may calculate the digital precoding vector values for smaller WTRU beamwidths from the widest beamwidth measurement. This may be possible if the angle of arrival (AoA) of the various beams at the WTRU are reliably estimated.

[0091] A primary PUCCH or primary control channel may be switched to another gNB based on link availability. In either a transmission from the gNB to a WTRU(s), or from a WTRU to a gNB, an acknowledge (ACK) message may be modified to signal successful signal reception under various conditions including: all digital spatial streams or spatially diverse streams are successfully received; some digital spatial streams or spatially diverse streams are received successfully; no spatial stream is successfully received (NACK).

[0092] While the ACK/NACK message may be transmitted using the same configuration that was used for signal reception, in case of link blockage affecting some, but not all, of the streams (i.e., some streams are successfully received), the ACK may be sent using the antenna on which successful data stream reception occurred. A partial ACK option, where some digital spatial streams or spatially diverse streams are received successfully, may be sent in that case.

[0093] Both network MIMO and non-network MIMO transmissions may occur simultaneously in the network. Therefore, some WTRUs may receive and transmit data to a single gNB at a time whereas other WTRUs may be communicating simultaneously with more than one gNB. In any scenario, example, or embodiment described herein, a single WTRU may be replaced with multiple WTRUs and a single gNB may be replaced with multiple gNB to demonstrate the system, apparatuses, and methods as described herein.

[0094] Although features and elements are described above in particular combinations, one of ordinary skill in the art will appreciate that each feature or element can be used alone or in any combination with the other features and elements. In addition, the methods described herein may be implemented in a computer program, software, or firmware incorporated in a computer-readable medium for execution by a computer or processor. Examples of computer-readable media include electronic signals (transmitted over wired or wireless connections) and computer-readable storage media. Examples of computer-readable storage media include, but are not limited to, a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, and optical media such as CD-ROM disks, and digital versatile disks (DVDs). A processor in association with software may be used to implement a radio frequency transceiver for use in a WTRU, UE, terminal, base station, RNC, or any host computer.

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CLAIMS

What is claimed is:

1. A method for hybrid beamforming based network multiple input and multiple output (MIMO) performed by a next generation Node-B (gNB) of a small cell, comprising:

receiving channel state information (CSI) from at least one wireless transmit/receive unit (WTRU);

aggregating the CSI received from the at least one WTRU;

receiving at least one precoding matrix from a network controller for each of the at least one WTRU;

receiving data from the network controller individually addressed to the at least one or more WTRU;

encoding the data based on the at least one precoding matrix for each of the at least one or more WTRU; and

transmitting the data to the at least one WTRU.

2. The method according to claim 1, further comprising:

computing, by the gNB, one or more analog beamforming weights based on an aggregation of the CSI from each of the at least one WTRUs.

3. The method according to claim 2, further comprising:

computing, by the gNB, postcoding matrices for each of the at least one WTRU; and

transmitting, by the gNB, one of the postcoding matrices via a physical downlink control channel (PDCCH) or a physical downlink shared channel (PDSCH) to each the at least one WTRU.

4. The method according to claim 2, wherein the transmitting of the encoded data to the at least one WTRU is based on the computed beamforming weights.

5. The method according to claim 4, wherein the data is transmitted by the gNB over a PDSCH.

6. The method according to claim 1, further comprising:
transmitting, by the gNB, a precoding matrix indicator (PMI) to the at least one WTRU.

7. The method according to claim 6, wherein the PMI is transmitted by the gNB over a physical downlink control channel (PDCCH).

8. The method according to claim 6, further comprising:
recovering, by the gNB, a plurality of signals from the at least one WTRU; and
resolving, by the gNB, each signal of the plurality of signals from the at least one WTRU using a transformation of a global PMI.

9. The method according to claim 1, further comprising:
exchanging, by the gNB, data and CSI with another gNB.

10. The method according to claim 1, further comprising:
performing, by the gNB, analog beamforming directed to a desired WTRU that is scheduled for hybrid beamforming.

11. The method according to claim 1, further comprising:
deriving, by the gNB, an overall precoding matrix from individual precoding matrixes of multiple gNBs.

12. A method for hybrid beamforming based network multiple input and multiple output (MIMO) for use in a wireless transmit/receive unit (WTRU) comprising:

measuring, by the WTRU, channel state information (CSI);
sending, by the WTRU, the CSI to a gNB;

receiving, by the WTRU, data from the gNB;
cancelling, by the WTRU, interference using a precoding matrix indicator (PMI); and
recovering, by the WTRU, data from the received data.

13. The method according to claim 12, further comprising:
receiving, by the WTRU, a PMI from the gNB.

14. The method according to claim 12, further comprising:
computing, by the WTRU, a WTRU precoding matrix from the PMI; and
synchronizing, by the WTRU, with other WTRUs using a primary synchronization signal (PSS), a secondary synchronization signal (SSS), or timing advance (TA).

15. The method according to claim 12, further comprising:
estimating, by the WTRU, CSI received from a gNB using orthogonal reference signals;
computing, by the WTRU, an analog beamforming weight;
computing, by the WTRU, a precoding matrix;
computing, by the WTRU, a postcoding matrix; and
computing, by the WTRU, a rank indicator (RI), wherein the RI indicates a number of digital layers that may be supported via spatial multiplexing.

16. The method according to claim 12, wherein the analog beamforming weight, the PMI, and the RI are transmitted over a physical uplink control channel (PUCCH) or a physical uplink shared channel (PUSCH).

17. The method according to claim 12, further comprising:
receiving, by the WTRU, data from multiple gNBs simultaneously.

18. The method according to claim 12, further comprising:
estimating, by a WTRU, CSI from reference signals that are embedded in a physical downlink control channel (PDCCH) or a physical downlink shared channel (PDSCH).

19. The method according to claim 12, wherein the method is performed in a millimeter wave (mmW) ultra dense network (UDN).

