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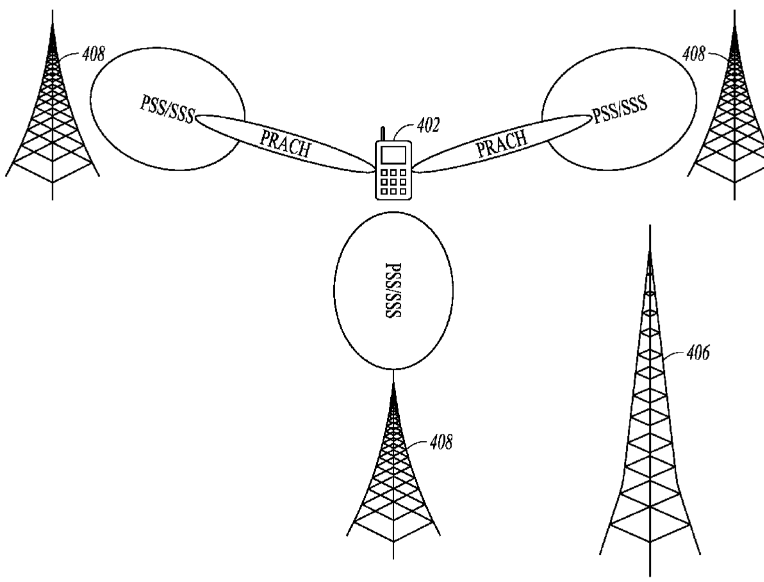

FIG. 4

(57) Abstract: A user equipment device (UE) comprises transceiver circuitry configured to: transmit and receive radio frequency signals with a macro enhanced node B device of a cellular communication network; and transmit and receive millimeter wave (mmWave) signals with one or more mmWave transmitting-receiving (T/R) points; and processing circuitry configured to: initiate beam scanning while the UE is communicating data with a first mmWave T/R point; detect a beam transmitted by a second mmWave T/R point; initiate transmission of a random access message to the second mmWave T/R point; decode physical control channel information received from the second mmWave T/R point; and communicate data with the second mmWave T/R point using physical channel allocations specified in the physical channel information, wherein the first and second mmWave T/R points are assigned a same value for a cell identifier.

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POINT SWITCHING IN CELL-LESS mmWAVE SMALL CELL

TECHNICAL FIELD

[0001] Embodiments pertain to transmitting voice data using radio access networks. Some embodiments relate to mobile cellular telephone communication networks.

BACKGROUND

[0002] Radio access networks can be used for delivering voice communications to user equipment such as a mobile cellular telephone or a smart phone. A cellular telephone network includes fixed location transceivers distributed land areas. Cell transceivers of the network may be included in cell towers to serve large land areas and cell transceivers may be arranged to serve smaller areas or to provide localized service such as within a building. The transceivers and the areas that they serve can be referred to as cells of the cellular network. The network traffic or load experienced by a cell depends on the number of UEs that request access to the cell and the demand for cell bandwidth by the UEs. When a cell experiences a high amount of traffic, a UE may experience delay or latency in communications or delay in accessing network service. It is desirable to balance the load of the cells of the network to maximize service to UEs. Thus, there are general needs for devices, systems and methods that provide a robust protocol for communication with UEs and yet minimize delay or interruption in end-to-end voice communications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] FIG. 1 shows an example of a portion of an end-to-end network architecture of a long term evolution (LTE) network with various components of the network in accordance with some embodiments;

[0004] FIG. 2 is diagram of an example of a cellular u-plane protocol stack in accordance with some embodiments;

[0005] FIG. 3 illustrates a functional block diagram of user equipment (UE) in accordance with some embodiments;

[0006] FIG. 4 is an illustration representing, a macro cell, multiple transmitting/receiving (T/R) points, and UE in accordance with some embodiments;

[0007] FIG. 5 is a diagram of an embodiment of a communication protocol between UE and T/R points in accordance with some embodiments;

[0008] FIG. 6 is a diagram of another embodiment of a communication protocol between UE and T/R points in accordance with some embodiments

[0009] FIG. 7 is a diagram of still another embodiment of a communication protocol between UE and T/R points in accordance with some embodiments; and

[0010] FIG. 8 is a diagram of still another embodiment of a communication protocol between UE and T/R points in accordance with some embodiments; and

[0011] FIG. 9 illustrates a block diagram of an example machine in accordance with some embodiments.

DETAILED DESCRIPTION

[0012] The following description and the drawings sufficiently illustrate specific embodiments to enable those skilled in the art to practice them. Other embodiments may incorporate structural, logical, electrical, process, and other changes. Portions and features of some embodiments may be included in, or substituted for, those of other embodiments. Embodiments set forth in the claims encompass all available equivalents of those claims.

[0013] FIG. 1 shows an example of a portion of an end-to-end network architecture of an LTE network with various components of the network in accordance with some embodiments. The network 100 comprises a radio access network (RAN) (e.g., as depicted, the evolved universal terrestrial radio access network or E-UTRAN 101, and the core network 120 (e.g., shown as an evolved packet core (EPC)) coupled together through an S1 interface 115. For convenience and brevity, only a portion of the core network 120, as well as the RAN 100, is shown in the example.

[0014] The core network 120 includes mobility management entity (MME) 122, serving gateway (serving GW) 124, and packet data network gateway (PDN GW) 126. The RAN includes enhanced node B's (eNBs) 104 (which may operate as base stations) for communicating with user equipment (UE) 102. The eNBs 104 may include macro eNBs and low power (LP) eNBs.

[0015] The MME is similar in function to the control plane of legacy Serving GPRS Support Nodes (SGSN). The MME manages mobility aspects in access such as gateway selection and tracking area list management. The serving GW 124 terminates the interface toward the RAN 100, and routes data packets between the RAN 100 and the core network 120. In addition, it may be a local mobility anchor point for inter-eNB handovers and also may provide an anchor for inter-3GPP mobility. Other responsibilities may include lawful intercept, charging, and some policy enforcement. The serving GW 124 and the MME 122 may be implemented in one physical node or separate physical nodes. The PDN GW 126 terminates an SGi interface toward the packet data network (PDN). The PDN GW 126 routes data packets between the EPC 120 and the external PDN, and may be a key node for policy enforcement and charging data collection. It may also provide an anchor point for mobility with non-LTE accesses. The external PDN can be any kind of IP network, as well as an IP Multimedia Subsystem (IMS) domain. The PDN GW 126 and the serving GW 124 may be implemented in one physical node or separated physical nodes.

[0016] The eNBs 104 (macro and LP) terminate the air interface protocol and may be the first point of contact for a UE 102. In some embodiments, an eNB 104 may fulfill various logical functions for the RAN 100 including but not limited to RNC (radio network controller functions) such as radio bearer management, uplink and downlink dynamic radio resource management and data packet scheduling, and mobility management. In accordance with embodiments, UEs 102 may be configured to communicate OFDM communication signals with an eNB 104 over a multicarrier communication channel in accordance with an OFDMA communication technique. The OFDM signals may comprise a plurality of orthogonal subcarriers.

[0017] In some embodiments, a downlink resource grid may be used for downlink transmissions from an eNB to a UE. The grid may be a time-frequency grid, called a resource grid, which is the physical resource in the downlink in each slot. Such a time-frequency plane representation is a common practice for OFDM systems, which makes it intuitive for radio resource allocation. Each column and each row of the resource grid correspond to one OFDM symbol and one OFDM subcarrier, respectively. The duration of the resource grid in the time domain corresponds to one slot in a radio frame. The smallest time-frequency unit in a resource grid is denoted as a resource element. Each resource grid comprises a number of resource blocks, which describe the mapping of certain physical channels to resource elements. Each resource block comprises a collection of resource elements and in the frequency domain; this represents the smallest quanta of resources that currently can be allocated. There are several different physical downlink channels that are conveyed using such resource blocks. Two of these physical downlink channels are the physical downlink shared channel and the physical down link control channel.

[0018] The physical downlink shared channel (PDSCH) carries user data and higher-layer signaling to a UE 102 (FIG. 1). The physical downlink control channel (PDCCH) carries information about the transport format and resource allocations related to the PDSCH channel, among other things. It also informs the UE about the transport format, resource allocation, and hybrid automatic repeat request (H-ARQ) information related to the uplink shared channel. Typically, downlink scheduling (assigning control and shared channel resource blocks to UEs within a cell) is performed at the eNB based on channel quality information fed back from the UEs to the eNB, and then the downlink resource assignment information is sent to a UE on the control channel (PDCCH) used for (assigned to) the UE.

[0019] The PDCCH uses CCEs (control channel elements) to convey the control information. Resource assignments are included in a downlink control information (DCI) message. Before being mapped to resource elements, the PDCCH complex-valued symbols are first organized into quadruplets, which are then permuted using a sub-block inter-leaver for rate matching. Each PDCCH is transmitted using one or more of these control channel elements (CCEs), where each CCE corresponds to nine sets of four physical resource elements known as resource element groups (REGs). Four QPSK symbols are mapped to each REG. The PDCCH can be transmitted using one or more CCEs, depending on the size of downlink control information (DCI) and the channel condition. There may be four or more different PDCCH formats defined in LTE with different numbers of CCEs (e.g., aggregation level, L = 1, 2, 4, or 8).

[0020] The physical uplink shared channel (PUSCH) carries traffic data from the UE. The PUSCH may carry in addition to user data any control information necessary to decode the information such as transport format indicators and MIMO parameters. Control data is multiplexed with information data prior to DFT spreading. The physical uplink control channel (PUCCH) conveys uplink control data transmitted independently of traffic data which may include HARQ ACK/NACK, channel quality indicators (CQI), MIMO feedback (Rank Indicator, RI; Precoding Matrix Indicator, PMI) and scheduling requests (SRs) for uplink transmission.

[0021] FIG. 2 is diagram of an example of a cellular u-plane protocol stack. The layers of the protocol stack include a packet data convergence protocol (PDCP) layer 208, a radio link control (RLC) protocol layer 206, and a MAC protocol layer 204. IP packets are processed from the top layer to the bottom layer of the protocol stack. Information processed using the layers may be passed to a physical or PHY layer for transmission. In the EPC 120 of FIG. 1, packets are encapsulated in a specific EPC protocol and tunneled between the PDN GW 126 and the eNBs 104. A general packet radio service (GPRS) tunneling protocol (GTP) may be used on the S1 interface between the eNBs 104 and the serving GW 124, and may also be used on the S5/8 interface between the PDN GW 126 and the serving GW 124. Different protocols may be used depending on the interface.

