(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
15 February 2018 (15.02.2018)

WIPO | PCT

(10) **International Publication Number**
WO 2018/027936 A1

(51) **International Patent Classification:**
H04B 7/06 (2006.01) ***H04B 7/08*** (2006.01)

(21) **International Application Number:** PCT/CN2016/094956

(22) **International Filing Date:** 12 August 2016 (12.08.2016)

(25) **Filing Language:** English

(26) **Publication Language:** English

(71) **Applicant: QUALCOMM INCORPORATED** [US/US]; ATTN: International IP Administration, 5775 Morehouse Drive, San Diego, California 92121-1714 (US).

(72) **Inventors; and**
(71) **Applicants** *(for US only)*: **SUNDARARAJAN, Jay Kumar** [IN/US]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US). **BHUSHAN, Naga** [US/US]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US). **SUN, Haitong** [CN/US]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US). **JI, Tingfang** [CN/US]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US). **ZHANG, Yu** [CN/CN]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US). **CHEN, Wanshi** [CN/US]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US).

(74) **Agent: NTD PATENT & TRADEMARK AGENCY LIMITED**; 10th Floor, Block A, Investment Plaza, 27 Jinrongdajie, Xicheng District, Beijing 100033 (CN).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

(54) **Title:** UPLINK MULTIPLE-INPUT MULTIPLE-OUTPUT (MIMO) SCHEDULING USING BEAMFORMED REFERENCE SIGNALS

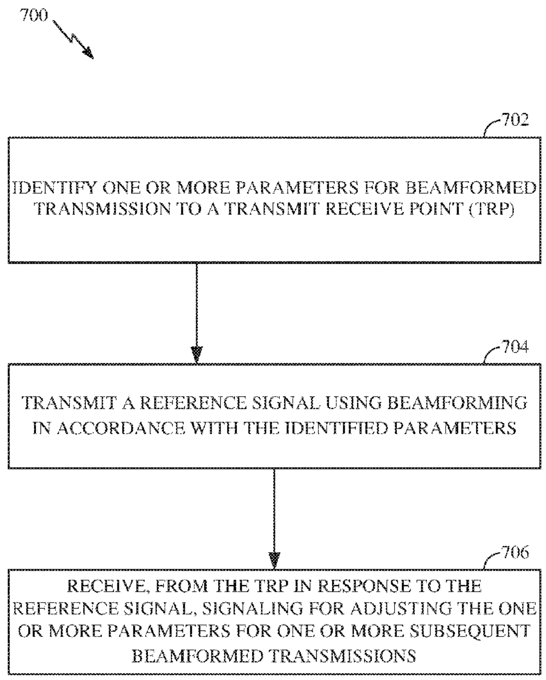

FIG. 7

(57) **Abstract:** Aspects of the present disclosure provide methods and apparatus for selecting beamforming parameters for uplink transmissions based on an uplink reference signal. An example method generally includes identifying one or more parameters for beamformed transmission to a transmit receive point (TRP), transmitting a reference signal using beamforming in accordance with the identified parameters, and receiving, from the TRP in response to the reference signal, signaling for adjusting the one or more parameters for one or more subsequent beamformed transmissions.

WO 2018/027936 A1

[Continued on next page]

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
— *of inventorship (Rule 4.17(iv))*

Published:
— *with international search report (Art. 21(3))*

UPLINK MULTIPLE-INPUT MULTIPLE-OUTPUT (MIMO) SCHEDULING USING BEAMFORMED REFERENCE SIGNALS

TECHNICAL FIELD

[0001] The present disclosure generally relates to wireless communications and, more particularly, to scheduling transmissions for a wireless node based on a beamformed reference signal.

INTRODUCTION

[0002] Wireless communication systems are widely deployed to provide various telecommunication services such as telephony, video, data, messaging, and broadcasts. Typical wireless communication systems may employ multiple-access technologies capable of supporting communication with multiple users by sharing available system resources (e.g., bandwidth, transmit power). Examples of such multiple-access technologies include code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, orthogonal frequency division multiple access (OFDMA) systems, single-carrier frequency divisional multiple access (SC-FDMA) systems, and time division synchronous code division multiple access (TD-SCDMA) systems.

[0003] These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level. An example of an emerging telecommunication standard is Long Term Evolution (LTE). LTE/LTE-Advanced is a set of enhancements to the Universal Mobile Telecommunications System (UMTS) mobile standard promulgated by Third Generation Partnership Project (3GPP). It is designed to better support mobile broadband Internet access by improving spectral efficiency, lower costs, improve services, make use of new spectrum, and better integrate with other open standards using OFDMA on the downlink (DL), SC-FDMA on the uplink (UL), and multiple-input multiple-output (MIMO) antenna technology. However, as the demand for mobile broadband access continues to increase, there exists a need for further improvements in LTE technology. Preferably, these improvements should be applicable to other multiaccess technologies and the telecommunication standards that employ these technologies.

[0004] Some wireless communication standards base user equipment handoff decisions based, at least in part, on downlink measurements. Future generation wireless communication may focus on user-centric networks. Accordingly, it may be desirable to have an efficient handover framework for user-centric networks.

BRIEF SUMMARY

[0005] The systems, methods, and devices of the disclosure each have several aspects, no single one of which is solely responsible for its desirable attributes. Without limiting the scope of this disclosure as expressed by the claims which follow, some features will now be discussed briefly. After considering this discussion, and particularly after reading the section entitled "Detailed Description" one will understand how the features of this disclosure provide advantages that include improved communications between access points and stations in a wireless network.

[0006] Certain aspects of the present disclosure provide a method for wireless communication by a wireless node. The method generally includes identifying one or more parameters for beamformed transmission to a transmit receive point (TRP), transmitting a reference signal using beamforming in accordance with the identified parameters, and receiving, from the TRP in response to the reference signal, signaling for adjusting the one or more parameters for one or more subsequent beamformed transmissions.

[0007] Certain aspects of the present disclosure provide a method for wireless communications by a transmit receive point (TRP). The method generally includes receiving, from a wireless node, a beamformed reference signal, determining, based on the beamformed reference signal, one or more parameters for the wireless node to use for adjusting subsequent beamformed transmissions, and signaling the parameters to the wireless node.

[0008] Aspects generally include methods, apparatus, systems, computer program products, and processing systems, as substantially described herein with reference to and as illustrated by the accompanying drawings.

[0009] Other aspects, features, and embodiments of the present invention will become apparent to those of ordinary skill in the art, upon reviewing the following description of specific, exemplary embodiments of the present invention in conjunction with the accompanying figures. While features of the present invention may be discussed relative to certain embodiments and figures below, all embodiments of the present invention can include one or more of the advantageous features discussed herein. In other words, while one or more embodiments may be discussed as having certain advantageous features, one or more of such features may also be used in accordance with the various embodiments of the invention discussed herein. In similar fashion, while exemplary embodiments may be discussed below as device, system, or method embodiments it should be understood that such exemplary embodiments can be implemented in various devices, systems, and methods.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] So that the manner in which the above-recited features of the present disclosure can be understood in detail, a more particular description, briefly summarized above, may be had by reference to aspects, some of which are illustrated in the appended drawings. The appended drawings illustrate only certain typical aspects of this disclosure, however, and are therefore not to be considered limiting of its scope, for the description may admit to other equally effective aspects.

[0011] FIG. 1 illustrates an exemplary deployment in which multiple wireless networks have overlapping coverage, in accordance with certain aspects of the disclosure.

[0012] FIG. 2 is a diagram illustrating an example of an access network, in accordance with certain aspects of the disclosure.

[0013] FIG. 3 is a diagram illustrating an example of a DL frame structure in LTE, in accordance with certain aspects of the disclosure.

[0014] FIG. 4 is a diagram illustrating an example of an UL frame structure in LTE, in accordance with certain aspects of the disclosure.