100

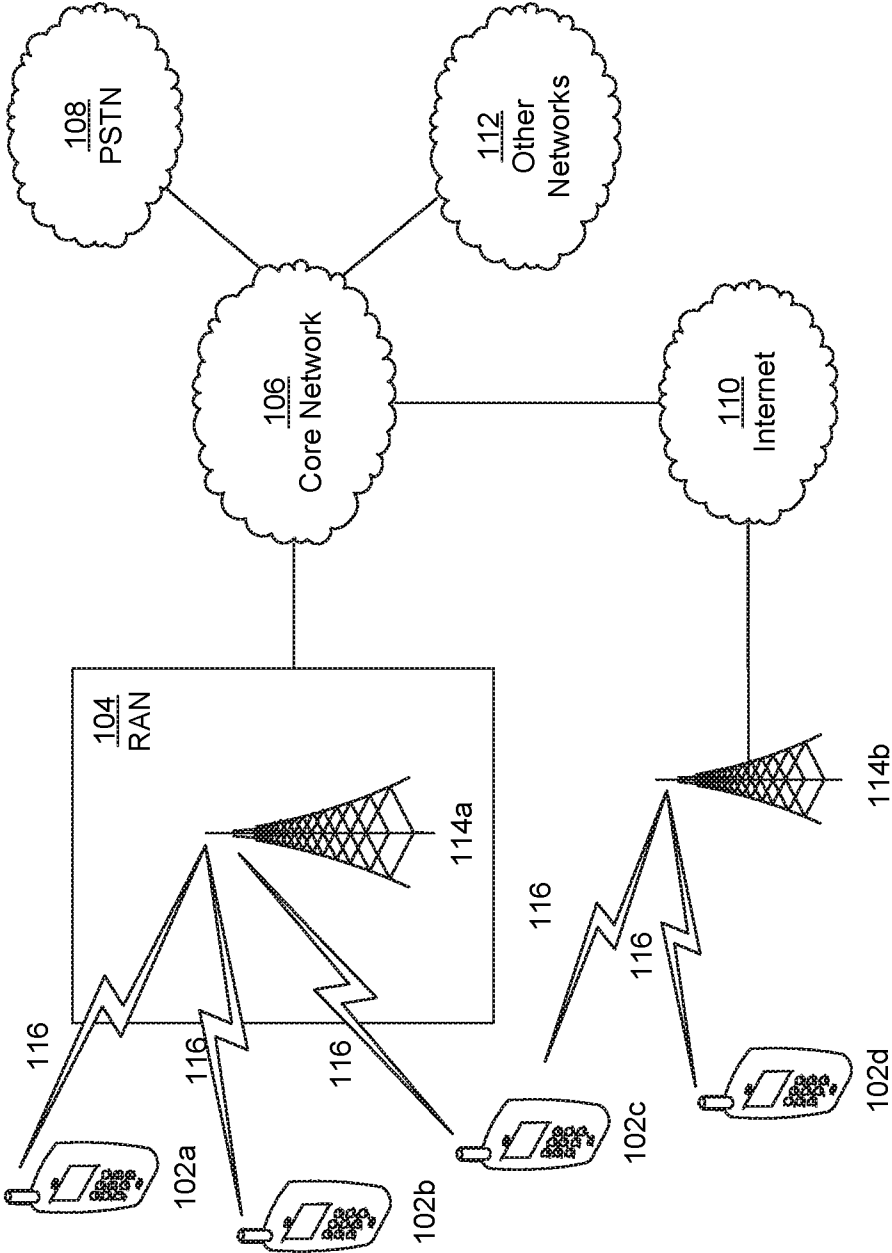


FIG. 1A

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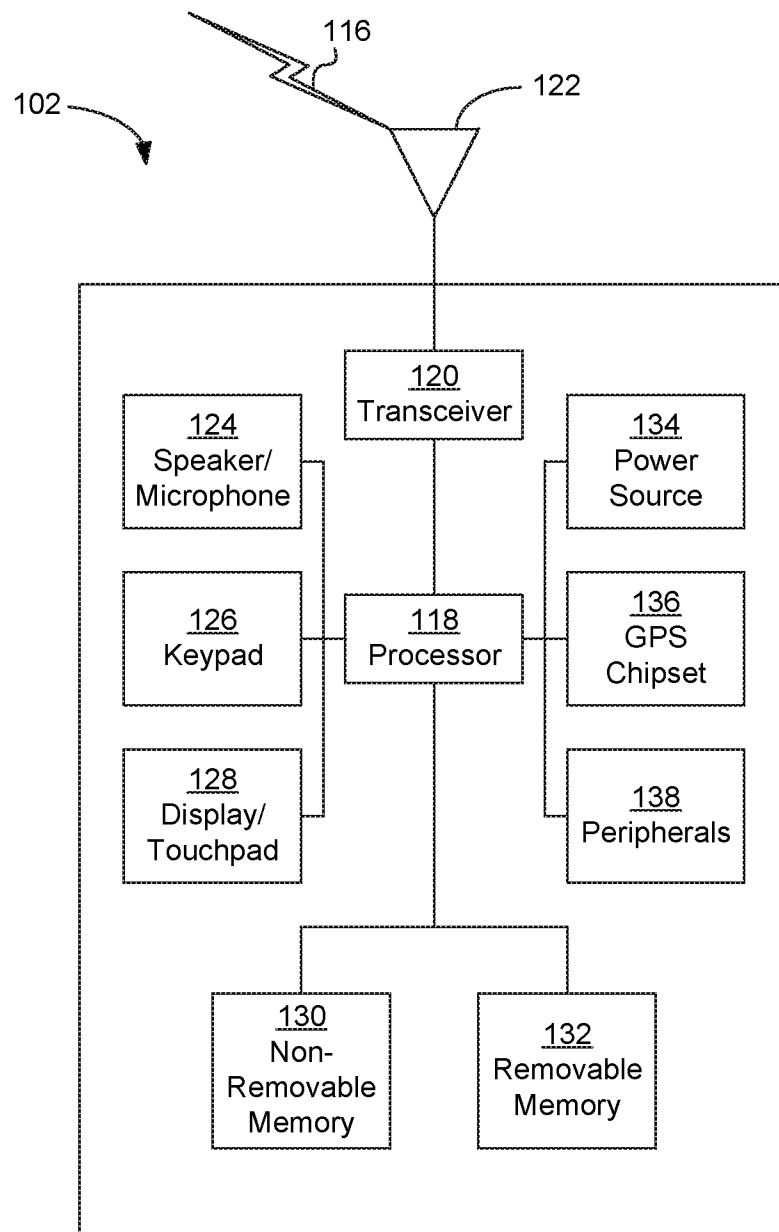