[0022] FIG. 3 illustrates a functional block diagram of a UE in accordance with some embodiments. The UE 300 may be suitable for use as any one or more of the UEs 102 illustrated in FIG. 1. The UE 300 may include PHY circuitry 302 that includes transceiver circuitry for transmitting and receiving radio frequency electrical signals to and from one or more nodes of a radio access network (e.g., eNBs 104 of FIG. 1) using one or more antennas 301 electrically coupled to the PHY circuitry 302. The PHY circuitry 302 may include circuitry for modulation/demodulation, upconversion/downconversion, filtering, amplification, etc. UE 300 may also include medium access control layer (MAC) circuitry 304 for controlling access to the wireless medium and to configure frames or packets for communicating over the wireless medium. UE 300 may also include processing circuitry 306 and memory 308 arranged to configure the various elements of the UE to perform the operations described herein. The memory 308 may be used to store information for configuring the processing circuitry 306 to perform the operations.

[0023] In some embodiments, the UE 300 may be part of a portable wireless communication device, such as a personal digital assistant (PDA), a laptop or portable computer with wireless communication capability, a web tablet, a wireless telephone, a smartphone, a wireless headset, a pager, an instant messaging device, a digital camera, an access point, a television, a medical device (e.g., a heart rate monitor, a blood pressure monitor, etc.), or other device that may receive and/or transmit information wirelessly. In some embodiments, the UE 300 may include one or more of a keyboard, a display, a non-volatile memory port, multiple antennas, a graphics processor, an application processor, speakers, and other mobile device elements. The display may be an LCD screen including a touch screen.

[0024] The one or more antennas 301 utilized by the UE 300 may comprise one or more directional or omnidirectional antennas, including, for example, dipole antennas, monopole antennas, patch antennas, loop antennas, microstrip antennas or other types of antennas suitable for transmission of RF signals. In some embodiments, instead of two or more antennas, a single antenna with multiple apertures may be used. In these embodiments, each aperture may be considered a separate antenna. In some multiple-input multiple-output (MIMO) embodiments, the antennas may be effectively separated to take advantage of spatial diversity and the different channel characteristics that may result between each of antennas and the antennas of a transmitting station. In some MIMO embodiments, the antennas may be separated by up to 1/10 of a wavelength or more.

[0025] Although the UE 300 is illustrated as having several separate functional elements, one or more of the functional elements may be combined and may be implemented by combinations of software-configured elements, such as processing elements including digital signal processors (DSPs), and/or other hardware elements. For example, some elements may comprise one or more microprocessors, DSPs, application specific integrated circuits (ASICs), radio-frequency integrated circuits (RFICs), and combinations of various hardware and logic circuitry for performing at least the functions described herein. In some embodiments, the functional elements may refer to one or more processes operating on one or more processing elements.

[0026] Embodiments may be implemented in one or a combination of hardware, firmware and software. Embodiments may also be implemented as instructions stored on a computer-readable storage medium, which may be read and executed by at least one processor to perform the operations described herein. A computer-readable storage medium may include any non-transitory mechanism for storing information in a form readable by a machine (e.g., a computer). For example, a computer-readable storage medium may include read-only memory (ROM), random-access memory (RAM), magnetic disk storage media, optical storage media, flash-memory devices, and other storage devices and media. In these embodiments, one or more processors may be configured with the instructions to perform the operations described herein.

[0027] The demand for communicating one or both of voice data and video data continues to increase. A RAN (e.g., RAN 100 of FIG. 1) may experience heavy communication traffic which can lead to adverse network effects such as communication latency for example. One approach to increasing network throughput is to add smaller cells (e.g., micro cells) to increase network capacity in areas with very dense phone usage, such as train stations. This can be referred to as an anchor booster architecture in which the macrocell is the anchor or anchor carrier. The smaller cell may be an LP cell and is the anchor booster or booster carrier. The anchor provides a reliable signaling connection, but traffic can be offloaded to local boosters according to traffic demands. Another approach to increase throughput is to use higher frequencies. Higher frequencies can lead to information being communicated faster than lower frequencies, but because using higher frequencies can reduce the range for communication, higher frequency communication is limited to the anchor boosters

[0028] Alleviating network traffic is complicated by the use of cell identifiers or Cell-IDs. Requiring one Cell-ID for each cell may limit peak throughput. A limited number of Cell-IDs can lead to a smaller set of scrambling sequences for interference randomization, which may prohibit further co-scheduling on a given time-frequency radio resource. Cell-less operation of at least a portion of a cellular network may improve network traffic throughput. In cell-less operation, multiple cells can have the same Cell-ID.

[0029] FIG. 4 is an illustration of a macrocell 406, multiple transmitting/receiving (T/R) points 408, and UE 402. The T/R points 408 transmit and receive millimeter wave (mmWave) signals. Millimeter wave refers to the wavelength of the signals and can include signals with frequencies of 60, 70, or 80 gigahertz (GHz). A mmWave T/R point may have an antenna panel suitable for beam forming for directional signal transmission or reception. A beam refers to electromagnetic energy radiated by the mmWave T/R point.

[0030] In some embodiments, a mmWave T/R point can be a radio head (RH) or remote radio heads (RRH). In some embodiments, a mmWave T/R point includes at least one functional layer of an eNB. A mmWave T/R point can be a RRH with PHY processing, a RRH with PHY/MAC processing, or a RRH with

PHY/MAC/PDCP processing. A mmWave T/R point may be connected to the network through the X2 link to another eNB such as a macro eNB of macrocell 406, or may be coupled to the EPC through the PDN GW. In the example embodiment of FIG. 4, the T/R points have the same Cell-ID. A mmWave T/R point includes transceiver circuitry that transmits and receives RF signals with the macro eNB, and transmits and receives millimeter wave (mmWave) electrical signals to communicate with the UE.

[0031] The UE 402 includes transceiver circuitry that transmits and receives RF signals with the macro eNB and transmits and receives mmWave signals to communicate with the mmWave T/R points. The UE 402 may perform one or both of receive beam scanning and received power measurement to determine the strongest beam direction. The high frequency of the signals may result in a narrower beam than for convention LTE frequencies. The UE is able to determine the beam direction due to the spacing of the mmWave T/R points. The UE communicates with a mmWave T/R point according to the determined strongest beam direction. This allows a mobile UE to communicate through multiple mmWave T/R points without being limited to any one cell by the Cell-ID. The UE may need to discover and synchronize to carriers of the multiple mmWave T/R points even though the communication is cell-less, and maintain a signaling relationship with the macro eNB.

[0032] FIG. 5 is a diagram of an embodiment of a communication protocol between a UE and mmWave T/R points. The communication protocol is an example embodiment using the mmWave T/R points in FIG. 4. Time advances from top to bottom of the diagram. At 505, the UE is in active communication with mmWave T/R point 2 (TP2) using a specified PDSCH and PUSCH. At 510, demodulation reference signals (DRSs) may be transmitted by TP3 and TP1.

[0033] While in active communication with TP2, the processing circuitry of the UE initiates beam scanning. At 515, the UE may perform beam scanning in different directions to determine the strongest received beam. In some embodiments, the UE performs beam scanning during the symbols reserved for the

DRS. For example, during transmission of a primary synchronization signal (PSS) or a secondary synchronization signal (SSS).

[0034] In conventional LTE networks, UE may obtain a physical layer identity from the PSS. From SSS, UE may obtain a physical layer cell identity group number. Using physical layer identity and cell identity group number, a UE typically can determine the physical cell ID (PCI) for the cell. However, in the embodiment of FIG. 5, all of the mmWave T/R points are transmitting the same physical cell identifiers. Because the transmission from the mmWave T/R points is cell-less, the transmission of the DRSs by the mmWave T/R points may form a single frequency network (SFN) type of transmission. In some embodiments, the UE performs time and frequency synchronization and may calculate reference signal received power (RSRP) based on the strongest detected beam (e.g., the beam with the strongest received signal intensity or received signal power).

[0035] At 520, the synchronization process may include transmissions over a Physical Random Access Channel (PRACH). The channel may be a mmWave channel or resource. The PRACH carries a random access preamble that a UE sends to access the network in non-synchronized mode and used to allow the UE to synchronize timing. The UE may transmit a random access message using the PRACH in the direction of the determined strongest beam to synchronize to TP1. In some embodiments, the preamble for a random access message in distributed to the UEs and mmWave T/R points by the macro eNB.

[0036] In the example of FIG. 5, the strongest beam is in the direction from TP1, and the UE transmits in the direction of TP1 using the PRACH. The transceiver circuitry of TP1 receives the PRACH transmission. The processing circuitry of TP1 detects the PRACH transmission from the UE, and decodes or otherwise identifies the transmission as a random access message. The processing circuitry of TP1 may then estimate the direction of the beam from the UE, and initiate transmission of a random access response message (RARM) to the UE.

[0037] TP1 also transmits physical control channel information to the UE, such as specifying the PDCCH and PUCCH for example. The UE can receive DCI using the PDCCH and determine the allocation of the PDSCH and the PUSCH using the channel information. If the backhaul of the network or the relative portion of the network is near ideal, there will be nearly no latency or negligible latency in the availability of downlink data, and the UE and TP1 can immediately begin communicating information using the PDSCH and PUSCH at 530. Backhaul refers to the portion of the cellular network from a cell (e.g., an anchor cell) to the EPC.

[0038] At 540, in some embodiments the mmWave T/R point performs a beam direction search and timing advance estimation using the random access message. Timing advance (TA) refers to an offset at the UE between the start of a received downlink subframe and a transmitted uplink subframe. In the example of FIG. 5, TP1 may transmit TA information for the UE to use for uplink transmissions. In some embodiments, the TA information is included in a RARM received from a mmWave T/R point. In some embodiments, the TA information is includes in a DCI transmission over the PDCCH. The UE receives the TA information and adjusts uplink transmission timing for one or more of PUCCH, PUSCH, and a sounding reference signal (SRS).