[0015] FIG. 5 is a diagram illustrating an example of a radio protocol architecture for the user and control plane, in accordance with certain aspects of the disclosure.

[0016] FIG. 6 is a diagram illustrating an example of an evolved Node B (eNB) and user equipment (UE) in an access network, in accordance with certain aspects of the disclosure.

[0017] FIG. 7 illustrates example operations that may be performed by a wireless node to transmit a beamformed reference signal and perform subsequent transmissions to a transmit receive point (TRP) based on feedback related to the beamformed reference signal, in accordance with certain aspects of the present disclosure.

[0018] FIG. 8 illustrates example operations that may be performed by a transmit receive point (TRP) to determine beamforming parameters for transmissions from a wireless node based on reception of a beamformed reference signal from the wireless node, in accordance with certain aspects of the present disclosure.

[0019] FIG. 9 illustrates an example frame exchange for scheduling uplink transmissions based on a beamformed reference signal, in accordance with certain aspects of the present disclosure.

[0020] FIG. 10 is an example call flow diagram of messages that may be exchanged by a wireless node and a transmit receive point (TRP) to schedule uplink transmissions based on a beamformed reference signal, in accordance with certain aspects of the present disclosure.

[0021] FIG. 11 illustrates an example frame exchange for scheduling uplink transmissions based on a beamformed reference signal, in accordance with certain aspects of the present disclosure.

[0022] FIG. 12 is an example call flow diagram of messages that may be exchanged by a wireless node and a transmit receive point (TRP) to schedule uplink transmissions based on a beamformed reference signal, in accordance with certain aspects of the present disclosure.

[0023] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements disclosed in one aspect may be beneficially utilized on other aspects without specific recitation.

DETAILED DESCRIPTION

[0024] Aspects of the present disclosure provide for selection of beamforming settings for uplink transmissions based on a beamformed uplink reference signal. By receiving a beamformed reference signal from a wireless node, a TRP can use the beamformed reference signal and other information available at the TRP (*e.g.*, mutual interference information) to identify transmission parameters for different wireless nodes to use in subsequent transmissions to the TRP.

[0025] Advantageously, downselection of users and beams may reduce the amount of data to provide in a uplink grant by the TRP. Downselection may also help avoid interference among the selected beams and/or users. In some cases, if the wireless node and the beams are selected without changes for data transmission, TRPs may obtain an accurate estimate of the interference covariance matrix, as the set of interferers may remain constant.

[0026] Various aspects of the disclosure are described more fully hereinafter with reference to the accompanying drawings. This disclosure may, however, be embodied in many different forms and should not be construed as limited to any specific structure or function presented throughout this disclosure. Rather, these aspects are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art. Based on the teachings herein one skilled in the art should appreciate that the scope of the disclosure is intended to cover any aspect of the disclosure disclosed herein, whether implemented independently of or combined with any other aspect of the disclosure. For example, an apparatus may be implemented or a method may be practiced using any number of the aspects set forth herein. In addition, the scope of the disclosure is intended to cover such an apparatus or method which is practiced using other structure, functionality, or structure and functionality in addition to or other than the various aspects of the disclosure set forth herein. It should be understood that any aspect of the disclosure disclosed herein may be embodied by one or more elements of a claim.

[0027] The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any aspect described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects.

[0028] Although particular aspects are described herein, many variations and permutations of these aspects fall within the scope of the disclosure. Although some benefits and advantages of the preferred aspects are mentioned, the scope of the disclosure is not intended to be limited to particular benefits, uses, or objectives. Rather, aspects of the disclosure are intended to be broadly applicable to different wireless technologies, system configurations, networks, and transmission protocols, some of which are illustrated by way of example in the figures and in the following description of the preferred aspects. The detailed description and drawings are merely illustrative of the disclosure rather than limiting, the scope of the disclosure being defined by the appended claims and equivalents thereof.

[0029] The detailed description set forth below in connection with the appended drawings is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. In some instances, well-known structures and components are shown in block diagram form in order to avoid obscuring such concepts.

[0030] Several aspects of telecommunication systems will now be presented with reference to various apparatus and methods. These apparatus and methods will be described in the following detailed description and illustrated in the accompanying drawings by various blocks, modules, components, circuits, steps, processes, algorithms, etc. (collectively referred to as "elements"). These elements may be implemented using hardware, software/firmware, or combinations thereof. Whether such elements are implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system.

[0031] By way of example, an element, or any portion of an element, or any combination of elements may be implemented with a "processing system" that includes one or more processors. Examples of processors include microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate arrays (FPGAs), programmable logic devices (PLDs), state machines, gated logic, discrete hardware circuits, and other suitable hardware configured to perform the various functionality described throughout this disclosure. One or more processors in the processing system may execute software. Software shall be construed broadly to mean instructions, instruction sets, code, code segments, program code, programs, subprograms, software modules, applications, software applications, software packages, routines, subroutines, objects, executables, threads of execution, procedures, functions, etc., whether referred to as software/firmware, middleware, microcode, hardware description language, or otherwise.

[0032] Accordingly, in one or more exemplary embodiments, the functions described may be implemented in hardware, software/firmware, or combinations thereof. If implemented in software, the functions may be stored or transmitted over as one or more instructions or code on a computer-readable medium. Software shall be construed broadly to mean instructions, data, or any combination thereof, whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise. Computer-readable media include both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. The processor may be responsible for managing the bus and general processing, including the execution of software modules stored on the machine-readable storage media. A computer-readable storage medium may be coupled to a processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. By way of example, the machine-readable media may include a transmission line, a carrier wave modulated by data, and/or a computer readable storage medium with instructions stored thereon separate from the wireless node, all of which may be accessed by the processor through the bus interface. Alternatively, or in addition, the machine-readable media, or any portion thereof, may be integrated into the processor, such as the case may be with cache and/or general register files. Examples of machine-readable storage media may include, by way of example, RAM (Random Access Memory), flash memory, ROM (Read Only Memory), PROM (Programmable Read-Only Memory), EPROM (Erasable Programmable Read-Only Memory), EEPROM

(Electrically Erasable Programmable Read-Only Memory), registers, magnetic disks, optical disks, hard drives, or any other suitable storage medium, or any combination thereof. The machine-readable media may be embodied in a computer-program product.

[0033] A software module may comprise a single instruction, or many instructions, and may be distributed over several different code segments, among different programs, and across multiple storage media. The computer-readable media may comprise a number of software modules. The software modules include instructions that, when executed by an apparatus such as a processor, cause the processing system to perform various functions. The software modules may include a transmission module and a receiving module. Each software module may reside in a single storage device or be distributed across multiple storage devices. By way of example, a software module may be loaded into RAM from a hard drive when a triggering event occurs. During execution of the software module, the processor may load some of the instructions into cache to increase access speed. One or more cache lines may then be loaded into a general register file for execution by the processor. When referring to the functionality of a software module below, it will be understood that such functionality is implemented by the processor when executing instructions from that software module.

[0034] Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared (IR), radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, include compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk, and Blu-ray® disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Thus, in some aspects computer-readable media may comprise non-transitory computer-readable media (e.g., tangible media). In addition, for other aspects computer-readable media may comprise transitory computer-readable media (e.g., a signal). Combinations of the above should also be included within the scope of computer-readable media.

[0035] Thus, certain aspects may comprise a computer program product for performing the operations presented herein. For example, such a computer program product may comprise a computer-readable medium having instructions stored (and/or encoded) thereon, the instructions being executable by one or more processors to perform the operations described herein.

[0036] Further, it should be appreciated that modules and/or other appropriate means for performing the methods and techniques described herein can be downloaded and/or otherwise obtained by a user terminal and/or base station as applicable. For example, such a device can be coupled to a server to facilitate the transfer of means for performing the methods described herein. Alternatively, various methods described herein can be provided via storage means (e.g., RAM, ROM, a physical storage medium such as a compact disc (CD) or floppy disk, etc.), such that a user terminal and/or base station can obtain the various methods upon coupling or providing the storage means to the device. Moreover, any other suitable technique for providing the methods and techniques described herein to a device can be utilized.