FIG. 1B

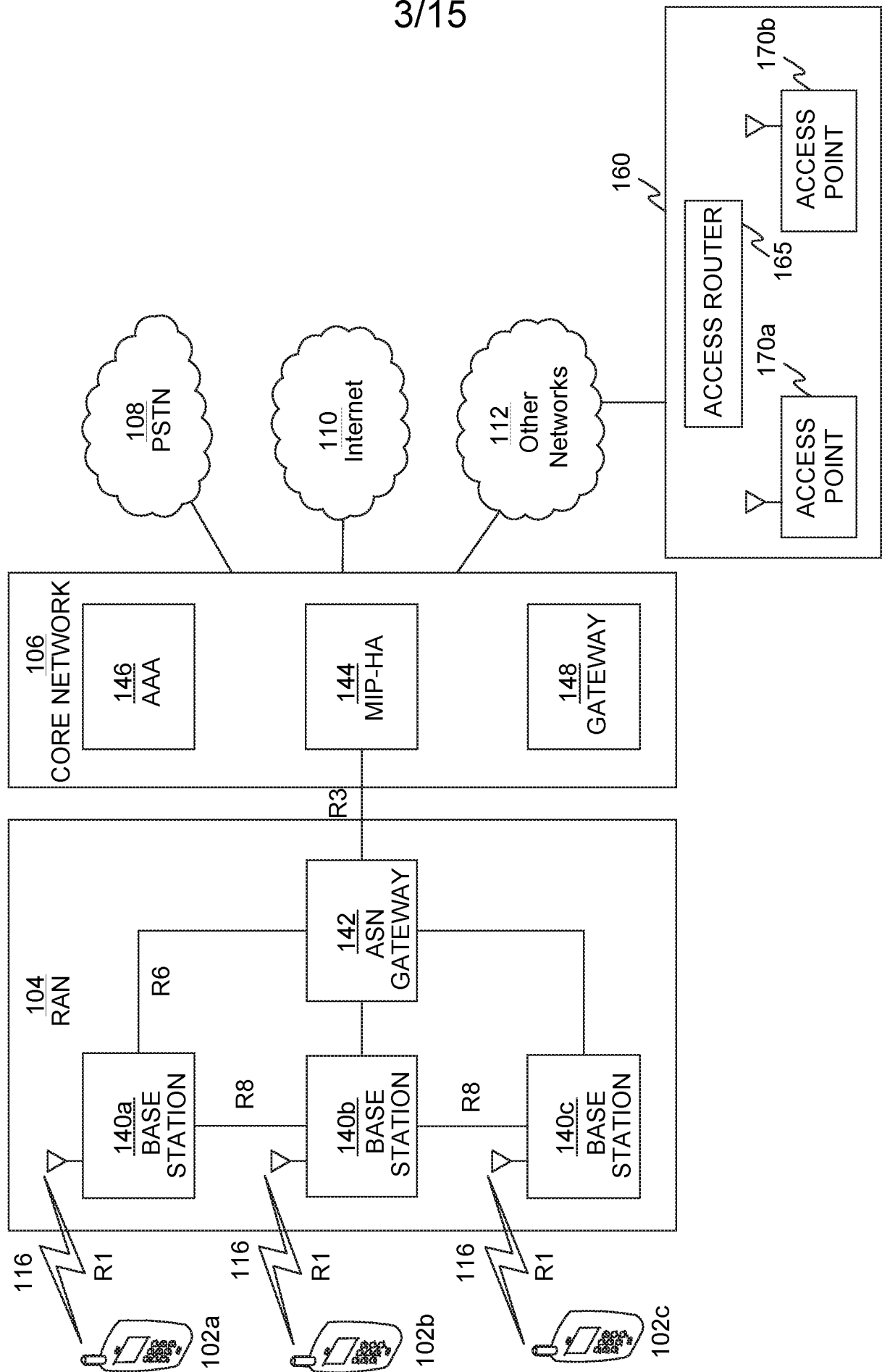


FIG. 1C

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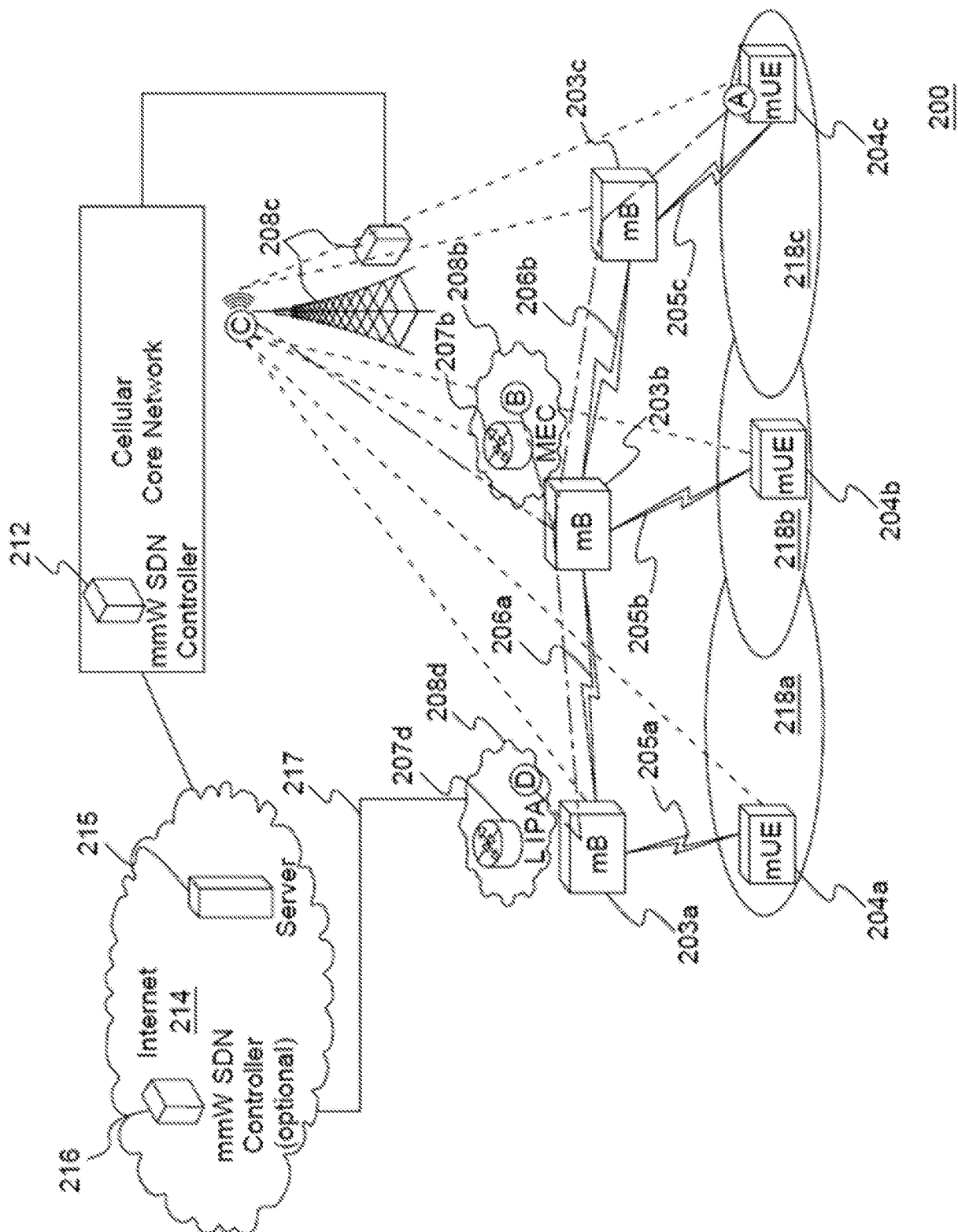


FIG. 2

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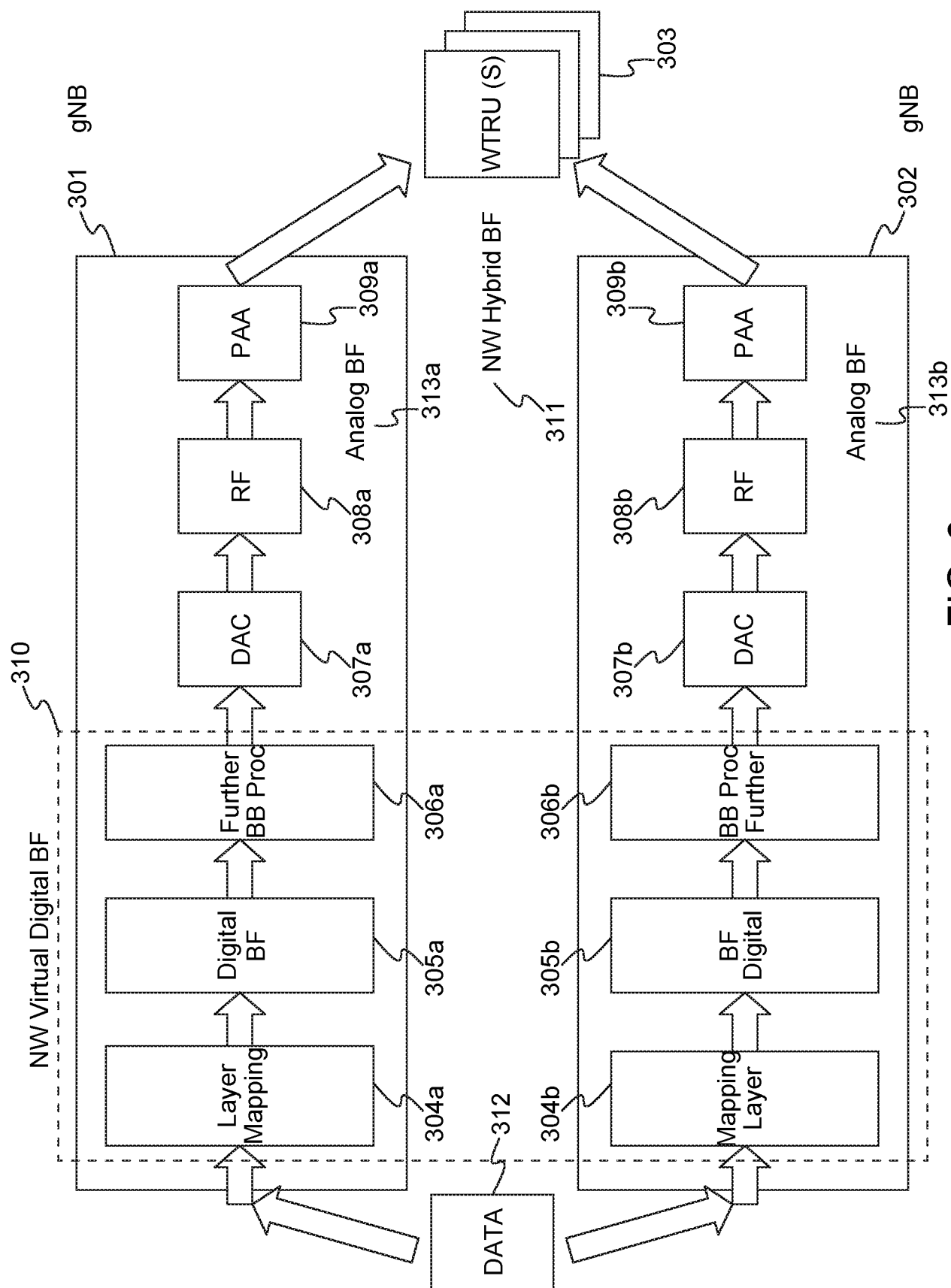