[0039] In FIGS. 4 and 5, the network is simplified for clarity. There may be more than three mmWave T/R points available to a UE. In some embodiments, the UE performs beam scanning and initializes synchronization with multiple mmWave T/R points. In this case, multiple mmWave T/R points may receive a random access message from the UE. In this case, the EPC may select the mmWave T/R point or points that will communicate with the UE. Assigning multiple mmWave T/R points to the communication with the UE may provide higher network throughput by higher data rates and mobility diversity. The communication protocol of FIG. 5 provides for a smooth handoff between mmWave T/R points for downlink data traffic to a UE.

[0040] FIG. 6 is a diagram of another embodiment of a communication protocol between a UE and mmWave T/R points, such as the UE and mmWave T/R points in FIG. 4. The protocol is similar to the embodiment in FIG. 5. At 615, the UE may perform beam scanning in different directions to determine the strongest received beam. When the strongest beam is determined to be TP1, the UE transmits a random access message using the PRACH to synchronize with TP1. At 620, the processing circuitry of the UE includes a scheduling request (SR) for uplink transmissions with the random access message transmitted to TP1. Two messages are sent to the UE using the PDCCH in response to the random access message. At 627, one of the messages can include the DCI and the TA information. The message may be a DCI message with a larger format to include the TA information. At 625, the other message can include the PUSCH allocation. At 630, the handoff for the UE downlink data traffic and the UE uplink data traffic from TP2 to TP1 is complete.

[0041] FIG. 7 is a diagram of another embodiment of a communication protocol between a UE and mmWave T/R points. In this example embodiment, the DCI message that includes the TA information is transmitted at 727 by the TP1 and decoded by the UE. When the UE determines the resource allocation, at 729 the UE transmits a message that includes a scheduling request using the PUCCH. At 725, a second message is transmit by TP1 using the PDCCH to communication the PUSCH allocation to the UE. At 730, the handoff for the UE downlink data traffic and the UE uplink data traffic from TP2 to TP1 is complete. The embodiments of FIGS. 6 and 7 show that the message including the PUSCH allocation is transmitted to the UE after the DCI is sent. In some embodiments, the message with the PUSCH allocation is transmitted before the message with DCI.

[0042] In the example embodiments of FIGS. 5-7 the latency of the backhaul is low and does not impact the timing of the communication protocol. If the latency becomes significant, the UE may need to wait until the downlink data to be forwarded by the backhaul to the newly selected mmWave T/R point. The waiting by the UE can lead to some challenges in communication among UEs and mmWave T/R points. One problem that may occur is if the waiting time leads the UE to initiate selection of another mmWave T/R point and continue to keep switching mmWave T/R points if latency of data in the backhaul continues. Another problem is that the UE may continue to send transmissions in an attempt to synchronize to the mmWave T/R point even though the T/R point switch is successful. For example, the UE may continue to retransmit a random access message using the PRACH under false determination that the PRACH communication failed.

[0043] FIG. 8 is a diagram of another embodiment of a communication protocol between a UE and mmWave T/R points. The embodiment includes explicit acknowledge signaling to indicate to the UE that the switch to a different mmWave T/R point was successful. At 815, the UE performs beam scanning while communicating with TP2, and at 820 attempts to synchronize to TP1 by transmitting a random access message using PRACH. At 840, the processing circuitry of TP1 estimates the direction of the beam from the UE and may perform a timing advance estimation using the random access message.

[0044] At 845, TP1 transmits an acknowledge message or ACK to the UE. Decoding of the ACK by processing circuitry of the UE indicates that the switch was successful. In certain embodiments, the ACK may initiate a specified wait period. In certain embodiments, the wait period is a time out period after which the UE again performs beam scanning. The ACK message may be transmit as an explicit message that is transmitted using an ACK channel, or the ACK may be included in a PDCCH transmission having a format that includes ACK capability. In certain embodiments, if a negative acknowledge or NACK is transmitted by TP1, the UE may immediately begin beam scanning.

[0045] The mmWave T/R point may transmit DCI to the UE subsequent to the ACK message. In some embodiments, the TA information is included in the DCI with resource allocation information as in the example of FIG. 7. In some embodiments, the DCI message also includes a delay indicator. The delay indicator provides the wait period information to the UE. In some embodiments, the delay indicator is the minimum value of delay between the current subframe to the first downlink transmission of data from the mmWave T/R point. The DCI may be formatted to include several bits of information to indicate a value for the delay indicator. In some embodiments, the delay indicator is communicated using the

PDSCH after the DCI information is transmitted by TP1 and received by the UE. In some examples, the processing circuitry of TP1 calculates the value of the delay indicator using one or both of the traffic load or load status of the mmWave T/R point and a delay in data being forwarded to the mmWave T/R point. Based on the delay indicator, the UE may initiate selection of another TP if the delay indicator communicated from TP1 is a value higher than a threshold delay indicator specified (e.g. programmed) in the UE.

[0046] At 850, the downlink delay data is forwarded to TP1 from TP2 and at 830 the downlink data is communicated using the PDSCH. Uplink resource allocation information may be communicated by any of the methods described previously herein, and the UE may transmit uplink data to TP1. The UE may continue to perform receive beam scanning after the T/R point switch and communications with TP1 are ongoing.

[0047] FIG. 9 illustrates a block diagram of an example machine 900 upon which any one or more of the techniques (e.g., methodologies) discussed herein may perform. In alternative embodiments, the machine 900 may operate as a standalone device or may be connected (e.g., networked) to other machines. In a networked deployment, the machine 900 may operate in the capacity of a server machine, a client machine, or both in server-client network environments. In an example, the machine 900 may act as a peer machine in peer-to-peer (P2P) (or other distributed) network environment. The machine 900 may be a mobile device such as a personal computer (PC), a tablet PC, a set-top box (STB), a personal digital assistant (PDA), a mobile telephone, a smart phone, a web appliance, a network router, switch or bridge, or any machine capable of executing instructions (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term “machine” shall also be taken to include any collection of machines that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein, such as cloud computing, software as a service (SaaS), other computer cluster configurations.

[0048] Examples, as described herein, may include, or may operate on, logic or a number of components, modules, or mechanisms. Modules are tangible entities (e.g., hardware) capable of performing specified operations and may be configured or arranged in a certain manner. In an example, circuits may be arranged (e.g., internally or with respect to external entities such as other circuits) in a specified manner as a module. In an example, the whole or part of one or more computer systems (e.g., a standalone, client or server computer system) or one or more hardware processors may be configured by firmware or software (e.g., instructions, an application portion, or an application) as a module that operates to perform specified operations. In an example, the software may reside on a machine readable medium. In an example, the software, when executed by the underlying hardware of the module, causes the hardware to perform the specified operations.

[0049] Accordingly, the term “module” is understood to encompass a tangible entity, be that an entity that is physically constructed, specifically configured (e.g., hardwired), or temporarily (e.g., transitorily) configured (e.g., programmed) to operate in a specified manner or to perform part or all of any operation described herein. Considering examples in which modules are temporarily configured, each of the modules need not be instantiated at any one moment in time. For example, where the modules comprise a general-purpose hardware processor configured using software, the general-purpose hardware processor may be configured as respective different modules at different times. Software may accordingly configure a hardware processor, for example, to constitute a particular module at one instance of time and to constitute a different module at a different instance of time.

[0050] Machine (e.g., computer system) 900 may include a hardware processor 902 (e.g., a central processing unit (CPU), a graphics processing unit (GPU), a hardware processor core, or any combination thereof), a main memory 904 and a static memory 906, some or all of which may communicate with each other via an interlink (e.g., bus) 908. The machine 900 may further include a display unit 910, an alphanumeric input device 912 (e.g., a keyboard), and a user interface (UI) navigation device 914 (e.g., a mouse). In an example, the display unit 910, input device 912 and UI navigation device 914 may be a touch screen display. The machine 900 may additionally include a storage device (e.g., drive unit) 916, a signal generation device 918 (e.g., a speaker), a network interface device 920, and one or more sensors 921, such as a global positioning system (GPS) sensor, compass, accelerometer, or other sensor. The machine 900 may include an output controller 928, such as a serial (e.g., universal serial bus (USB), parallel, or other wired or wireless (e.g., infrared (IR), near field communication (NFC), etc.) connection to communicate or control one or more peripheral devices (e.g., a printer, card reader, etc.).

[0051] The storage device 916 may include a machine readable medium 922 on which is stored one or more sets of data structures or instructions 924 (e.g., software) embodying or utilized by any one or more of the techniques or functions described herein. The instructions 924 may also reside, completely or at least partially, within the main memory 904, within static memory 906, or within the hardware processor 902 during execution thereof by the machine 900. In an example, one or any combination of the hardware processor 902, the main memory 904, the static memory 906, or the storage device 916 may constitute machine readable media.

[0052] While the machine readable medium 922 is illustrated as a single medium, the term "machine readable medium" may include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) configured to store the one or more instructions 924.

[0053] The term “machine readable medium” may include any medium that is capable of storing, encoding, or carrying instructions for execution by the machine 900 and that cause the machine 900 to perform any one or more of the techniques of the present disclosure, or that is capable of storing, encoding or carrying data structures used by or associated with such instructions. Non-limiting machine readable medium examples may include solid-state memories, and optical and magnetic media. Specific examples of machine readable media may include:

non-volatile memory, such as semiconductor memory devices (e.g., Electrically Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM)) and flash memory devices; magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; Random Access Memory (RAM); and CD-ROM and DVD-ROM disks. In some examples, machine readable media may include non-transitory machine readable media. In some examples, machine readable media may include machine readable media that is not a transitory propagating signal.

[0054] The instructions 924 may further be transmitted or received over a communications network 926 using a transmission medium via the network interface device 920 utilizing any one of a number of transfer protocols (e.g., frame relay, internet protocol (IP), transmission control protocol (TCP), user datagram protocol (UDP), hypertext transfer protocol (HTTP), etc.). Example communication networks may include a local area network (LAN), a wide area network (WAN), a packet data network (e.g., the Internet), mobile telephone networks (e.g., cellular networks), Plain Old Telephone (POTS) networks, and wireless data networks (e.g., Institute of Electrical and Electronics Engineers (IEEE) 802.11 family of standards known as Wi-Fi®, IEEE 802.16 family of standards known as WiMax®), IEEE 802.15.4 family of standards, a Long Term Evolution (LTE) family of standards, a Universal Mobile Telecommunications System (UMTS) family of standards, peer-to-peer (P2P) networks, among others. In an example, the network interface device 920 may include one or more physical jacks (e.g., Ethernet, coaxial, or phone jacks) or one or more antennas to connect to the communications network 926. In an example, the network interface device 920 may include a plurality of antennas to wirelessly communicate using at least one of single-input multiple-output (SIMO), multiple-input multiple-output (MIMO), or multiple-input single-output (MISO) techniques. In some examples, the network interface device 920 may wirelessly communicate using Multiple User MIMO techniques. The term “transmission medium” shall be taken to include any intangible medium that is capable of storing, encoding or carrying instructions for execution by the machine 900, and includes digital or analog communications signals or other intangible medium to facilitate communication of such software.