[0037] The techniques described herein may be used for various wireless communication networks 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 other networks. The terms "network" and "system"" are often used interchangeably. A CDMA network may implement a radio access technology (RAT) such as universal terrestrial radio access (UTRA), cdma2000, etc. UTRA includes wideband CDMA (WCDMA) and other variants of CDMA. cdma2000 covers IS-2000, IS-95 and IS-856 standards. IS-2000 is also referred to as 1x radio transmission technology (1xRTT), CDMA2000 1X, etc. A TDMA network may implement a RAT such as global system for mobile communications (GSM), enhanced data rates for GSM evolution (EDGE), or GSM/EDGE radio access network (GERAN). An OFDMA network may implement a RAT such as evolved UTRA (E-UTRA), ultra mobile broadband (UMB), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDM.RTM., etc. UTRA and E-UTRA are part of universal mobile telecommunication system (UMTS). 3GPP long-term evolution (LTE) and LTE-Advanced (LTE-A) are new releases of UMTS that use E-UTRA, which employs OFDMA on the downlink and SC-FDMA on the uplink. UTRA, E-UTRA, UMTS, LTE, LTE-A and GSM are described in documents from an organization named "3rd Generation Partnership Project" (3GPP). cdma2000 and UMB are described in documents from an organization named "3rd Generation Partnership Project 2" (3GPP2). The techniques described herein may be used for the wireless networks and RATs mentioned above as well as other wireless networks and RATs.

[0038] It is noted that while aspects may be described herein using terminology commonly associated with 3G and/or 4G wireless technologies, aspects of the present disclosure can be applied in other generation-based communication systems, such as 5G and later.

AN EXAMPLE WIRELESS COMMUNICATION SYSTEM

[0039] FIG. 1 illustrates an example deployment in which aspects of the present disclosure may be implemented. For example, a user equipment (UE) 110transmits an uplink reference signal to a base station (BS) such as eNB 122 (e.g., a transmission reception point (TRP)). The uplink reference signal can include an indication of a preferred downlink beam. The UE 110 can receive a downlink from the eNB 122 based, at least in part, on the uplink reference signal. For downlink-based mobility, the UE may receive measurement reference signals (MRS) transmitted with different beams from the eNB 122. The UE 110 can select the preferred beam based on the MRS. The eNB 122 can beamform the downlink signal to the UE using the preferred beam and/or the eNB 122 can send a handover command to the UE 110 based, at least in part, on the uplink reference signal. For uplink-based mobility the UE 110 sends the uplink reference signal, without MRS from the eNB 122, and the eNB 122 can perform beam selection and/or handover decisions based on measurement of the uplink reference signal. In some cases a non-serving eNB can receive the uplink reference signals and send a handover command to the UE 110.

[0040] FIG. 1 shows an exemplary deployment in which multiple wireless networks have overlapping coverage. A radio access network such as an evolved universal terrestrial radio access network (E-UTRAN) 120 may support LTE and may include a number of evolved Node Bs (eNBs) 122 (e.g., TRPs) and other network entities that can support wireless communication for user equipments (UEs). Each eNB may provide communication coverage for a particular geographic area. The term "cell" can refer to a coverage area of an eNB and/or an eNB subsystem serving this coverage area. A serving gateway (S-GW) 124 may communicate with E-UTRAN 120 and may perform various functions such as packet routing and forwarding, mobility anchoring, packet buffering, initiation of network-triggered services, etc. A mobility management entity (MME) 126 may communicate with E-UTRAN 120 and serving gateway 124 and may perform various functions such as mobility management, bearer management, distribution of paging messages, security control, authentication, gateway selection, etc. The network entities in LTE are described in 3GPP TS 36.300, entitled "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description," which is publicly available.

[0041] A radio access network (RAN) 130 may support GSM and may include a number of base stations 132 and other network entities that can support wireless communication for UEs. A mobile switching center (MSC) 134 may communicate with the RAN 130 and may support voice services, provide routing for circuit-switched calls, and perform mobility management for UEs located within the area served by MSC 134. Optionally, an inter-working function (IWF) 140 may facilitate communication between MME 126 and MSC 134 (e.g., for 1xCSFB).

[0042] E-UTRAN 120, serving gateway 124, and MME 126 may be part of an LTE network 102. RAN 130 and MSC 134 may be part of a GSM network 104. For simplicity, FIG. 1 shows only some network entities in the LTE network 102 and the GSM network 104. The LTE and GSM networks may also include other network entities that may support various functions and services.

[0043] In general, any number of wireless networks may be deployed in a given geographic area. Each wireless network may support a particular RAT and may operate on one or more frequencies. A RAT may also be referred to as a radio technology, an air interface, etc. A frequency may also be referred to as a carrier, a frequency channel, etc. Each frequency may support a single RAT in a given geographic area in order to avoid interference between wireless networks of different RATs.

[0044] A UE 110 may be stationary or mobile and may also be referred to as a mobile station, a terminal, an access terminal, a subscriber unit, a station, etc. UE 110 may be a cellular phone, a personal digital assistant (PDA), a wireless modem, a wireless communication device, a handheld device, a laptop computer, a cordless phone, a wireless local loop (WLL) station, etc. In aspects, UE 110 may be a Dual SIM dual standby (DSDS) UE.

[0045] Upon power up, UE 110 may search for wireless networks from which it can receive communication services. If more than one wireless network is detected, then a wireless network with the highest priority may be selected to serve UE 110 and may be referred to as the serving network. UE 110 may perform registration with the serving network, if necessary. UE 110 may then operate in a connected mode to actively communicate with the serving network. Alternatively, UE 110 may operate in an idle mode and camp on the serving network if active communication is not required by UE 110.

[0046] UE 110 may be located within the coverage of cells of multiple frequencies and/or multiple RATs while in the idle mode. For LTE, UE 110 may select a frequency and a RAT to camp on based on a priority list. This priority list may include a set of frequencies, a RAT associated with each frequency, and a priority of each frequency. For example, the priority list may include three frequencies X, Y and Z. Frequency X may be used for LTE and may have the highest priority, frequency Y may be used for GSM and may have the lowest priority, and frequency Z may also be used for GSM and may have medium priority. In general, the priority list may include any number of frequencies for any set of RATs and may be specific for the UE location. UE 110 may be configured to prefer LTE, when available, by defining the priority list with LTE frequencies at the highest priority and with frequencies for other RATs at lower priorities, e.g., as given by the example above.

[0047] UE 110 may operate in the idle mode as follows. UE 110 may identify all frequencies/RATs on which it is able to find a "suitable" cell in a normal scenario or an "acceptable" cell in an emergency scenario, where "suitable" and "acceptable" are specified in the LTE standards. UE 110 may then camp on the frequency/RAT with the highest priority among all identified frequencies/RATs. UE 110 may remain camped on this frequency/RAT until either (i) the frequency/RAT is no longer available at a predetermined threshold or (ii) another frequency/RAT with a higher priority reaches this threshold. This operating behavior for UE 110 in the idle mode is described in 3GPP TS 36.304, entitled "Evolved Universal Terrestrial Radio Access (E-UTRA);

User Equipment (UE) procedures in idle mode," which is publicly available.

[0048] UE 110 may be able to receive packet-switched (PS) data services from LTE network 102 and may camp on the LTE network while in the idle mode. LTE network 102 may have limited or no support for voice-over-Internet protocol (VoIP), which may often be the case for early deployments of LTE networks. Due to the limited VoIP support, UE 110 may be transferred to another wireless network of another RAT for voice calls. This transfer may be referred to as circuit-switched (CS) fallback. UE 110 may be transferred to a RAT that can support voice service such as 1xRTT, WCDMA, GSM, etc. For call origination with CS fallback, UE 110 may initially become connected to a wireless network of a source RAT (e.g., LTE) that may not support voice service. The UE may originate a voice call with this wireless network and may be transferred through higher-layer signaling to another wireless network of a target RAT that can support the voice call. The higher-layer signaling to transfer the UE to the target RAT may be for various procedures, e.g., connection release with redirection, PS handover, etc.