FIG. 3

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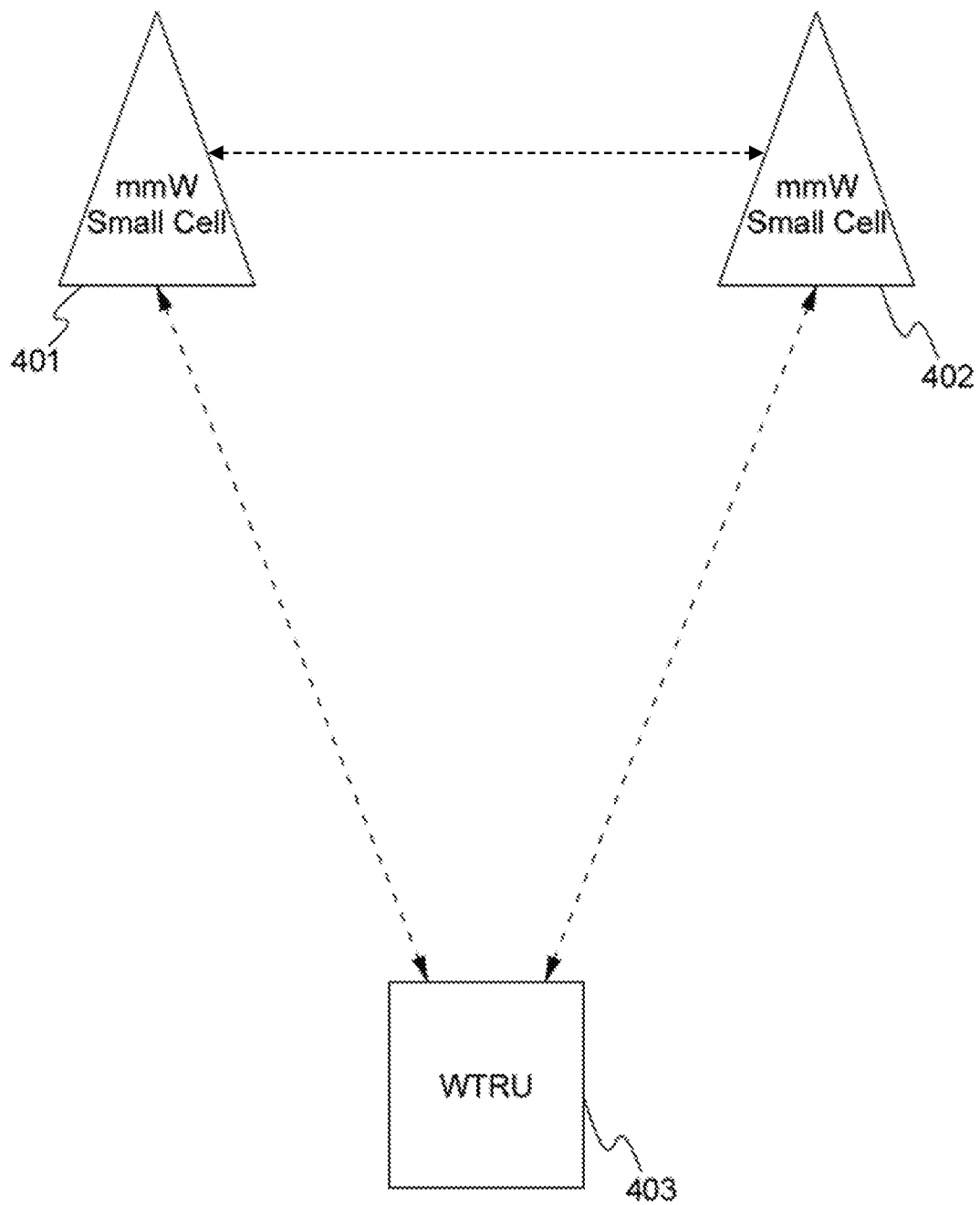


FIG. 4

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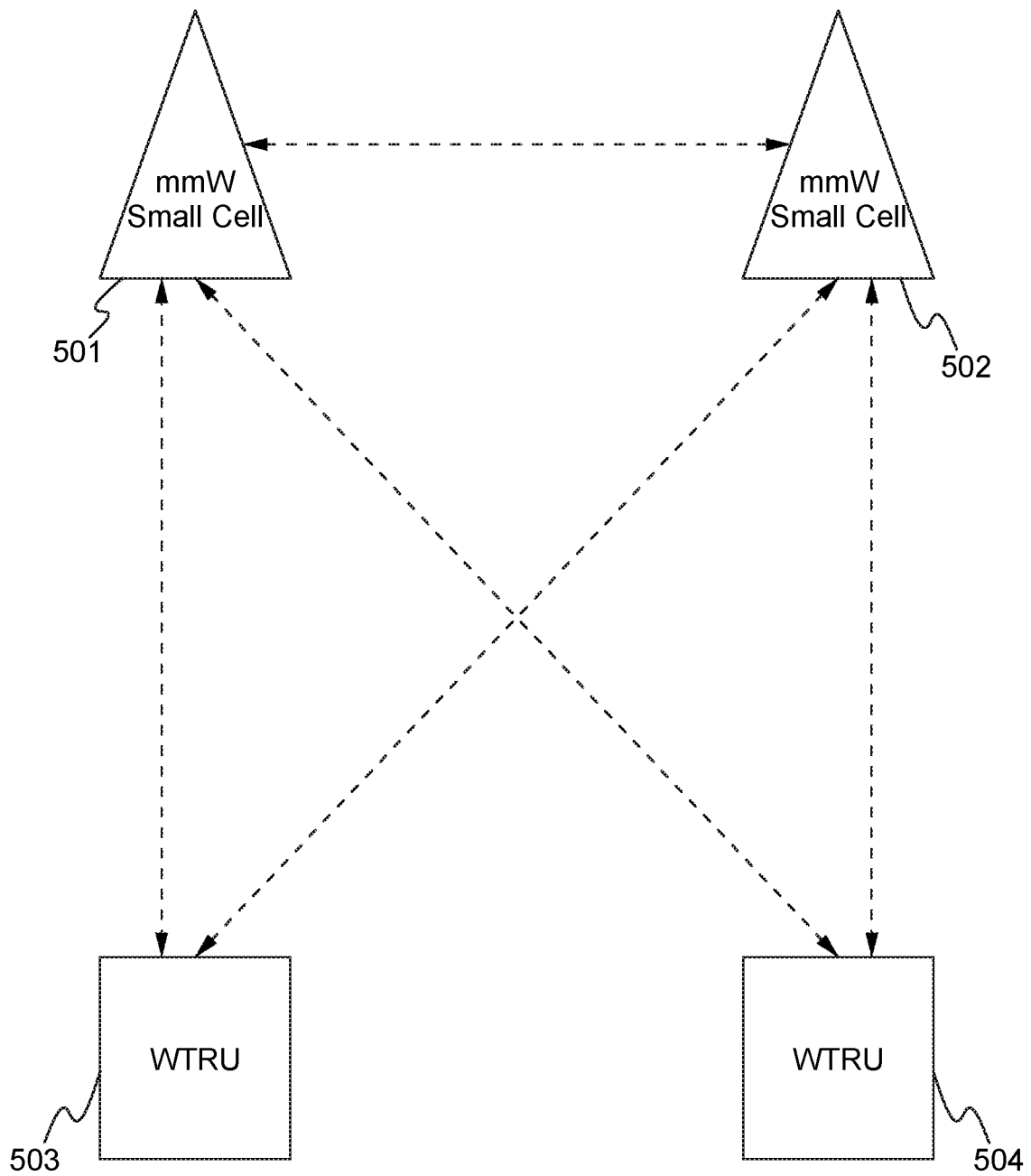