[0055] The several examples described herein increase network throughput to reduce latency in a radio access network or reduce interruption in service. The network takes advantage of smaller cells that communicate using higher frequencies than conventional cellular networks and provides cell-less operation to reduce limits on throughput due to requiring Cell-IDs for each individual cell.

ADDITIONAL DESCRIPTION AND EXAMPLES

[0056] Example 1 can include subject matter (such as an apparatus of user equipment (UE)) comprising transceiver circuitry configured to: transmit and receive radio frequency (RF) signals with a macro enhanced node B device (macro eNB) of a cellular communication network; and transmit and receive millimeter wave (mmWave) signals with one or more mmWave transmitting-receiving (T/R) points; and processing circuitry configured to: initiate beam scanning while the UE is communicating data with a first mmWave T/R point; determine that a beam of a second mmWave T/R point has greater signal intensity than a beam of the first mmWave T/R point; initiate transmission of a random access message in a direction of the second mmWave T/R point; decode physical control channel information received from the second mmWave T/R point; and communicate data with the second mmWave T/R point using a downlink (DL) channel allocation and an uplink (UL) channel allocation specified in the physical channel information, wherein the first and second mmWave T/R points are assigned a same physical cell identifier.

[0057] In Example 2, the subject matter of Example 1 optionally includes processing circuitry configured to decode uplink timing advance (TA) information included in a random access response message (RARM) received from the second mmWave T/R point.

[0058] In Example 3, the subject matter of one or any combination of Examples 1 and 2 optionally includes processing circuitry configured to include a scheduling request for uplink transmissions with the random access message transmitted to the second mmWave T/R point.

[0059] In Example 4, the subject matter of one or any combination of Examples 1-3 optionally includes processing circuitry configured to decode uplink TA information included in a downlink control information (DCI) message received from the second mmWave T/R point, wherein the DCI message also includes resource allocation information.

[0060] In Example 5, the subject matter of one or any combination of Examples 1-4 optionally includes processing circuitry configured to decode uplink TA information included in one DCI message received from the second mmWave T/R point, and decode resource allocation information included in another DCI message received from the second mmWave T/R point.

[0061] In Example 6, the subject matter of one or any combination of Examples 1-5 optionally includes processing circuitry configured to transmit a scheduling request for uplink transmissions to the second mmWave T/R point using a physical uplink control channel (PUCCH).

[0062] In Example 7, the subject matter of one or any combination of Examples 1-6 optionally includes processing circuitry configured to decode an acknowledge (ACK) message transmitted by the second mmWave T/R point in response to the random access message, and decode uplink TA information included in a DCI message received from the second mmWave T/R point, wherein the DCI message also includes resource allocation information.

[0063] In Example 8, the subject matter of Example 7 optionally includes processing circuitry configured to decode a delay indicator included in the DCI message, wherein the delay indicator is a minimum value of delay between the current subframe to the first downlink transmission of data from the second mmWave T/R point.

[0064] In example 9, the subject matter of one or any combination of Examples 1-8 optionally includes processing circuitry configured to decode a delay indicator included in a physical downlink shared channel (PDSCH) transmission, wherein the delay indicator includes a minimum value of delay between the current subframe to the first downlink transmission of data from the mmWave T/R point. The processing circuitry optionally includes a baseband processor configured to decode the delay indicator included in the PDSCH transmission.

[0065] In Example 10, the subject matter of one or any combination of Examples 1-9 optionally includes one or more antennas electrically connected to the transceiver circuitry.

[0066] Example 11 can include subject matter (such as a millimeter wave transmitting-receiving point device (mmWave T/R point)), or can optionally be combined with the subject matter of one or any combination of Example 1-10 to include such subject matter, comprising transceiver circuitry configured to: transmit and receive radio frequency (RF) signals with a macro enhanced node B device (macro eNB) of a cellular communication network; and transmit and receive millimeter wave (mmWave) electrical signals to communicate with user equipment (UE) of the cellular communication network; and processing circuitry configured to: detect a physical random access channel (PRACH) transmission by a UE via a mmWave channel and perform a beam search using the PRACH; initiate transmission of a random access response message to the UE; initiate transmission of physical channel information to the UE; and communicate data to the UE using a physical downlink shared channel (PDSCH) allocation and a physical uplink shared channel (PUSCH) allocation specified in the physical channel information, wherein the PDSCH and PUSCH are mmWave channels.

[0067] In Example 12, the subject matter of Example 11 optionally includes processing circuitry is configured to include uplink timing advance (TA) information in a random access response message (RARM) transmitted to the UE.

[0068] In Example 13, the subject matter of one or any combination of Examples 11 and 12 optionally include processing circuitry configured to decode a scheduling request for uplink transmissions included in the random access message received from the UE.

[0069] In Example 14, the subject matter of one or any combination of Examples 11-13 optionally includes processing circuitry configured to include uplink TA information and resource allocation information in a downlink control information (DCI) message transmitted to the UE.

[0070] In Example 15, the subject matter of one or any combination of Examples 11-14 optionally includes processing circuitry configured to include resource allocation information in a first downlink control information (DCI) message transmitted to the UE, and include uplink TA information in a second DCI message transmitted to the UE.

[0071] In Example 16, the subject matter of one or any combination of Examples 11-15 optionally includes processing circuitry configured to decode a scheduling request message received from the UE via a physical uplink control channel (PUCCH), wherein the PUCCH is a mmWave channel.

[0072] In Example 17, the subject matter of one or any combination of Examples 11-16 optionally includes processing circuitry configured to initiate transmission of an acknowledge (ACK) message to the UE in response to detecting the random access message, and initiate transmission of a DCI message subsequent to transmission of the ACK message, wherein the DCI message includes uplink TA information and resource allocation information.

[0073] In Example 18, the subject matter of Example 17 optionally includes processing circuitry configured to include a delay indicator included in the DCI message, wherein the delay indicator is a minimum value of delay between the current subframe to the first downlink transmission of data from the mmWave T/R point.

[0074] In Example 19, the subject matter of Example 18 optionally includes processing circuitry configured to calculate the value of the delay indicator using one or both of the traffic load of the mmWave T/R point and a delay in data being forwarded to the mmWave T/R point.

[0075] In Example 20 the subject matter of one or any combination of Examples 11-19 optionally includes processing circuity configured to initiate transmission of a message that includes a delay indicator using the PDSCH, wherein the delay indicator includes a minimum value of delay between the current subframe to the first downlink transmission of data from the mmWave T/R point.

[0076] In Example 21, the subject matter of one or any combination of Examples 11-19 optionally includes processing circuitry configured to receive a preamble sequence for a random access message from the macro eNB.

[0077] In Example 22, the subject matter of one or any combination of Examples 11-21 optionally includes mmWave T/R point that is a millimeter wave remote radio head (mm Wave RRH) that includes one or more functional layers of an eNB.

[0078] In Example 23, the subject matter of one or any combination of Examples 11-22 optionally includes a plurality of antennas electrically connected to the transceiver circuitry.

[0079] Example 24 includes subject matter (such as a method, a means for performing acts, or a computer readable storage medium including instructions that, when executed by hardware processing circuitry of user equipment (UE) of a cellular communication network, cause the UE to perform acts), or can optionally be combined with the subject matter of one or any combination of Examples 1-23 to include such subject matter, comprising transmitting and receive radio frequency electrical signals from a macro enhanced node B device (macro eNB) via the cellular communication network; transmitting and receive millimeter wave (mmWave) signals to communicate with one or more mmWave transmitting-receiving point device (mmWave T/R points); initiating beam scanning while the UE is communicating data with a first mmWave T/R point; determining that a beam of a second mmWave T/R point has greater received signal power than a beam of the first mmWave T/R point, wherein the first and second mmWave T/R points are assigned a same value for a cell identifier (cell-ID); initiating transmission of a random access message to the second mmWave T/R point, wherein the random access message includes a scheduling request for uplink transmissions; decoding physical downlink control channel (PDCCH) information received from the second mmWave T/R point; and communicating data with the second mmWave T/R point using a physical downlink shared channel (PDSCH) allocation and a physical uplink shared channel (PUSCH) allocation specified in the PDCCH information, wherein the first and second T/R point are assigned a same value for a cell identifier (cell-ID).

[0080] In Example 25, the subject matter of Example 24 optionally includes decoding uplink timing advance (TA) information included in a random access response message (RARM) received from the second mmWave T/R point.

[0081] In Example 26, the subject matter of Example 24 or Example 25 optionally includes decoding uplink TA information included in a downlink control information (DCI) message received from the second mmWave T/R point, wherein the DCI message also includes resource allocation information.

[0082] In Example 27, the subject matter of one or any combination of Examples 24-26 optionally includes decoding an acknowledge (ACK) message transmitted by the second mmWave T/R point in response to the random access message, and decode TA information included in a DCI message received from the second mmWave T/R point, wherein the DCI message also includes resource allocation information.

[0083] These non-limiting Examples can be combined in any permutation or combination.

[0084] The above detailed description includes references to the accompanying drawings, which form a part of the detailed description. The drawings show, by way of illustration, specific embodiments in which the invention can be practiced. These embodiments are also referred to herein as “examples.” All publications, patents, and patent documents referred to in this document are incorporated by reference herein in their entirety, as though individually incorporated by reference. In the event of inconsistent usages between this document and those documents so incorporated by reference, the usage in the incorporated reference(s) should be considered supplementary to that of this document; for irreconcilable inconsistencies, the usage in this document controls.