[0049] FIG. 2 is a diagram illustrating an example of an access network 200 in an LTE network architecture. UE 206 may transmit an uplink reference signal which may be received by both a serving and non-serving eNB. Serving and non-serving eNBs 204, 208 may receive the uplink reference signal and either of the eNBs may transmit a handover command to the UE based, at least in part, on the uplink reference signal.

[0050] In FIG. 2, the access network 200 is divided into a number of cellular regions (cells) 202. One or more lower power class eNBs 208 may have cellular regions 210 that overlap with one or more of the cells 202. A lower power class eNB 208 may be referred to as a remote radio head (RRH). The lower power class eNB 208 may be a femto cell (e.g., home eNB (HeNB)), pico cell, or micro cell. The macro eNBs 204 are each assigned to a respective cell 202 and are configured to provide an access point to the EPC 110 for all the UEs 206 in the cells 202. There is no centralized controller in this example of an access network 200, but a centralized controller may be used in alternative configurations. The eNBs 204 are responsible for all radio related functions including radio bearer control, admission control, mobility control, scheduling, security, and connectivity to the serving gateway 124.

[0051] The modulation and multiple access scheme employed by the access network 200 may vary depending on the particular telecommunications standard being deployed. In LTE applications, OFDM is used on the DL and SC-FDMA is used on the UL to support both frequency division duplexing (FDD) and time division duplexing (TDD). As those skilled in the art will readily appreciate from the detailed description to follow, the various concepts presented herein are well suited for LTE applications. However, these concepts may be readily extended to other telecommunication standards employing other modulation and multiple access techniques. By way of example, these concepts may be extended to Evolution-Data Optimized (EV-DO) or Ultra Mobile Broadband (UMB). EV-DO and UMB are air interface standards promulgated by the 3rd Generation Partnership Project 2 (3GPP2) as part of the CDMA2000 family of standards and employs CDMA to provide broadband Internet access to mobile stations. These concepts may also be extended to Universal Terrestrial Radio Access (UTRA) employing Wideband-CDMA (W-CDMA) and other variants of CDMA, such as TD-SCDMA; Global System for Mobile Communications (GSM) employing TDMA; and Evolved UTRA (E-UTRA), Ultra Mobile Broadband (UMB), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, and Flash-OFDM employing OFDMA. UTRA, E-UTRA, UMTS, LTE and GSM are described in documents from the 3GPP organization. CDMA2000 and UMB are described in documents from the 3GPP2 organization. The actual wireless communication standard and the multiple access technology employed will depend on the specific application and the overall design constraints imposed on the system.

[0052] The eNBs 204 may have multiple antennas supporting MIMO technology. The use of MIMO technology enables the eNBs 204 to exploit the spatial domain to support spatial multiplexing, beamforming, and transmit diversity. Spatial multiplexing may be used to transmit different streams of data simultaneously on the same frequency. The data streams may be transmitted to a single UE 206 to increase the data rate or to multiple UEs 206 to increase the overall system capacity. This is achieved by spatially precoding each data stream (e.g., applying a scaling of an amplitude and a phase) and then transmitting each spatially precoded stream through multiple transmit antennas on the DL. The spatially precoded data streams arrive at the UE(s) 206 with different spatial signatures, which enables each of the UE(s) 206 to recover the one or more data streams destined for that UE 206. On the UL, each UE 206 transmits a spatially precoded data stream, which enables the eNB 204 to identify the source of each spatially precoded data stream.

[0053] Spatial multiplexing is generally used when channel conditions are good. When channel conditions are less favorable, beamforming may be used to focus the transmission energy in one or more directions. This may be achieved by spatially precoding the data for transmission through multiple antennas. To achieve good coverage at the edges of the cell, a single stream beamforming transmission may be used in combination with transmit diversity.

[0054] In the detailed description that follows, various aspects of an access network will be described with reference to a MIMO system supporting OFDM on the DL. OFDM is a spread-spectrum technique that modulates data over a number of subcarriers within an OFDM symbol. The subcarriers are spaced apart at precise frequencies. The spacing provides "orthogonality" that enables a receiver to recover the data from the subcarriers. In the time domain, a guard interval (e.g., cyclic prefix) may be added to each OFDM symbol to combat inter-OFDM-symbol interference. The UL may use SC-FDMA in the form of a DFT-spread OFDM signal to compensate for high peak-to-average power ratio (PAPR).

[0055] FIG. 3 is a diagram 300 illustrating an example of a DL frame structure in LTE. A frame (10 ms) may be divided into 10 equally sized sub-frames with indices of 0 through 9. Each sub-frame may include two consecutive time slots. A resource grid may be used to represent two time slots, each time slot including a resource block. The resource grid is divided into multiple resource elements. In LTE, a resource block contains 12 consecutive subcarriers in the frequency domain and, for a normal cyclic prefix in each OFDM symbol, 7 consecutive OFDM symbols in the time domain, or 84 resource elements. For an extended cyclic prefix, a resource block contains 6 consecutive OFDM symbols in the time domain and has 72 resource elements. Some of the resource elements, as indicated as R 302, 304, include DL reference signals (DL-RS). The DL-RS include Cell-specific RS (CRS) (also sometimes called common RS) 302 and UE-specific RS (UE-RS) 304. UE-RS 304 are transmitted only on the resource blocks upon which the corresponding physical DL shared channel (PDSCH) is mapped. The number of bits carried by each resource element depends on the modulation scheme.

Thus, the more resource blocks that a UE receives and the higher the modulation scheme, the higher the data rate for the UE.

[0056] In LTE, an eNB may send a primary synchronization signal (PSS) and a secondary synchronization signal (SSS) for each cell in the eNB. The primary and secondary synchronization signals may be sent in symbol periods 6 and 5, respectively, in each of subframes 0 and 5 of each radio frame with the normal cyclic prefix (CP). The synchronization signals may be used by UEs for cell detection and acquisition. The eNB may send a Physical Broadcast Channel (PBCH) in symbol periods 0 to 3 in slot 1 of subframe 0. The PBCH may carry certain system information.

[0057] The eNB may send a Physical Control Format Indicator Channel (PCFICH) in the first symbol period of each subframe. The PCFICH may convey the number of symbol periods (M) used for control channels, where M may be equal to 1, 2 or 3 and may change from subframe to subframe. M may also be equal to 4 for a small system bandwidth, e.g., with less than 10 resource blocks. The eNB may send a Physical HARQ Indicator Channel (PHICH) and a Physical Downlink Control Channel (PDCCH) in the first M symbol periods of each subframe. The PHICH may carry information to support hybrid automatic repeat request (HARQ). The PDCCH may carry information on resource allocation for UEs and control information for downlink channels. The eNB may send a Physical Downlink Shared Channel (PDSCH) in the remaining symbol periods of each subframe. The PDSCH may carry data for UEs scheduled for data transmission on the downlink.

[0058] The eNB may send the PSS, SSS, and PBCH in the center 1.08 MHz of the system bandwidth used by the eNB. The eNB may send the PCFICH and PHICH across the entire system bandwidth in each symbol period in which these channels are sent. The eNB may send the PDCCH to groups of UEs in certain portions of the system bandwidth. The eNB may send the PDSCH to specific UEs in specific portions of the system bandwidth. The eNB may send the PSS, SSS, PBCH, PCFICH, and PHICH in a broadcast manner to all UEs, may send the PDCCH in a unicast manner to specific UEs, and may also send the PDSCH in a unicast manner to specific UEs.