FIG. 5A

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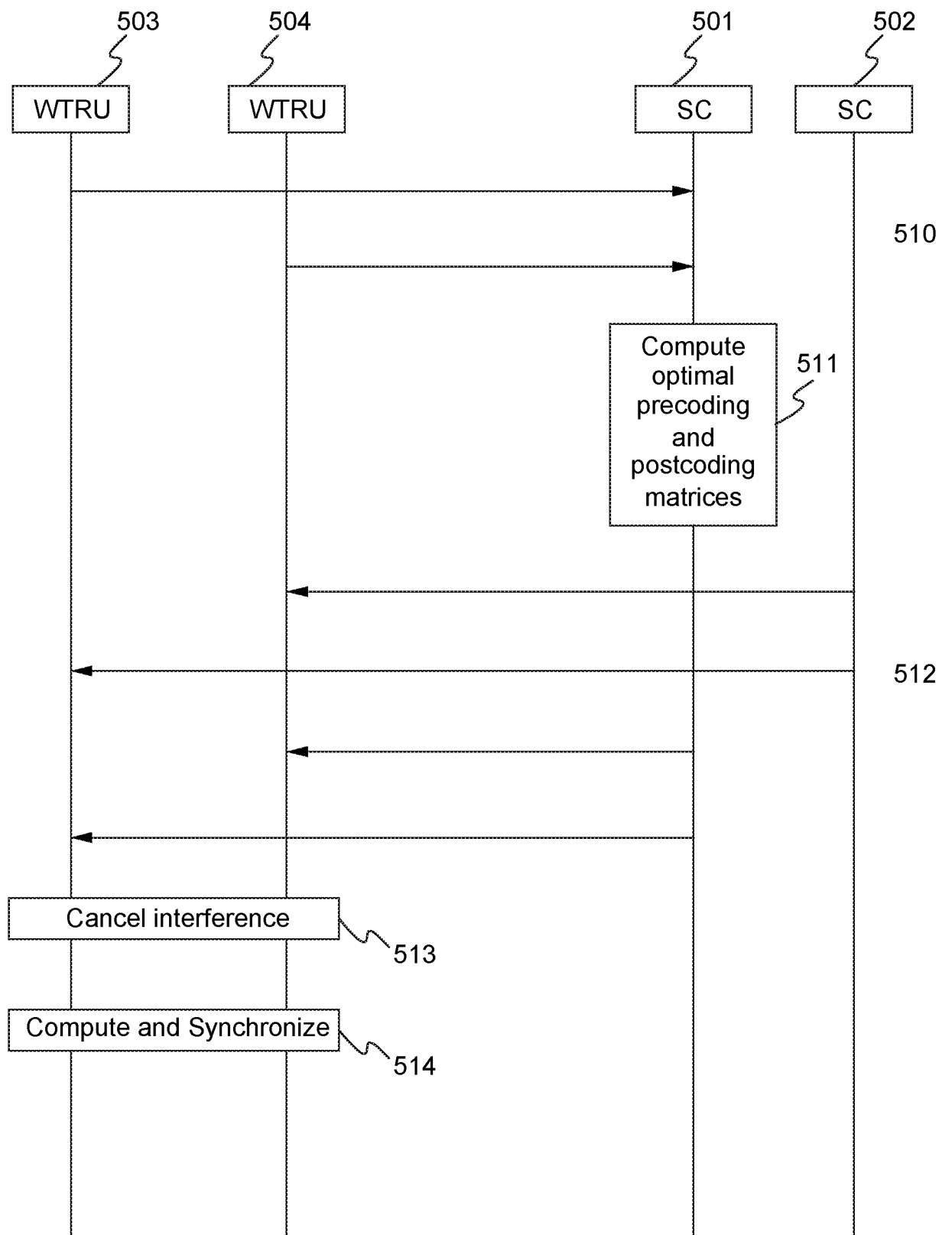


FIG. 5B

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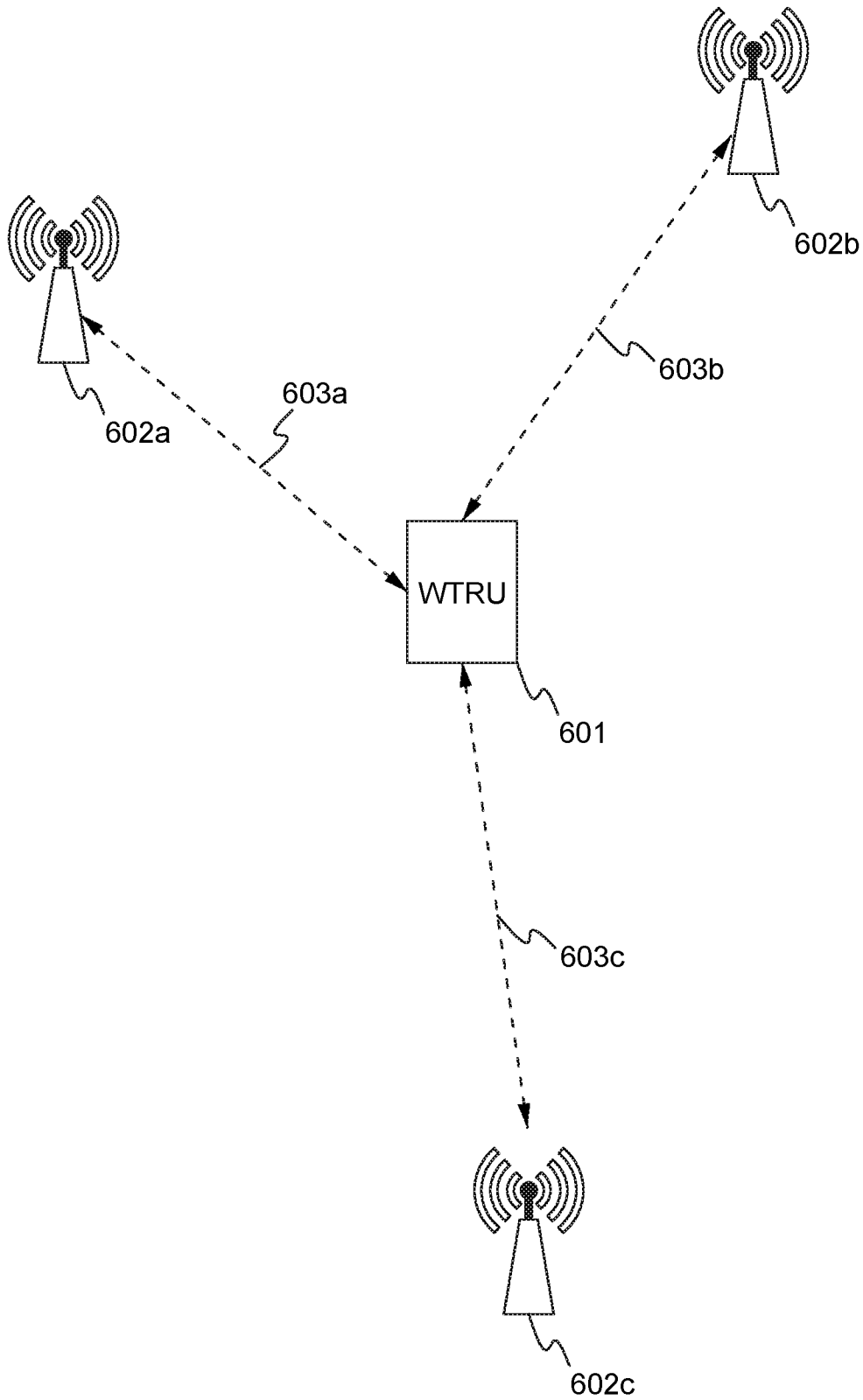