[0085] The Abstract is submitted with the understanding that it will not be used to limit or interpret the scope or meaning of the claims. The following claims are hereby incorporated into the detailed description, with each claim standing on its own as a separate embodiment. Also, in the following claims, the terms "including" and "comprising" are open-ended, that is, a system, device, article, or process that includes elements in addition to those listed after such a term in a claim are still deemed to fall within the scope of that claim. Moreover, in the following claims, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects.

CLAIMS

What is claimed is:

1. An apparatus of a millimeter wave transmitting-receiving point device (mmWave T/R point), the apparatus comprising:

transceiver circuitry configured to: transmit and receive radio frequency (RF) signals with a macro enhanced node B device (macro eNB); and transmit and receive millimeter wave (mmWave) electrical signals to communicate with user equipment (UE); and

processing circuitry configured to:

detect a physical random access channel (PRACH) transmission by a UE via a mmWave channel and perform a beam search using the PRACH;

initiate transmission of a random access response message to the UE;

initiate transmission of physical channel information to the UE; and

communicate data to the UE using a physical downlink shared channel (PDSCH) allocation and a physical uplink shared channel (PUSCH) allocation specified in the physical channel information, wherein the PDSCH and PUSCH are mmWave channels.

2. The apparatus of claim 1, wherein the processing circuitry is configured to include uplink timing advance (TA) information in a random access response message (RARM) transmitted to the UE.

3. The apparatus of claim 1, wherein the processing circuitry is configured to decode a scheduling request for uplink transmissions included in the random access message received from the UE.

4. The apparatus of claim 1, wherein the processing circuitry is configured to include uplink TA information and resource allocation information in a downlink control information (DCI) message transmitted to the UE.

5. The apparatus of claim 1, wherein the processing circuitry is configured to include resource allocation information in a first downlink control information (DCI) message transmitted to the UE, and include uplink TA information in a second DCI message transmitted to the UE.

6. The apparatus of claim 1, wherein the processing circuitry is configured to decode a scheduling request message received from the UE via a physical uplink control channel (PUCCH), wherein the PUCCH is a mmWave channel.

7. The apparatus of claim 1, wherein the processing circuitry is configured to initiate transmission of an acknowledge (ACK) message to the UE in response to detecting the random access message, and initiate transmission of a DCI message subsequent to transmission of the ACK message, wherein the DCI message includes uplink TA information and resource allocation information.

8. The apparatus of claim 7, wherein the processing circuitry is configured to include a delay indicator included in the DCI message, wherein the delay indicator is a minimum value of delay between the current subframe to the first downlink transmission of data from the mmWave T/R point.

9. The apparatus of claim 8, wherein the processing circuitry is configured to calculate the value of the delay indicator using one or both of the traffic load of the mmWave T/R point and a delay in data being forwarded to the mmWave T/R point.

10. The apparatus of claim 1, wherein processing circuity is configured to initiate transmission of a message that includes a delay indicator using the PDSCH, wherein the delay indicator includes a minimum value of delay between the current subframe to the first downlink transmission of data from the mmWave T/R point.

11. The apparatus of claim 1, wherein the processing circuitry is configured to receive a preamble sequence for a random access message from the macro eNB.

12. The apparatus of any one of claims 1-11, wherein the mmWave T/R point is a millimeter wave remote radio head (mmWave RRH) that includes one or more functional layers of an eNB and includes a plurality of antennas electrically connected to the transceiver circuitry.

13. An apparatus of user equipment (UE), the apparatus comprising:

transceiver circuitry configured to: transmit and receive radio frequency (RF) signals with a macro enhanced node B device (macro eNB); and transmit and receive millimeter wave (mmWave) signals with one or more mmWave transmitting-receiving (T/R) points; and

processing circuitry configured to: initiate beam scanning while the UE is communicating data with a first mmWave T/R point; determine that a beam of a second mmWave T/R point has greater signal intensity than a beam of the first mmWave T/R point; initiate transmission of a random access message in a direction of the second mmWave T/R point; decode physical control channel information received from the second mmWave T/R point; and communicate data with the second mmWave T/R point using a downlink (DL) channel allocation and an uplink (UL) channel allocation specified in the physical channel information, wherein the first and second mmWave T/R points are assigned a same physical cell identifier.

14. The apparatus of claim 13, wherein the processing circuitry is configured to decode uplink timing advance (TA) information included in a random access response message (RARM) received from the second mmWave T/R point.

15. The apparatus of claim 13, wherein the processing circuitry is configured to include a scheduling request for uplink transmissions with the random access message transmitted to the second mmWave T/R point.

16. The apparatus of claim 13, wherein the processing circuitry is configured to decode uplink TA information included in a downlink control information (DCI) message received from the second mmWave T/R point, wherein the DCI message also includes resource allocation information.

17. The apparatus of claim 13, wherein the processing circuitry is configured to decode uplink TA information included in one DCI message received from the second mmWave T/R point, and decode resource allocation information included in another DCI message received from the second mmWave T/R point.

18. The apparatus of claim 13, wherein the processing circuitry is configured to transmit a scheduling request for uplink transmissions to the second mmWave T/R point using a physical uplink control channel (PUCCH).

19. The apparatus of claim 13, wherein the processing circuitry is configured to decode an acknowledge (ACK) message transmitted by the second mmWave T/R point in response to the random access message, and decode uplink TA information included in a DCI message received from the second mmWave T/R point, wherein the DCI message also includes resource allocation information.

20. The apparatus of claim 19, wherein the processing circuitry is configured to decode a delay indicator included in the DCI message, wherein the delay indicator is a minimum value of delay between the current subframe to the first downlink transmission of data from the second mmWave T/R point.

21. The apparatus of any one of claims 13-20, wherein the processing circuitry is configured to decode a delay indicator included in a physical downlink shared channel (PDSCH) transmission, wherein the delay indicator includes a minimum value of

delay between the current subframe to the first downlink transmission of data from the mmWave T/R point.

22. The apparatus of claim 21, wherein the processing circuitry includes a baseband processor configured to decode the delay indicator included in the PDSCH transmission.

23. The apparatus of claim 21, including one or more antennas electrically connected to the transceiver circuitry.

24. A computer readable storage medium including instructions that, when executed by hardware processing circuitry of user equipment (UE), cause the UE to:

transmit and receive radio frequency electrical signals to communicate with a macro enhanced node B device (macro eNB);

transmit and receive millimeter wave (mmWave) signals to communicate with one or more mmWave transmitting-receiving point device (mmWave T/R points);

initiate beam scanning while the UE is communicating data with a first mmWave T/R point;

determine that a beam of a second mmWave T/R point has greater received signal power than a beam of the first mmWave T/R point, wherein the first and second mmWave T/R points are assigned a same value for a cell identifier (cell-ID);

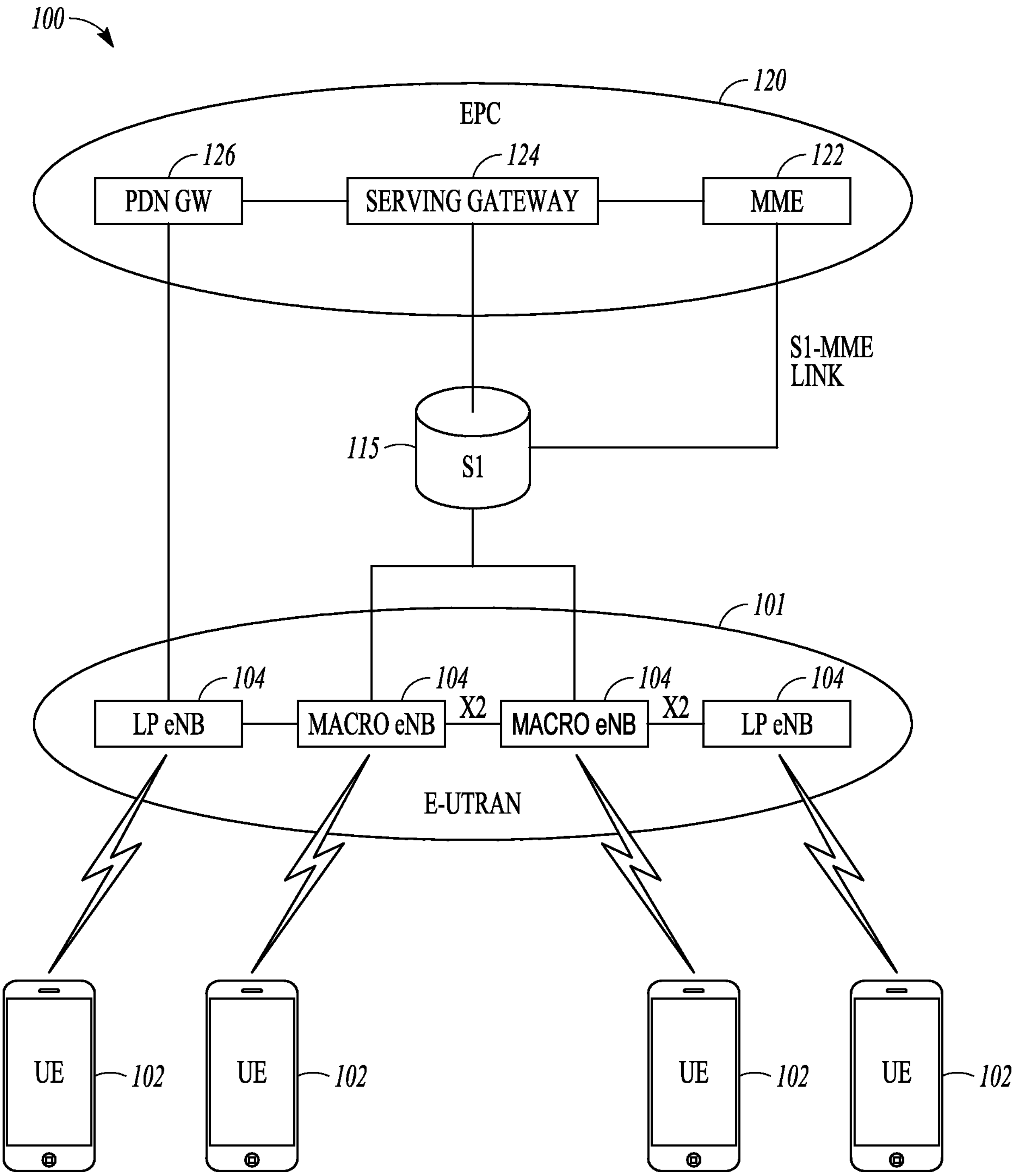
initiate transmission of a random access message in a direction of the second mmWave T/R point, wherein the random access message includes a scheduling request for uplink transmissions;

decode physical downlink control channel (PDCCH) information received from the second mmWave T/R point; and

communicate data with the second mmWave T/R point using a physical downlink shared channel (PDSCH) allocation and a physical uplink shared channel

(PUSCH) allocation specified in the PDCCH information, wherein the first and second T/R point are assigned a same value for a cell identifier (cell-ID).