[0059] A number of resource elements may be available in each symbol period. Each resource element (RE) may cover one subcarrier in one symbol period and may be used to send one modulation symbol, which may be a real or complex value. Resource elements not used for a reference signal in each symbol period may be arranged into resource element groups (REGs). Each REG may include four resource elements in one symbol period. The PCFICH may occupy four REGs, which may be spaced approximately equally across frequency, in symbol period 0. The PHICH may occupy three REGs, which may be spread across frequency, in one or more configurable symbol periods. For example, the three REGs for the PHICH may all belong in symbol period 0 or may be spread in symbol periods 0, 1, and 2. The PDCCH may occupy 9, 18, 36, or 72 REGs, which may be selected from the available REGs, in the first M symbol periods, for example. Only certain combinations of REGs may be allowed for the PDCCH.

[0060] A UE may know the specific REGs used for the PHICH and the PCFICH. The UE may search different combinations of REGs for the PDCCH. The number of combinations to search is typically less than the number of allowed combinations for the PDCCH. An eNB may send the PDCCH to the UE in any of the combinations that the UE will search.

[0061] FIG. 4 is a diagram 400 illustrating an example of an UL frame structure in LTE. The available resource blocks for the UL may be partitioned into a data section and a control section. The control section may be formed at the two edges of the system bandwidth and may have a configurable size. The resource blocks in the control section may be assigned to UEs for transmission of control information. The data section may include all resource blocks not included in the control section. The UL frame structure results in the data section including contiguous subcarriers, which may allow a single UE to be assigned all of the contiguous subcarriers in the data section.

[0062] A UE may be assigned resource blocks 410a, 410b in the control section to transmit control information to an eNB. The UE may also be assigned resource blocks 420a, 420b in the data section to transmit data to the eNB. The UE may transmit control information in a physical UL control channel (PUCCH) on the assigned resource blocks in the control section. The UE may transmit only data or both data and control information in a physical UL shared channel (PUSCH) on the assigned resource blocks in the data section. A UL transmission may span both slots of a subframe and may hop across frequency.

[0063] A set of resource blocks may be used to perform initial system access and achieve UL synchronization in a physical random access channel (PRACH) 430. The PRACH 430 carries a random sequence and cannot carry any UL data/signaling. Each random access preamble occupies a bandwidth corresponding to six consecutive resource blocks. The starting frequency is specified by the network. That is, the transmission of the random access preamble is restricted to certain time and frequency resources. There is no frequency hopping for the PRACH. The PRACH attempt is carried in a single subframe (1 ms) or in a sequence of few contiguous subframes and a UE can make only a single PRACH attempt per frame (10 ms).

[0064] FIG. 5 is a diagram 500 illustrating an example of a radio protocol architecture for the user and control planes in LTE. The radio protocol architecture for the UE and the eNB is shown with three layers: Layer 1, Layer 2, and Layer 3. Layer 1 (L1 layer) is the lowest layer and implements various physical layer signal processing functions. The L1 layer will be referred to herein as the physical layer 506. Layer 2 (L2 layer) 508 is above the physical layer 506 and is responsible for the link between the UE and eNB over the physical layer 506.

[0065] In the user plane, the L2 layer 508 includes a media access control (MAC) sublayer 510, a radio link control (RLC) sublayer 512, and a packet data convergence protocol (PDCP) 514 sublayer, which are terminated at the eNB on the network side. Although not shown, the UE may have several upper layers above the L2 layer 508 including a network layer (e.g., IP layer) that is terminated at the PDN gateway 118 on the network side, and an application layer that is terminated at the other end of the connection (e.g., far end UE, server, etc.).

[0066] The PDCP sublayer 514 provides multiplexing between different radio bearers and logical channels. The PDCP sublayer 514 also provides header compression for upper layer data packets to reduce radio transmission overhead, security by ciphering the data packets, and handover support for UEs between eNBs. The RLC sublayer 512 provides segmentation and reassembly of upper layer data packets, retransmission of lost data packets, and reordering of data packets to compensate for out-of-order reception due to hybrid automatic repeat request (HARQ). The MAC sublayer 510 provides multiplexing between logical and transport channels. The MAC sublayer 510 is also responsible for allocating the various radio resources (e.g., resource blocks) in one cell among the UEs. The MAC sublayer 510 is also responsible for HARQ operations.

[0067] In the control plane, the radio protocol architecture for the UE and eNB is substantially the same for the physical layer 506 and the L2 layer 508 with the exception that there is no header compression function for the control plane. The control plane also includes a radio resource control (RRC) sublayer 516 in Layer 3 (L3 layer). The RRC sublayer 516 is responsible for obtaining radio resources (i.e., radio bearers) and for configuring the lower layers using RRC signaling between the eNB and the UE.

[0068] FIG. 6 is a block diagram of an eNB 610 in communication with a UE 650 in an access network in accordance with aspects of the present disclosure. The eNBs of FIGs. 1 and FIG. 2 may include one or more components of eNB 610 illustrated in FIG. 6. Similarly, the UEs illustrated in FIGs 1 and 2 may include one or more components of UE 650 as illustrated in FIG. 6. One or more components of the UE 650 and eNB 610 may be configured to perform the operations described herein.

[0069] In the DL, upper layer packets from the core network are provided to a controller/processor 675. The controller/processor 675 implements the functionality of the L2 layer. In the DL, the controller/processor 675 provides header compression, ciphering, packet segmentation and reordering, multiplexing between logical and transport channels, and radio resource allocations to the UE 650 based on various priority metrics. The controller/processor 675 is also responsible for HARQ operations, retransmission of lost packets, and signaling to the UE 650.

[0070] The TX processor 616 implements various signal processing functions for the L1 layer (i.e., physical layer). The signal processing functions includes coding and interleaving to facilitate forward error correction (FEC) at the UE 650 and mapping to signal constellations based on various modulation schemes (e.g., binary phase-shift keying (BPSK), quadrature phase-shift keying (QPSK), M-phase-shift keying (M-PSK), M-quadrature amplitude modulation (M-QAM)). The coded and modulated symbols are then split into parallel streams. Each stream is then mapped to an OFDM subcarrier, multiplexed with a reference signal (e.g., pilot) in the time and/or frequency domain, and then combined together using an Inverse Fast Fourier Transform (IFFT) to produce a physical channel carrying a time domain OFDM symbol stream. The OFDM stream is spatially precoded to produce multiple spatial streams. Channel estimates from a channel estimator 674 may be used to determine the coding and modulation scheme, as well as for spatial processing. The channel estimate may be derived from a reference signal and/or channel condition feedback transmitted by the UE 650. Each spatial stream is then provided to a different antenna 620 via a separate transmitter 618TX. Each transmitter 618TX modulates an RF carrier with a respective spatial stream for transmission.

[0071] At the UE 650, each receiver 654RX receives a signal through its respective antenna 652. Each receiver 654RX recovers information modulated onto an RF carrier and provides the information to the receiver (RX) processor 656. The RX processor 656 implements various signal processing functions of the L1 layer. The RX processor 656 performs spatial processing on the information to recover any spatial streams destined for the UE 650. If multiple spatial streams are destined for the UE 650, they may be combined by the RX processor 656 into a single OFDM symbol stream. The RX processor 656 then converts the OFDM symbol stream from the time-domain to the frequency domain using a Fast Fourier Transform (FFT). The frequency domain signal comprises a separate OFDM symbol stream for each subcarrier of the OFDM signal. The symbols on each subcarrier, and the reference signal, is recovered and demodulated by determining the most likely signal constellation points transmitted by the eNB 610. These soft decisions may be based on channel estimates computed by the channel estimator 658. The soft decisions are then decoded and deinterleaved to recover the data and control signals that were originally transmitted by the eNB 610 on the physical channel. The data and control signals are then provided to the controller/processor 659.