FIG. 6

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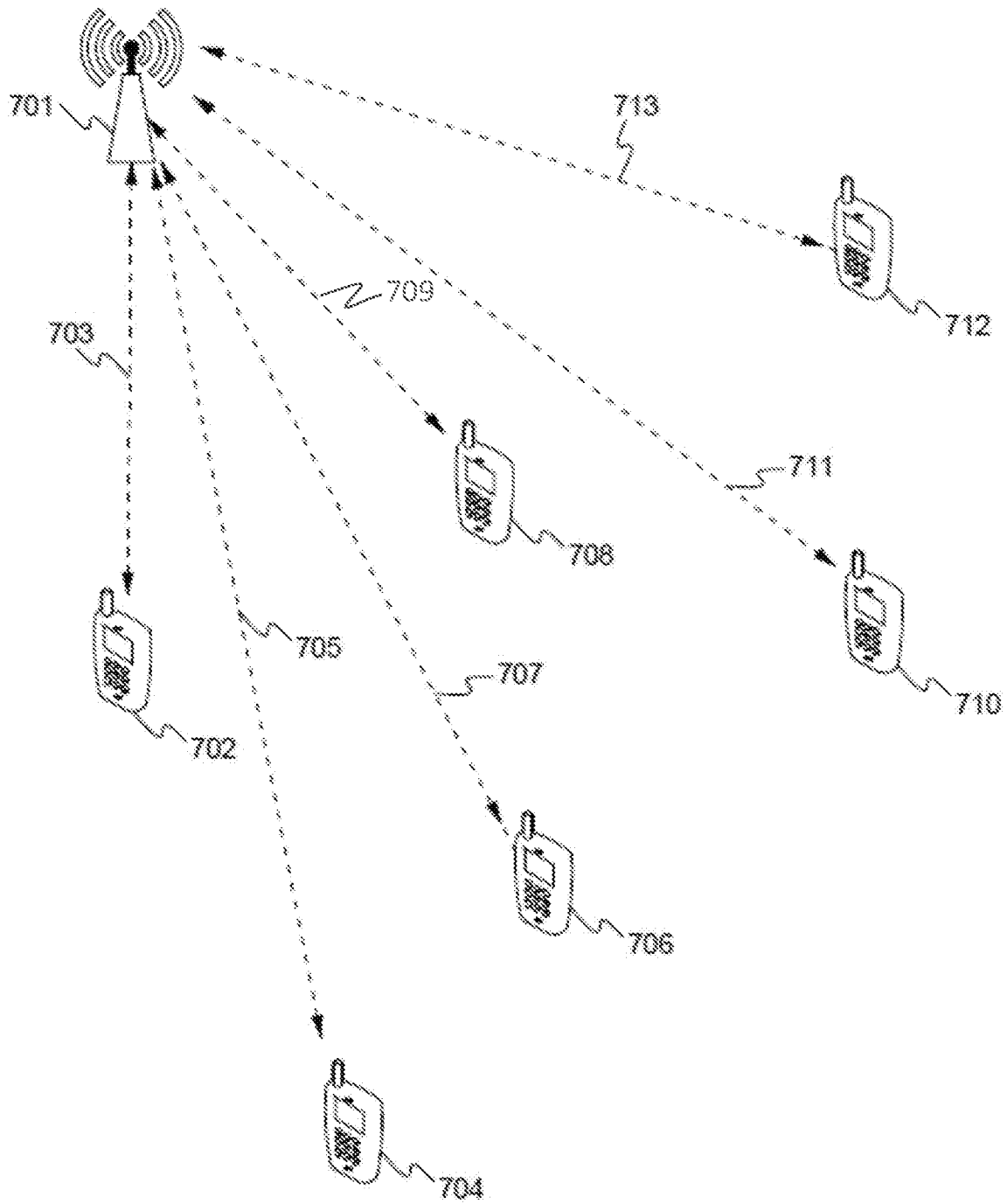