25. The computer readable storage medium of claim 24, including instructions that, when executed by the hardware processing circuitry of the UE cause the UE to decode uplink timing advance (TA) information included in a random access response message (RARM) received from the second mmWave T/R point.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120
EPC
126
PDN GW
124
SERVING GATEWAY
122
MME
S1-MME
LINK
115
S1
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LP eNB
104
MACRO eNB
X2
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MACRO eNB
X2
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LP eNB
E-UTRAN
UE
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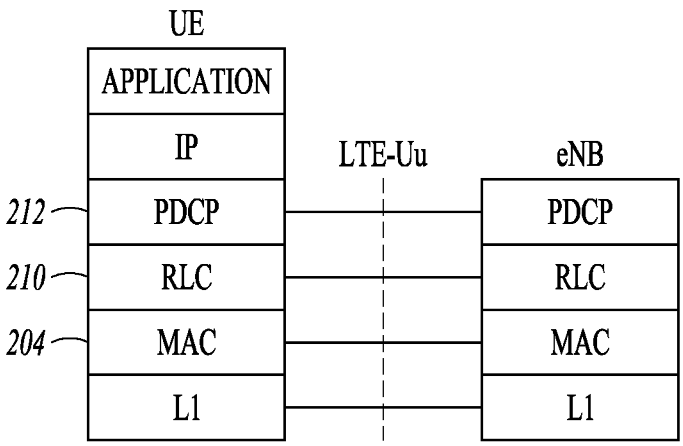
UE
102
UE
102
UE
102

FIG. 1


UE
APPLICATION
IP
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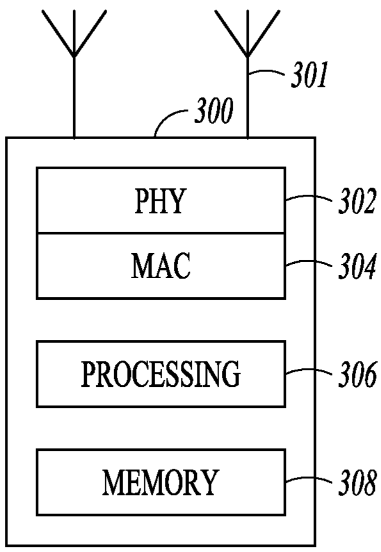
eNB
212
PDCP
PDCP
210
RLC
RLC
204
MAC
MAC
L1
L1

FIG. 2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PHY
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MAC
304
PROCESSING
306
MEMORY
308

FIG. 3

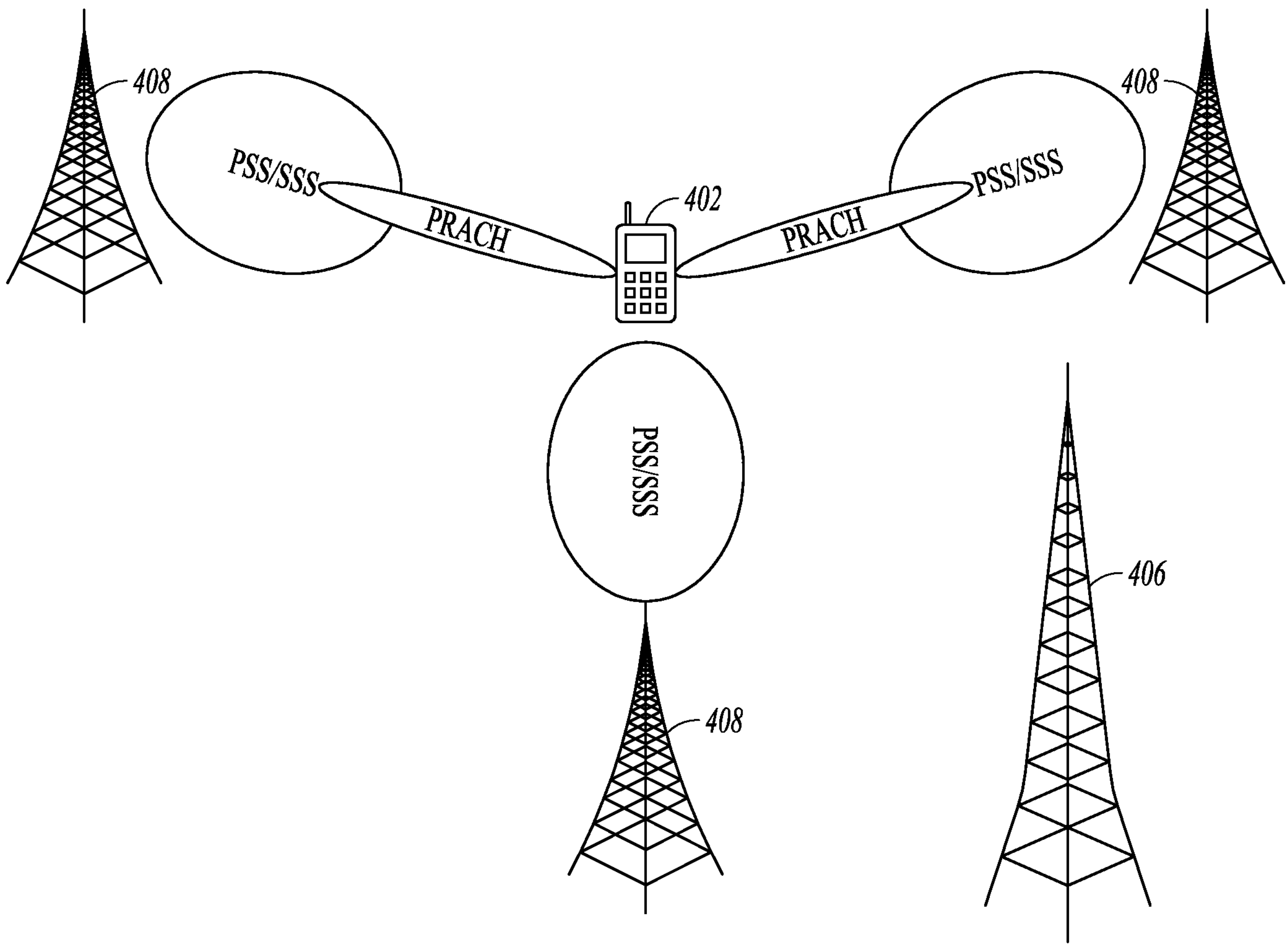

FIG. 4

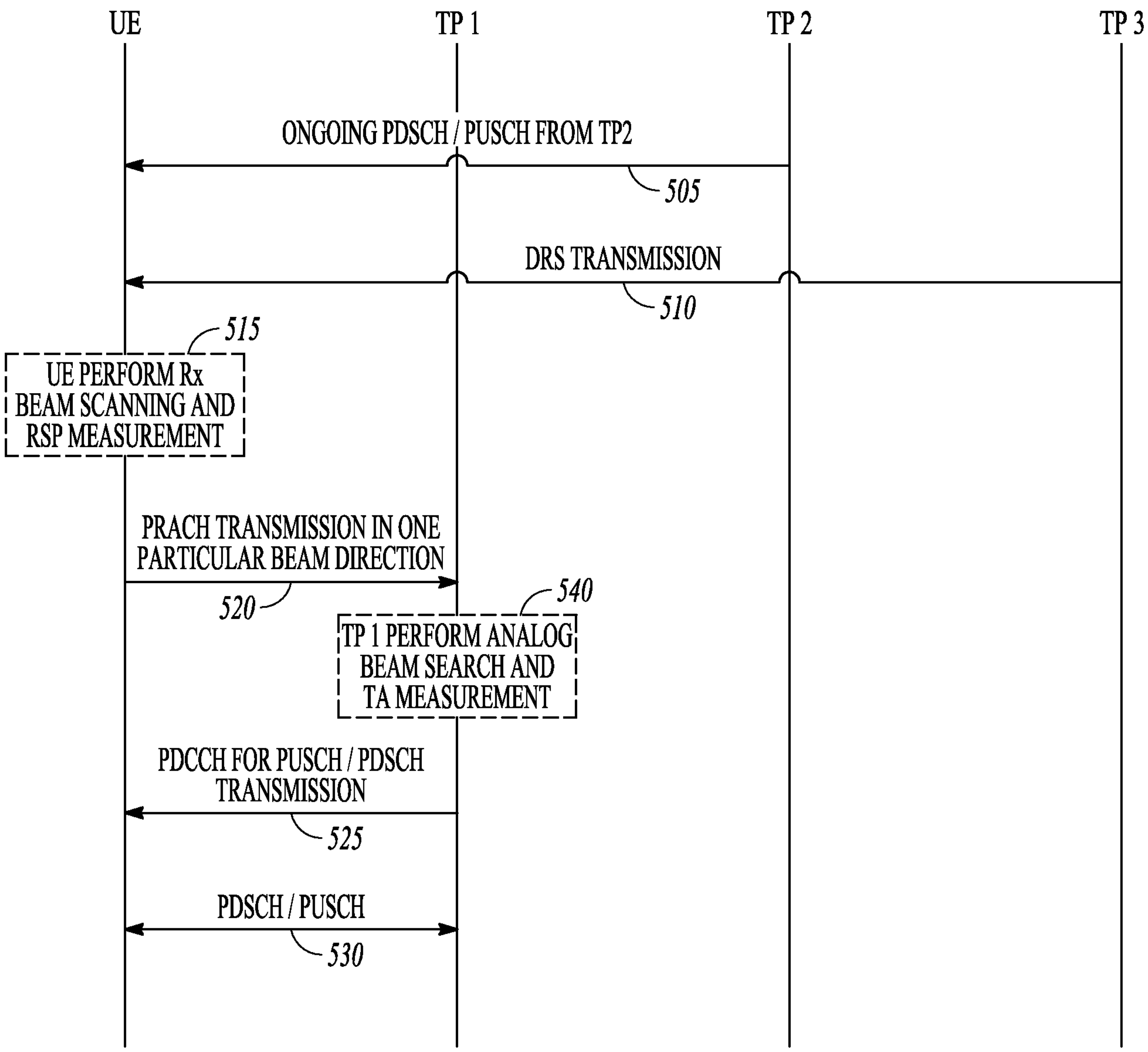
UE
TP 1
TP 2
TP 3
ONGOING PDSCH / PUSCH FROM TP2
505
DRS TRANSMISSION
510
515
UE PERFORM Rx BEAM SCANNING AND RSP MEASUREMENT
PRACH TRANSMISSION IN ONE PARTICULAR BEAM DIRECTION
520
540
TP 1 PERFORM ANALOG BEAM SEARCH AND TA MEASUREMENT
PDCCH FOR PUSCH / PDSCH TRANSMISSION
525
PDSCH / PUSCH
530