[0072] The controller/processor 659 implements the L2 layer. The controller/processor 659 can be associated with a memory 660 that stores program codes and data. The memory 660 may be referred to as a computer-readable medium. In the UL, the controller/processor 659 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, control signal processing to recover upper layer packets from the core network. The upper layer packets are then provided to a data sink 662, which represents all the protocol layers above the L2 layer. Various control signals may also be provided to the data sink 662 for L3 processing. The controller/processor 659 is also responsible for error detection using an acknowledgement (ACK) and/or negative acknowledgement (NACK) protocol to support HARQ operations.

[0073] In the UL, a data source 667 is used to provide upper layer packets to the controller/processor 659. The data source 667 represents all protocol layers above the L2 layer. Similar to the functionality described in connection with the DL transmission by the eNB 610, the controller/processor 659 implements the L2 layer for the user plane and the control plane by providing header compression, ciphering, packet segmentation and reordering, and multiplexing between logical and transport channels based on radio resource allocations by the eNB 610. The controller/processor 659 is also responsible for HARQ operations, retransmission of lost packets, and signaling to the eNB 610.

[0074] Channel estimates derived by a channel estimator 658 from a reference signal or feedback transmitted by the eNB 610 may be used by the TX processor 668 to select the appropriate coding and modulation schemes, and to facilitate spatial processing. The spatial streams generated by the TX processor 668 are provided to different antenna 652 via separate transmitters 654TX. Each transmitter 654TX modulates an RF carrier with a respective spatial stream for transmission.

[0075] The UL transmission is processed at the eNB 610 in a manner similar to that described in connection with the receiver function at the UE 650. Each receiver 618RX receives a signal through its respective antenna 620. Each receiver 618RX recovers information modulated onto an RF carrier and provides the information to a RX processor 670. The RX processor 670 may implement the L1 layer.

[0076] The controller/processor 675 implements the L2 layer. The controller/processor 675 can be associated with a memory 676 that stores program codes and data. The memory 676 may be referred to as a computer-readable medium. In the UL, the controller/processor 675 provides demultiplexing between transport and logical channels, packet reassembly, deciphering, header decompression, control signal processing to recover upper layer packets from the UE 650. Upper layer packets from the controller/processor 675 may be provided to the core network. The controller/processor 675 is also responsible for error detection using an ACK and/or

NACK protocol to support HARQ operations.

[0077] The controller/processor 659 may direct the operation at the UE 650. The controller/processor 659 and/or other processors, components, and/or modules at the UE 650 may perform or direct operations performed by the UE as described herein. The controller/processor 675 may direct the operations at the eNB 610. The controller/processor 675 and/or other processors, components, and/or modules at the eNB 610 may perform or direct operations performed by the eNB as described herein. In aspects, one or more of any of the components shown in FIG. 6 may be employed to perform example operations 900, 1000, 1300, and 1400 shown in FIGs 9, 10, 13, and 14, respectively, and can also perform other UE and eNB operations for the techniques described herein.

[0078] For example, one or more of the antenna 620, transceiver 618, controller/processor, and memory 676 may be configured to receive an uplink reference signal from a UE, measure the uplink reference signal, and transmit a handover command, as described herein. One or more of the antenna 652, transceiver 654, controller/processor 659, and memory 660 may be configured to transmit an uplink reference signal and receive a beamformed downlink signal or handover command, as described herein.

EXAMPLE UPLINK MULTIPLE-INPUT MULTIPLE-OUTPUT (MIMO) SCHEDULING USING BEAMFORMED REFERENCE SIGNALS

[0079] In closed loop uplink multiple-input-multiple-output (MIMO), a transmit receive point (TRP) may estimate an uplink channel and an uplink interference covariance matrix to select beamforming parameters for wireless nodes (*e.g.*, UEs) to use for subsequent uplink transmissions. The TRP can estimate the channel using an uplink reference signal, such as an uplink sounding reference signal (SRS) or an uplink channel state information reference signal (CSI-RS), and the TRP can estimate the interference covariance matrix based on past receptions. Using the estimates, the TRP can select wireless nodes and precoders for each wireless node. In some cases, a TRP can use multi-user MIMO with subband scheduling in the frequency domain, which may indicate, for example, the wireless nodes that can perform uplink transmissions to the TRP, the rank each wireless node can use for uplink transmissions, the subbands (in the frequency domain) each wireless node can use, and the precoder(s) each wireless node can use on each allocated subband.

[0080] Closed loop uplink MIMO generally allows a TRP to select wireless nodes and precoders by taking into account mutual interference between wireless nodes and other cell interference. In some cases, conveying a scheduling decision for each wireless node may consume a large amount of channel capacity on the downlink control channel. To reduce the amount of data transmitted on the downlink control channel, a TRP can use a codebook of precoders, and the TRP can convey the scheduling decision for each wireless node as an index in the codebook. In some cases, the TRP can use the same precoder for part or all of the allocated resources, which may reduce the signaling overhead for conveying the allocation to the wireless nodes. The use of the same precoder for the allocated resources may result in losses in link efficiency. In some cases, the interference estimates used for determining transmission parameters for the wireless nodes may differ from actual interference in a subsequent subframe, as the wireless nodes scheduled in different subframes may change.

[0081] In open loop uplink MIMO, a wireless node may select a precoder and transmit data using the selected precoder. Because the wireless node can select a precoder, an amount of data transmitted on the downlink control channel may be reduced. In some cases, a wireless node can select a precoder without using a codebook or being restricted to using the same precoder across several resources. In some cases, however, a wireless node may not have sufficient information to select an optimal precoder. For example, each wireless node may select precoders independently and may not be able to predict interference from other UEs or other cells at the TRP. The modulation and coding scheme (MCS) and MU-MIMO pairing may not be optimal, which may affect system efficiency.

[0082] Aspects of the present disclosure provide techniques to use a beamformed uplink reference signal to determine beamforming adjustments for subsequent uplink transmissions from a wireless node to a TRP. By receiving a beamformed reference signal from a wireless node, a TRP can use the beamformed reference signal and other information available at the TRP (*e.g.*, mutual interference information) to identify transmission parameters for different wireless nodes to use in subsequent transmissions to the TRP. Advantageously, downselection of users and beams may reduce the amount of data to provide in a uplink grant by the TRP. In some cases, if the wireless node and the beams are selected without changes for data transmission, TRPs may obtain an accurate estimate of the interference covariance matrix, as the set of interferers may remain constant.

[0083] FIG. 7 illustrates example operations that may be performed by a wireless node (*e.g.*, a UE) to beamform uplink transmissions to a transmit receive point (TRP), in accordance with certain aspects of the present disclosure. As illustrated, operations 700 begin at 702, where the wireless node identifies one or more parameters for beamformed transmission to a TRP. In some cases, the wireless node can identify the one or more parameters for beamformed transmission from an initial uplink grant from the TRP. The initial uplink grant may include, for example, a beam identification for a specific wireless node, an indication of a precoder matrix index, and so on. In some cases, the TRP may provide information to a wireless node for selection of a beam. The information may, for example, include an inter-cell interference covariance matrix estimated by the TRP based on past receptions. In some cases, the data may be received at the wireless node in a broadcast transmission from the TRP, which may reduce signaling overhead.

[0084] In some cases, the wireless node can identify the one or more parameters for beamformed transmission to the TRP independently of the TRP. The one or more parameters may be identified, for example, based on conditions at the wireless node, channel conditions, and/or knowledge of an interference profile for the TRP. In some cases, the wireless node can select a beam direction for transmitting the reference signal by cycling through a predefined codebook. In some cases, the beam direction may be selected using cyclic delay diversity.

[0085] At 704, the wireless node transmits a reference signal using beamforming in accordance with the identified parameters. The reference signal may be, for example, a sounding reference signal (SRS) or a channel state information reference signal (CSI-RS).