FIG. 7

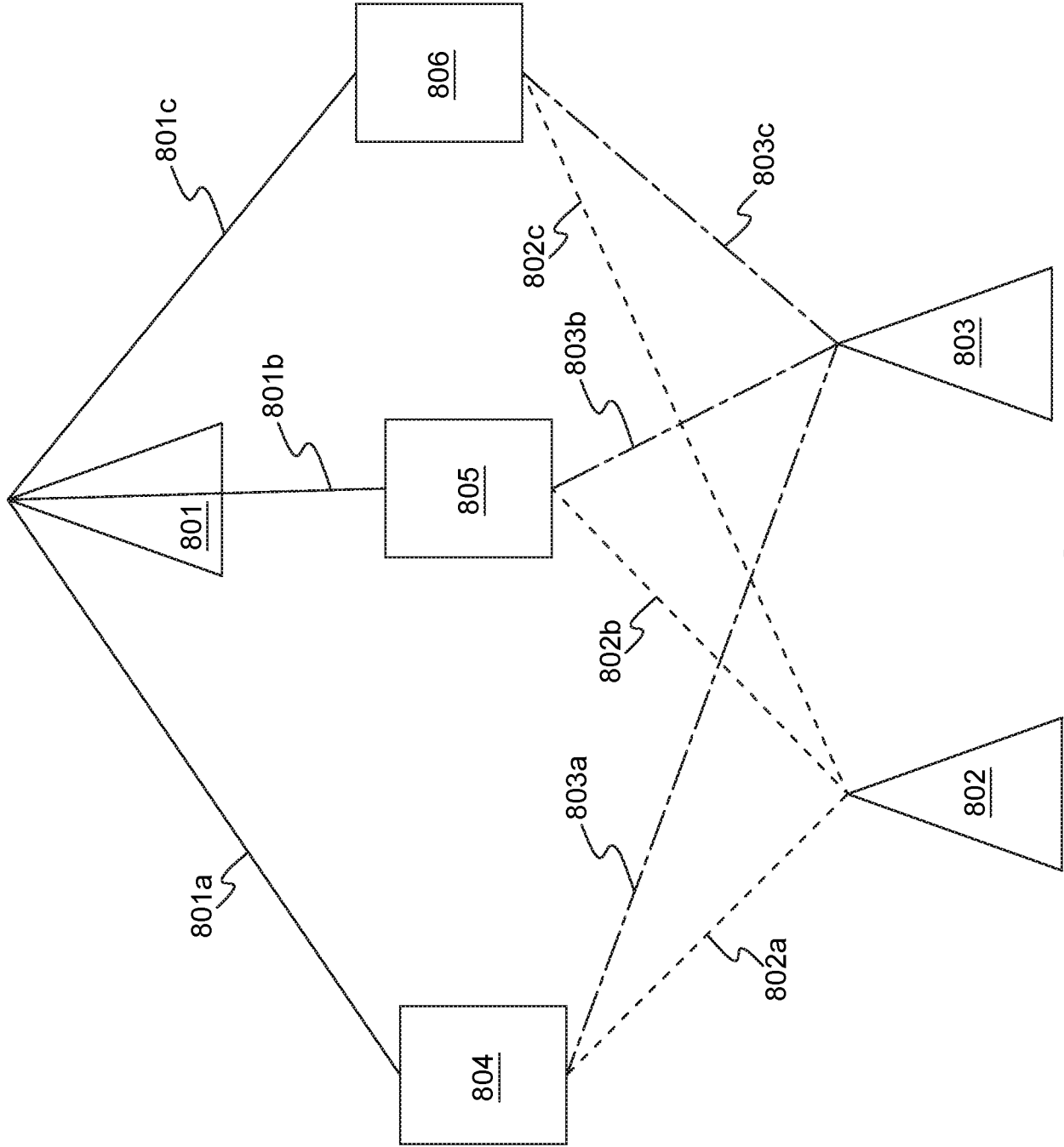


FIG. 8

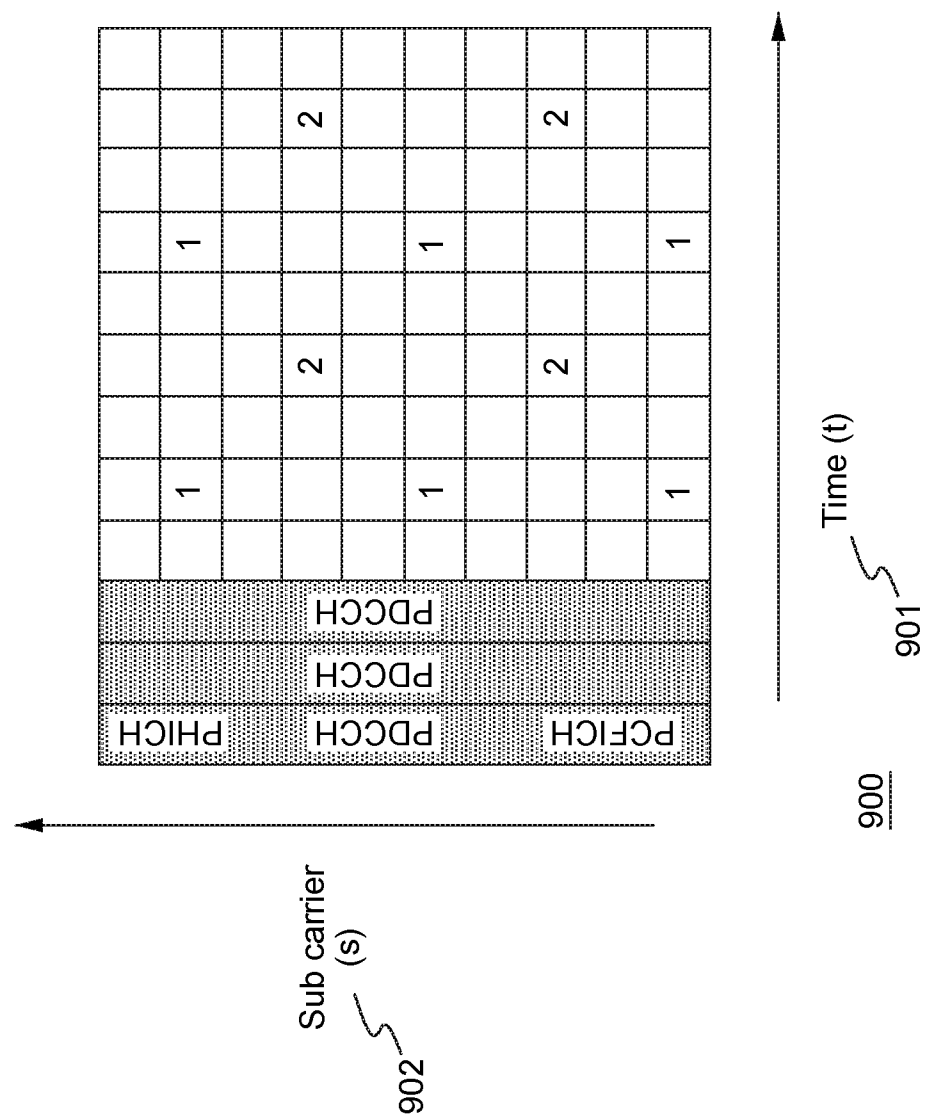
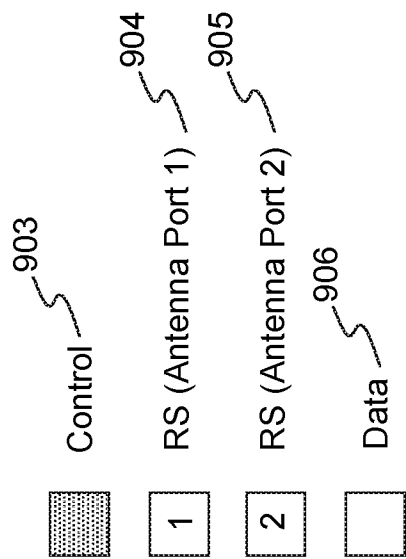


FIG. 9

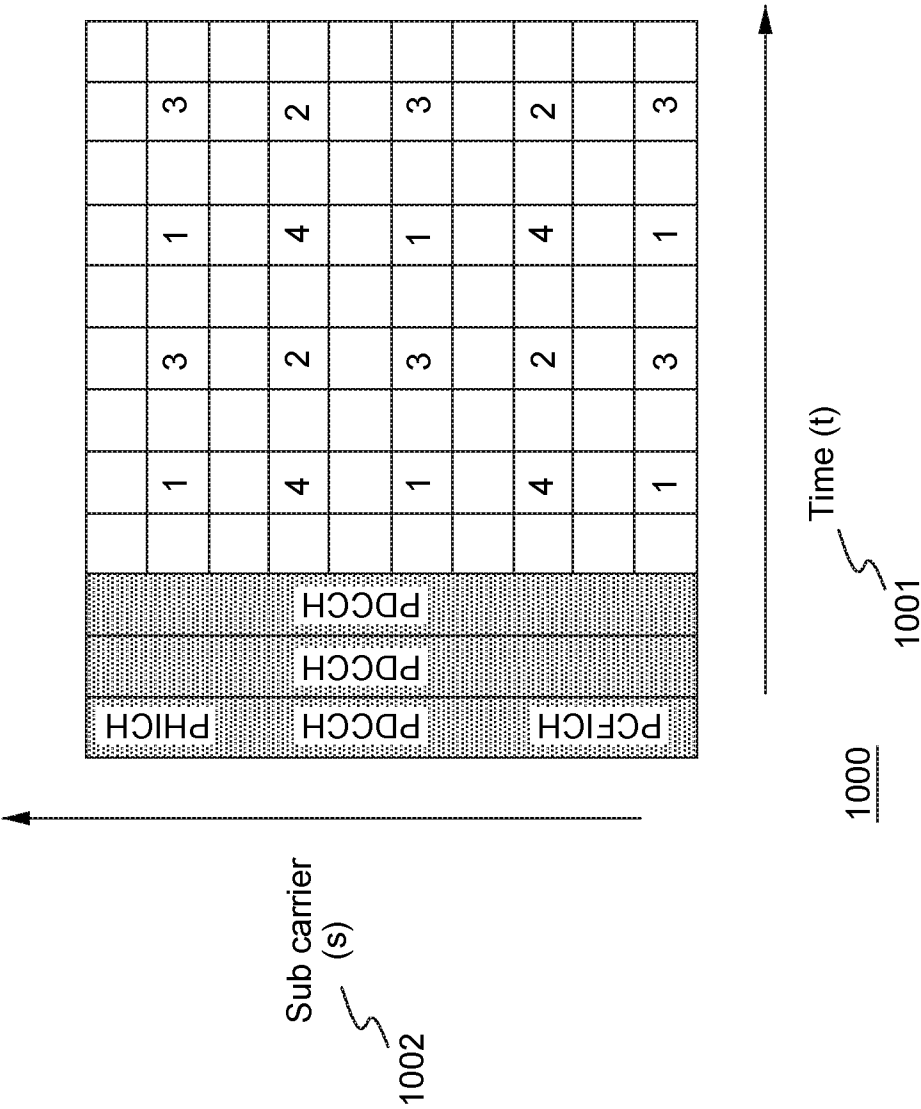
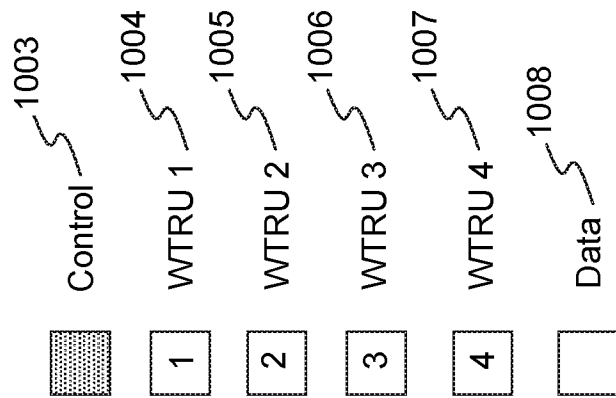