FIG. 5

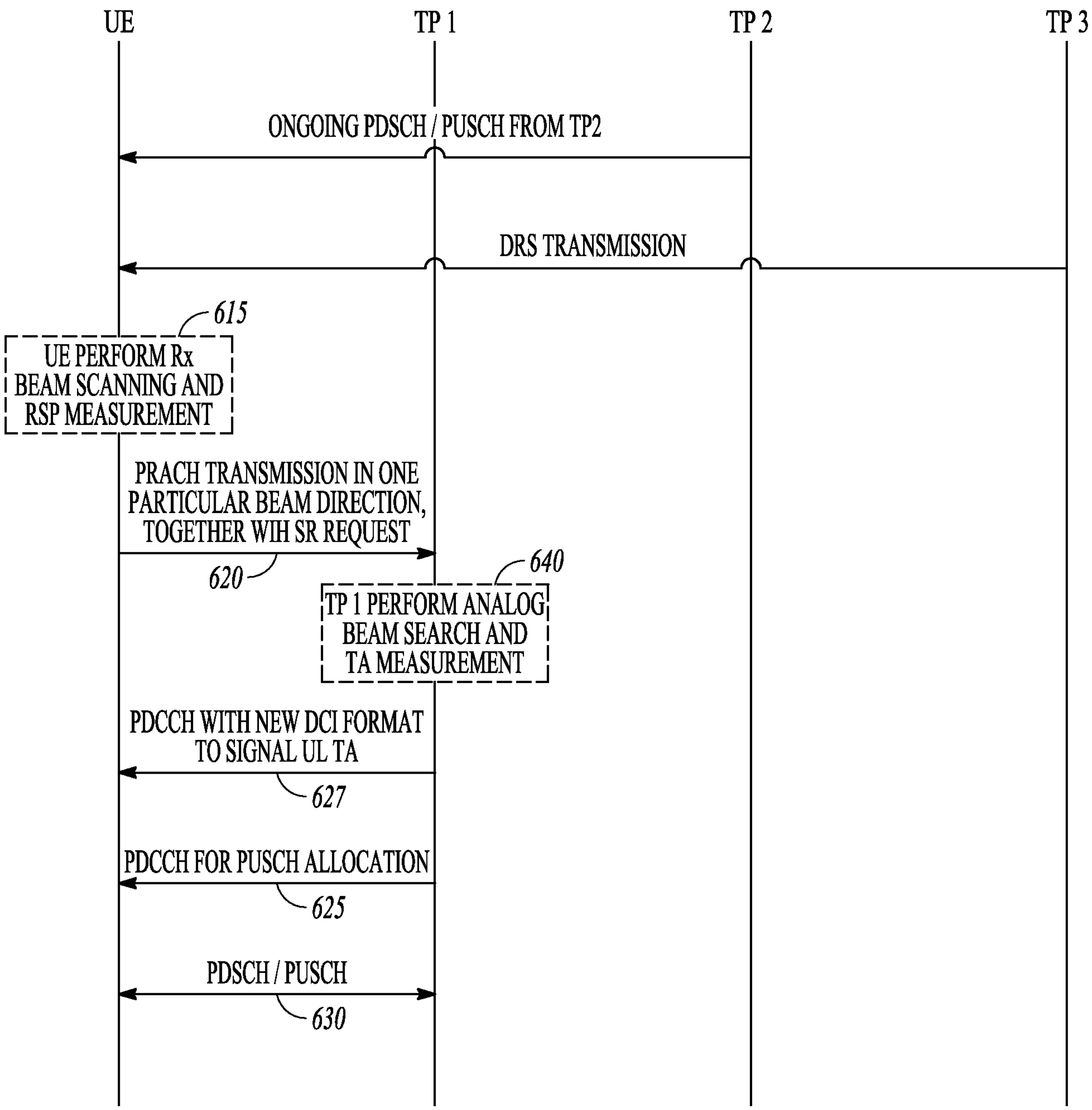
UE
TP 1
TP 2
TP 3
ONGOING PDSCH / PUSCH FROM TP2
DRS TRANSMISSION
615
UE PERFORM Rx BEAM SCANNING AND RSP MEASUREMENT
PRACH TRANSMISSION IN ONE PARTICULAR BEAM DIRECTION, TOGETHER WIH SR REQUEST
620
640
TP 1 PERFORM ANALOG BEAM SEARCH AND TA MEASUREMENT
PDCCH WITH NEW DCI FORMAT TO SIGNAL UL TA
627
PDCCH FOR PUSCH ALLOCATION
625
PDSCH / PUSCH
630

FIG. 6

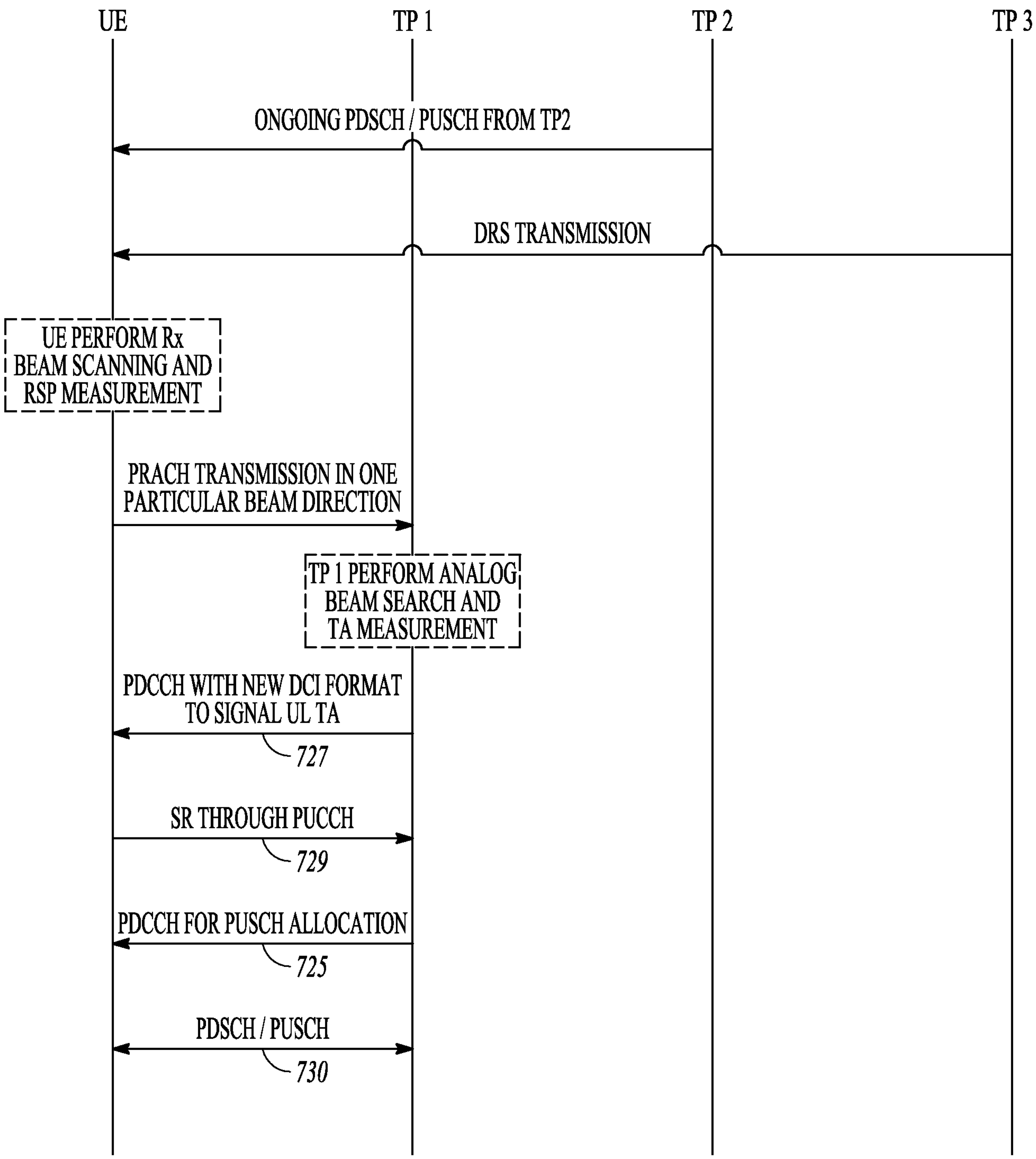
UE
TP 1
TP 2
TP 3
ONGOING PDSCH / PUSCH FROM TP2
DRS TRANSMISSION
UE PERFORM Rx BEAM SCANNING AND RSP MEASUREMENT
PRACH TRANSMISSION IN ONE PARTICULAR BEAM DIRECTION
TP 1 PERFORM ANALOG BEAM SEARCH AND TA MEASUREMENT
PDCCH WITH NEW DCI FORMAT TO SIGNAL UL TA
727
SR THROUGH PUCCH
729
PDCCH FOR PUSCH ALLOCATION
725
PDSCH / PUSCH
730