[0086] At 706, the wireless node receives, from the TRP and in response to the reference signal, signaling for adjusting the one or more parameters for one or more subsequent beamformed transmissions.

[0087] FIG. 8 illustrates example operations that may be performed by a transmit receive point (TRP) to select beamforming parameters for subsequent uplink transmissions by a wireless node based on a beamformed uplink reference signal, in accordance with certain aspects of the present disclosure. As illustrated, operations 800 begin at 802, where the TRP receives, from a wireless node, a beamformed reference signal. As discussed, the reference signal may be, for example, an SRS, a CSI-RS, and so on. The reference signal may be beamformed according to information provided to the wireless node by the TRP or based on a beamforming determination performed by the wireless node. The information may, in some cases, be provided to the wireless nodes via broadcast signaling.

[0088] At 804, the TRP determines, based on the beamformed reference signal, one or more parameters for the wireless node to use for adjusting subsequent beamformed transmissions to the TRP. At 808, the TRP signals the parameters to the wireless node. The TRP can signal the parameters to the wireless node, for example, in an uplink grant.

[0089] In some cases, the TRP can use the beamformed reference signal received from a wireless node to down-select nodes and beams to a set of nodes and beams that can be scheduled together. The set of nodes and beams may be selected, for example, based on mutual interference between the nodes and beams. The TRP may select a modulation and coding scheme (MCS) for each wireless node based on the downselected set of beams. In some cases, for a selected wireless node, the TRP may select its beam to be the same as the beam that the wireless node used for its beamformed reference signal. In some other cases, the TRP can modify and/or refine the beams selected for the wireless nodes to use for subsequent uplink transmissions based on interference between the selected beams of intra-cell wireless nodes.

[0090] In some cases, wireless nodes may be scheduled on the uplink such that uplink transmissions by a wireless node do not cause interference at a neighbor cell. With massive MIMO systems, TRPs and wireless nodes may have more antennas and use narrower beams, and the impact of a wireless node transmission on a neighbor TRP may be influenced on the proximity of the wireless node to the neighbor TRP, the transmit beam direction used by the wireless node, and the reception direction used by the neighbor TRP for receiver beamforming.

[0091] In some cases, the TRP can receive information from neighbor TRPs regarding interference caused by a wireless node. In some cases, the neighbor TRP can estimate interference from a wireless node based on the beamformed reference signal transmitted by the wireless node (*e.g.*, by measuring interference on a reference signal resource). If the neighbor TRP determines that the wireless node is causing interference to the neighbor TRP, the neighbor TRP can indicate the interference to the serving TRP for the wireless node (*e.g.*, via backhaul messaging). The indication of interference may, in some cases, include a request for the serving TRP to exclude the wireless node from beam and node downselection, which may mitigate interference. The serving TRP may subsequently exclude the wireless nodes from a group of downselected nodes and beams for subsequent uplink transmission to the serving TRP.

[0092] FIG. 9 illustrates an example frame exchange 900 between a wireless node and a TRP for transmitting a beamformed reference signal from the wireless node to the TRP and receiving, from the TRP, signaling for adjusting one or more parameters for subsequent beamformed transmissions, in accordance with an aspect of the present disclosure. As illustrated, in the first frame, in an initial downlink portion (*e.g.*, downlink control signaling), the TRP can provide an uplink grant to the wireless node identifying the wireless node and a beam for the wireless node to use for transmitting an uplink reference signal to the TRP. The wireless node can use the identified beam direction to transmit the uplink reference signal (*e.g.*, an SRS or CSI-RS) in an uplink control portion of the frame. As discussed, based on the beamformed uplink reference signal, the TRP can perform user and/or beam downselection, MCS selection, and beam refinement.

[0093] In the downlink control portion of a subsequent frame, the TRP can provide an uplink grant to the wireless node indicating beamforming parameters for the UE to use in subsequent uplink transmissions. The parameters may include, for example, an MCS and, optionally, beam adjustment information. The wireless node can beamform subsequent uplink transmissions (*e.g.*, the uplink data and control portions of a frame) based on the received beamforming parameters.

[0094] FIG. 10 illustrates a call flow diagram of messages that may be exchanged between a wireless node 1002 and a TRP 1004, in accordance with certain aspects of the present disclosure. As illustrated, TRP 1004 may provide an uplink grant 1006 to the wireless node. Uplink grant 1006 may include beamforming parameters for the wireless node to use in transmitting an uplink reference signal. Based on the beamforming parameters received in uplink grant 1006, wireless node may transmit beamformed reference signal 1008 to TRP 1004.

[0095] At 1010, the TRP determines parameters for subsequent transmissions from the wireless node. As discussed, the TRP can determine the parameters for subsequent uplink transmissions from wireless node 1002 (*e.g.*, beam selection, beam refinement, modulation and coding scheme, and so on) based, for example, on the beamformed reference signal, mutual interference information, and so on. TRP 1004 may subsequently transmit an uplink grant 1012 to wireless node 1002 with beamforming parameters for a subsequent uplink transmission. For a selected wireless node, if the TRP selects a precoding that is identical to the precoding used by the wireless node for its beamformed reference signal transmission, then the TRP may not indicate the precoding or any refinement in the uplink grant. Correspondingly, if the parameters in the grant do not indicate the precoding or any refinement to the precoding, the wireless node may apply the same precoding to its subsequent uplink transmission as the one that it applied to the beamformed reference signal. This option may help reduce the control signaling required to convey the grant. Wireless node 1002 can perform a subsequent uplink transmission 1014 according to the received beamforming parameters.

[0096] FIG. 11 illustrates an example frame exchange 1100 between a wireless node and a TRP, in accordance with certain aspects of the present disclosure. As illustrated, in a first frame, the wireless node may beamform an uplink reference signal (*e.g.*, SRS or CSI-RS) based on a selection performed by the wireless node. The TRP receives the beamformed uplink reference signal and, as discussed, can perform user and/or beam downselection, MCS selection, and beam refinement based at least in part on the beamformed uplink reference signal.

[0097] As illustrated, the TRP may provide an uplink grant to the wireless node in a subsequent frame. The uplink grant may indicate, for example, an MCS selection and, optionally, beam adjustment information for the wireless node to use in subsequent uplink transmissions. The wireless node can beamform subsequent uplink transmissions (*e.g.*, the uplink data and control portions of a frame) based on the received beamforming parameters.

[0098] FIG. 12 illustrates an example call flow 1200 of messages that may be transmitted between a wireless node 1202 and a TRP 1204 for selecting uplink beamforming parameters based on receiving, at the TRP, a beamformed reference signal, in accordance with certain aspects of the present disclosure.

[0099] As illustrated, at 1206, the wireless node selects parameters for transmitting the uplink reference signal to TRP 1204. As discussed, the wireless node can select a beam for transmitting the reference signal, for example, based on a channel condition, based on a TRP interference profile, by cycling through a predefined codebook, using cyclic delay diversity, and so on. At 1208, based on the selected parameters, wireless node 1202 can transmit beamformed reference signal 1208 to TRP 1204.

[00100] At 1210, the TRP determines parameters for subsequent transmissions from the wireless node. As discussed, the TRP can determine the parameters for subsequent uplink transmissions from wireless node 1202 (*e.g.*, beam selection, beam refinement, modulation and coding scheme, and so on) based, for example, on the beamformed reference signal, mutual interference information, and so on. TRP 1204 may subsequently transmit an uplink grant 1212 to wireless node 1202 with beamforming parameters for a subsequent uplink transmission. Wireless node 1202 can perform a subsequent uplink transmission 1214 according to the received beamforming parameters.

[00101] It is understood that the specific order or hierarchy of steps in the processes disclosed is an illustration of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the processes may be rearranged. Further, some steps may be combined or omitted. The accompanying method claims present elements of the various steps in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

[00102] As used herein, a phrase referring to "at least one of" a list of items refers to any combination of those items, including single members. As an example, "at least one of: a, b, or c" is intended to cover a, b, c, a-b, a-c, b-c, and a-b-c, as well as any combination with multiples of the same element (e.g., a-a, a-a-a, a-a-b, a-a-c, a-b-b, a-c-c, b-b, b-b-b, b-b-c, c-c, and c-c-c or any other ordering of a, b, and c).