FIG. 10

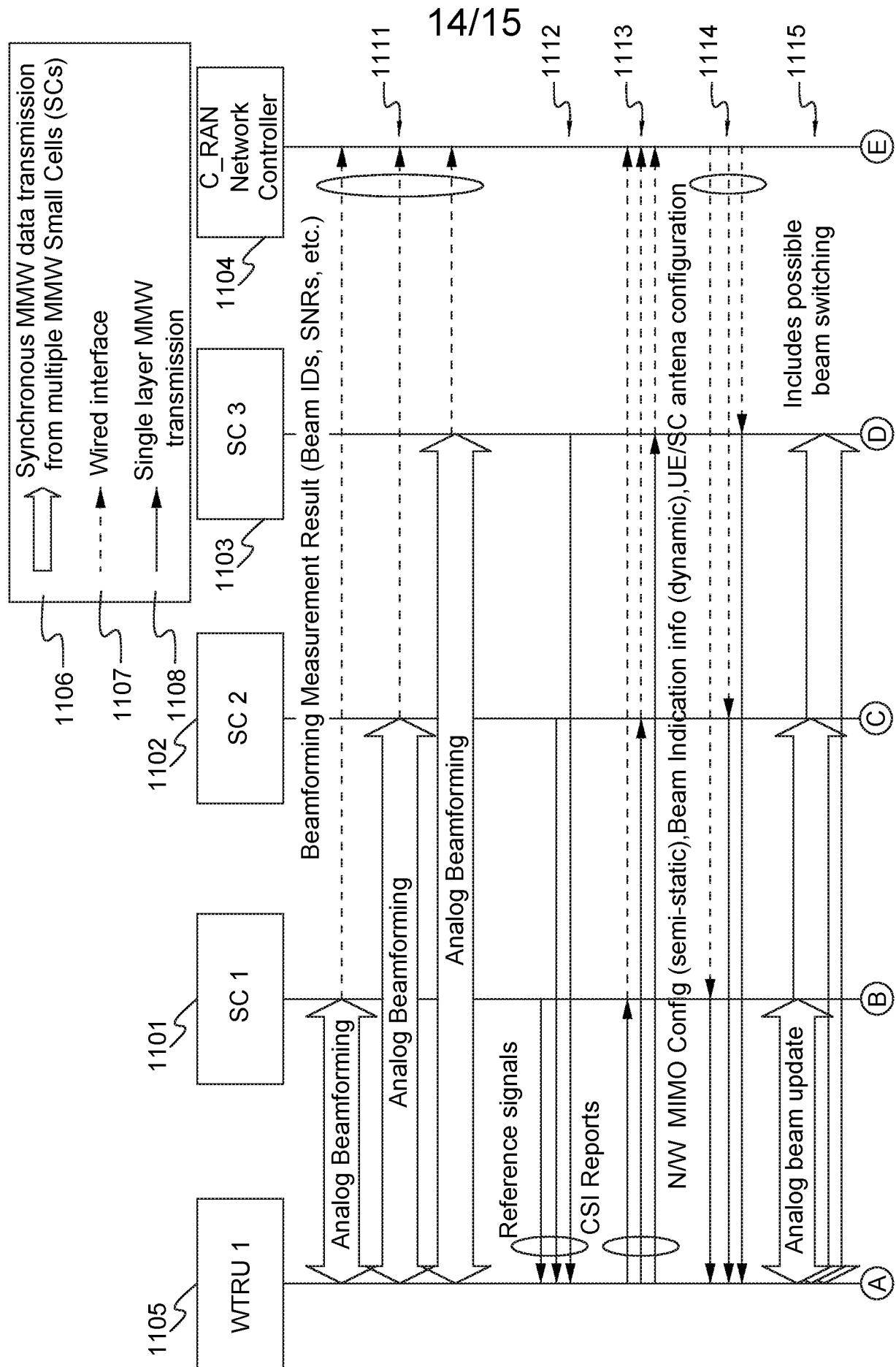
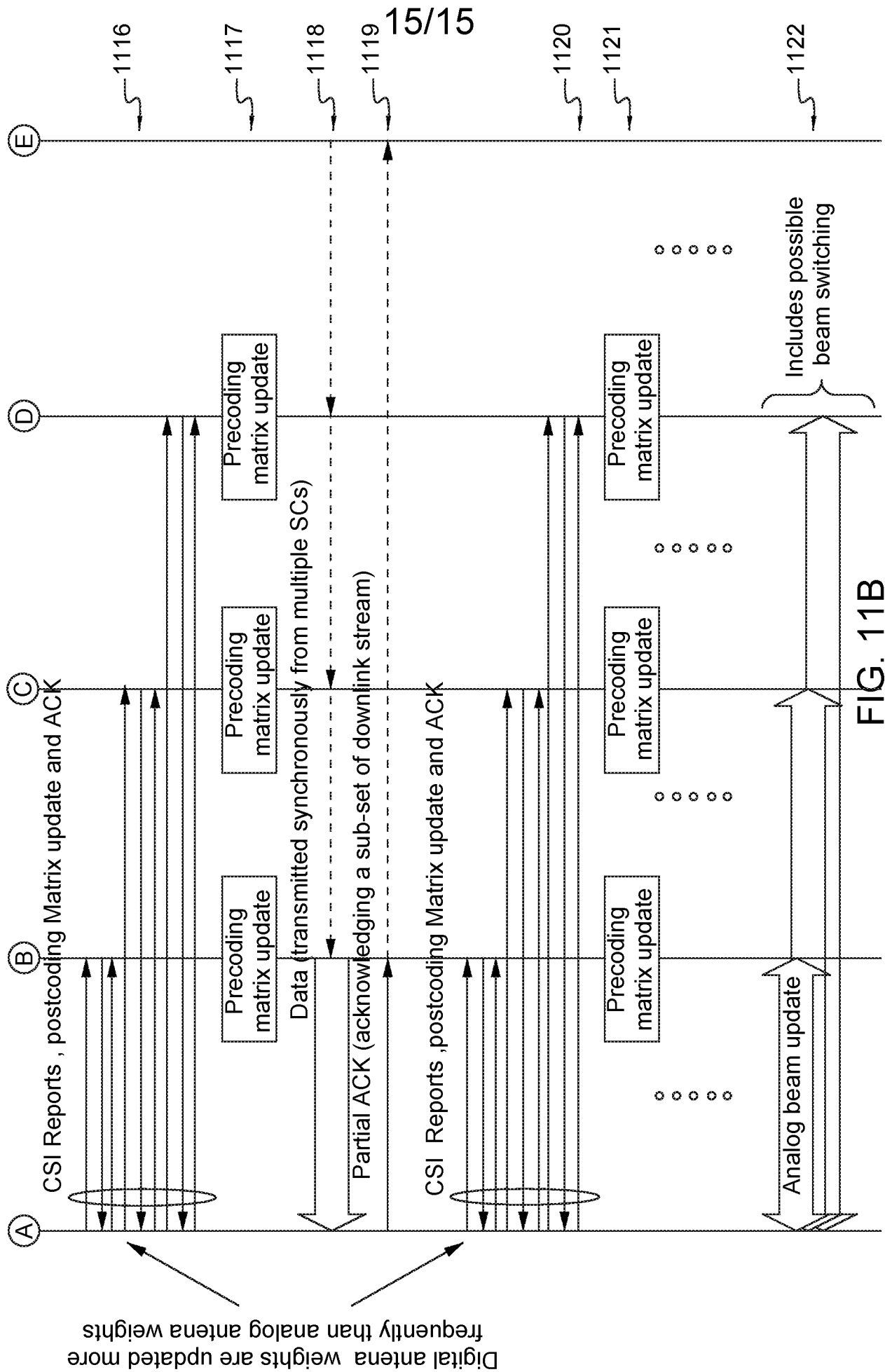


FIG. 11A



INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/040762

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B7/024 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 2012/064998 A2 (INTERDIGITAL PATENT HOLDINGS [US]; SAHIN ONUR [US]; LI JIALING [US]; L) 18 May 2012 (2012-05-18) paragraph [0004] - paragraph [0014] paragraph [0039] - paragraph [0046] paragraph [0059] - paragraph [0066] paragraph [0071] - paragraph [0078] paragraph [0129] - paragraph [0131] paragraph [0149] - paragraph [0187] paragraph [0315] - paragraph [0321] figures 1A, 1C, 1D, 1E, 1F, 2-5 -----	1-19
A	EP 2 938 142 A1 (LG ELECTRONICS INC [KR]) 28 October 2015 (2015-10-28) paragraph [0040] - paragraph [0045]; figure 7 paragraph [0059] - paragraph [0063] ----- -/-	1-19



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

22 September 2017

Date of mailing of the international search report

02/10/2017

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Authorized officer

Spinnler, Florian

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2017/040762

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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