FIG. 7

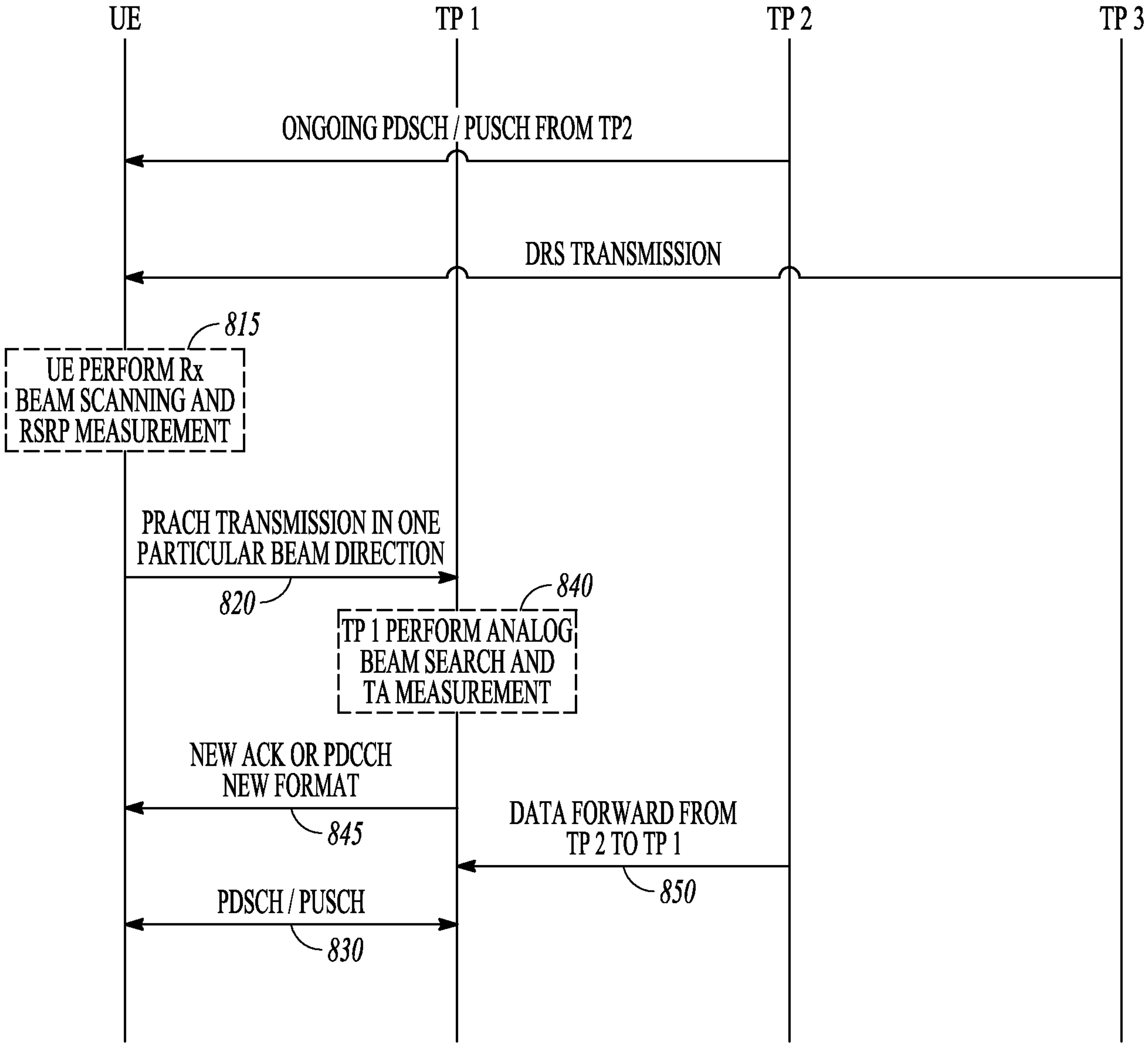
UE
TP 1
TP 2
TP 3
ONGOING PDSCH / PUSCH FROM TP2
DRS TRANSMISSION
815
UE PERFORM Rx BEAM SCANNING AND RSRP MEASUREMENT
PRACH TRANSMISSION IN ONE PARTICULAR BEAM DIRECTION
820
840
TP 1 PERFORM ANALOG BEAM SEARCH AND TA MEASUREMENT
NEW ACK OR PDCCH NEW FORMAT
845
DATA FORWARD FROM TP 2 TO TP 1
850
PDSCH / PUSCH
830

FIG. 8

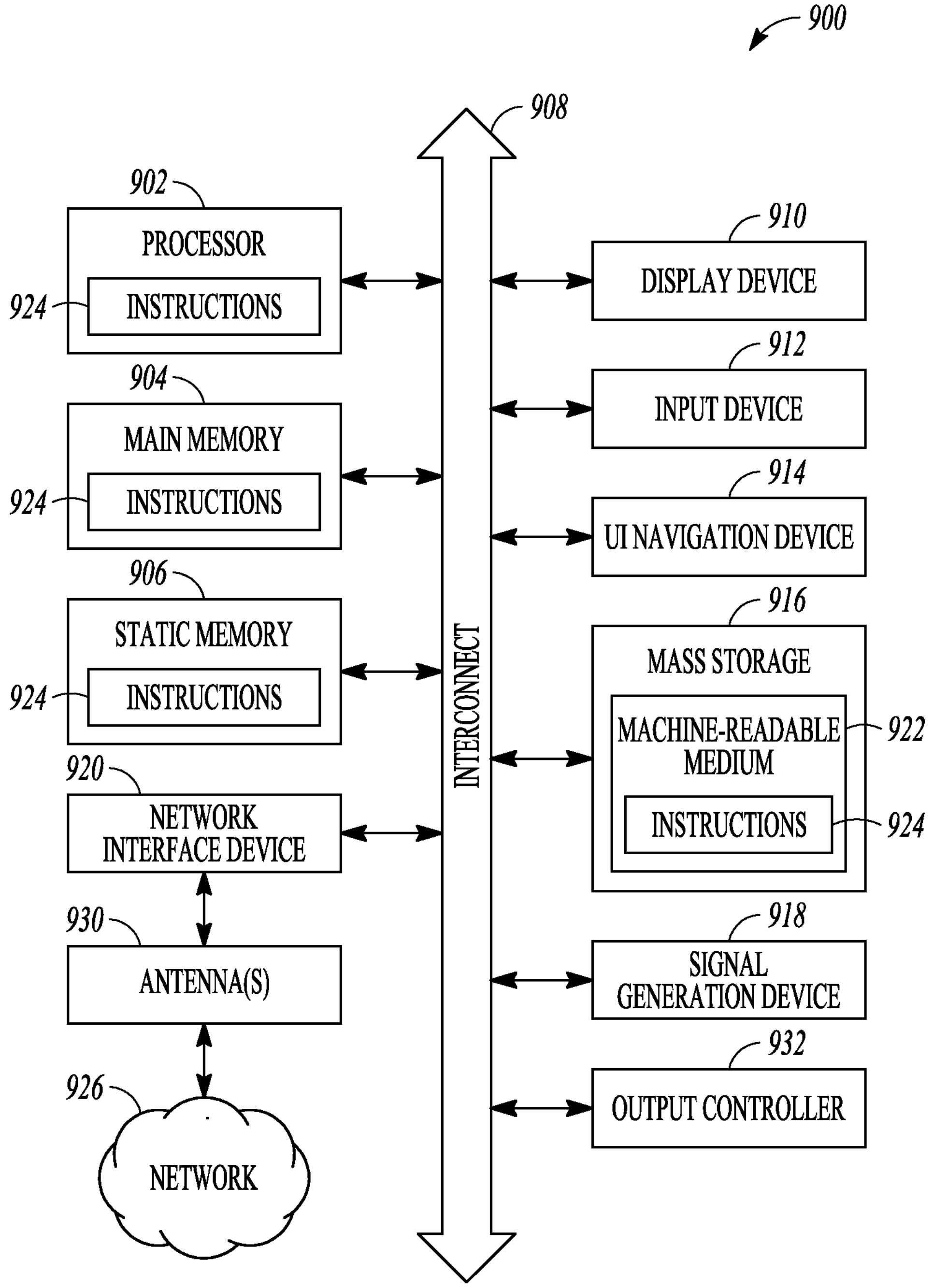
900
908
902
PROCESSOR
924
INSTRUCTIONS
904
MAIN MEMORY
924
INSTRUCTIONS
906
STATIC MEMORY
924
INSTRUCTIONS
920
NETWORK INTERFACE DEVICE
930
ANTENNA(S)
926
NETWORK
INTERCONNECT
910
DISPLAY DEVICE
912
INPUT DEVICE
914
UI NAVIGATION DEVICE
916
MASS STORAGE
MACHINE-READABLE MEDIUM
922
INSTRUCTIONS
924
918
SIGNAL GENERATION DEVICE
932
OUTPUT CONTROLLER

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/066692

A. CLASSIFICATION OF SUBJECT MATTER

H04B 7/26(2006.01)i, H04B 7/02(2006.01)i

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 7/26; H04W 74/08; H04L 25/02; H04B 7/155; H04W 72/04; H04W 72/08; H04B 7/04; H04B 7/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: mmWave T/R point, PRACH, PDSCH, PUSCH, mmWave channel, beam scanning, same physical cell identifier, random access message

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2014-124164 A1 (INTERDIGITAL PATENT HOLDINGS, INC.) 14 August 2014 See paragraphs [0044], [0050]-[0055], [0073]-[0074], [0078], [0088], [0097]-[0099], [0103]-[0104]; and figure 3.	1-6,11-12
A		7-10,13-25
Y	US 2014-0010178 A1 (SAMSUNG ELECTRONICS CO., LTD.) 09 January 2014 See paragraphs [0004], [0045], [0049], [0084]; claim 21; and figure 3A.	1-6,11-12
Y	US 2015-0208386 A1 (LG ELECTRONICS INC.) 23 July 2015 See paragraphs [0010], [0058]-[0059], [0074]-[0076]; and figure 9.	2,4-5
Y	US 8879447 B1 (MOTOROLA SOLUTIONS, INC.) 04 November 2014 See column 7, lines 55-62; and figure 7.	3,6
Y	US 2014-0010214 A1 (KARI JUHANI HOOLI et al.) 09 January 2014 See paragraphs [0027]-[0028], [0066]-[0067]; claim 6; and figure 2.	11
A	US 2015-0009951 A1 (SAMSUNG ELECTRONICS CO., LTD.) 08 January 2015 See paragraphs [0064], [0097]-[0098]; claim 15; and figure 3.	1-25

☐ 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
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