[00103] The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless specifically so stated, but rather "one or more." Unless specifically stated otherwise, the term "some" refers to one or more. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. No claim element is to be construed as a means plus function unless the element is expressly recited using the phrase "means for."

CLAIMS

1. A method for wireless communications by a wireless node, comprising:

identifying one or more parameters for beamformed transmission to a transmit receive point (TRP);

transmitting a reference signal using beamforming in accordance with the identified parameters; and

receiving, from the TRP in response to the reference signal, signaling for adjusting the one or more parameters for one or more subsequent beamformed transmissions.

2. The method of claim 1, wherein the one or more parameters comprise at least one of a beam direction, a rank, or a modulation and coding scheme (MCS).

2A. The method of claim 1, wherein the signaling received from the TRP comprises an adjustment relative to a beam direction of the beamformed reference signal.

3. The method of claim 1, wherein the identifying is based on information received from the TRP.

4. The method of claim 3, wherein the information comprises an indication of a precoder matrix index.

5. The method of claim 3, wherein the information comprises interference information estimated by the TRP.

6. The method of claim 3, wherein the information is received via broadcast signaling.

7. The method of claim 1, wherein the identifying comprises selecting a beam for transmitting the reference signal based on at least one of a channel condition or a TRP interference profile.

8. The method of claim 1, wherein the identifying comprises selecting a beam direction for transmitting the reference signal by cycling through a predefined codebook.

9. The method of claim 1, wherein the identifying comprises selecting a beam direction for transmitting the reference signal using cyclic delay diversity.

10. The method of claim 1, wherein the reference signal comprises a channel state information reference signal (CSI-RS).

11. The method of claim 1, wherein the reference signal comprises a sounding reference signal (SRS).

12. A method for wireless communications by a transmit receive point (TRP), comprising:

receiving, from a wireless node, a beamformed reference signal;

determining, based on the beamformed reference signal, one or more parameters for the wireless node to use for adjusting subsequent beamformed transmissions; and

signaling the parameters to the wireless node.

13. The method of claim 12, wherein the one or more parameters comprise at least one of a beam direction, a rank, or a modulation and coding scheme (MCS).

13A. The method of claim 12, wherein the determining comprises selecting a same beam direction the wireless node used for the beamformed reference signal.

14. The method of claim 12, further comprising:

transmitting, to the wireless node, parameters for beamformed transmission.

15. The method of claim 14, wherein the information comprises an indication of a precoder matrix index.

16. The method of claim 14, wherein the information comprises interference estimation information estimated by the TRP.

17. The method of claim 14, wherein the parameters are transmitted via broadcast signaling.

18. The method of claim 12, wherein determining the one or more parameters comprises generating a down-selected set of beams for a group of wireless nodes based, at least in part, on mutual interference between wireless nodes in the group.

19. The method of claim 18, further comprising:

selecting a modulation and coding scheme for the wireless node and the one or more other wireless nodes based on the down-selected group of beams.

20. The method of claim 18, further comprising:

receiving, from a neighbor TRP, information indicating that the wireless node is causing interference to the neighbor TRP; and

excluding the wireless node from the group of wireless nodes.

21. The method of claim 20, wherein the information indicating that the wireless node is causing interference to the neighbor TRP is received via a backhaul link between the TRP and the neighbor TRP.

22. A method, apparatus, system, computer program product, non-transitory computer-readable medium, user equipment, and wireless communication device as described herein with reference to and as illustrated by the accompanying drawings.

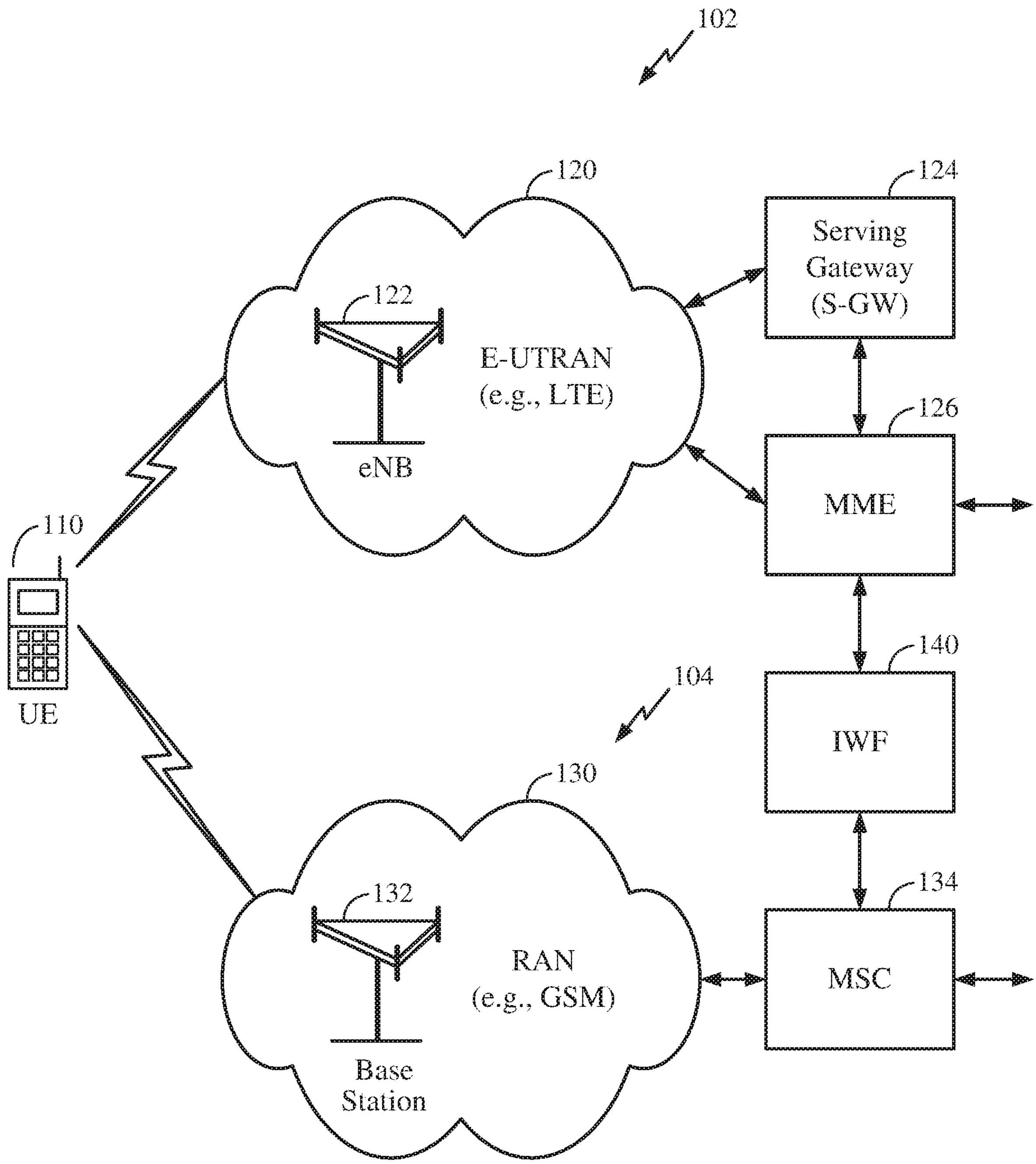
102
120
122
E-UTRAN
(e.g., LTE)
eNB
124
Serving
Gateway
(S-GW)
126
MME
110
UE
104
140
IWF
130
132
RAN
(e.g., GSM)
Base
Station
134
MSC

FIG. 1

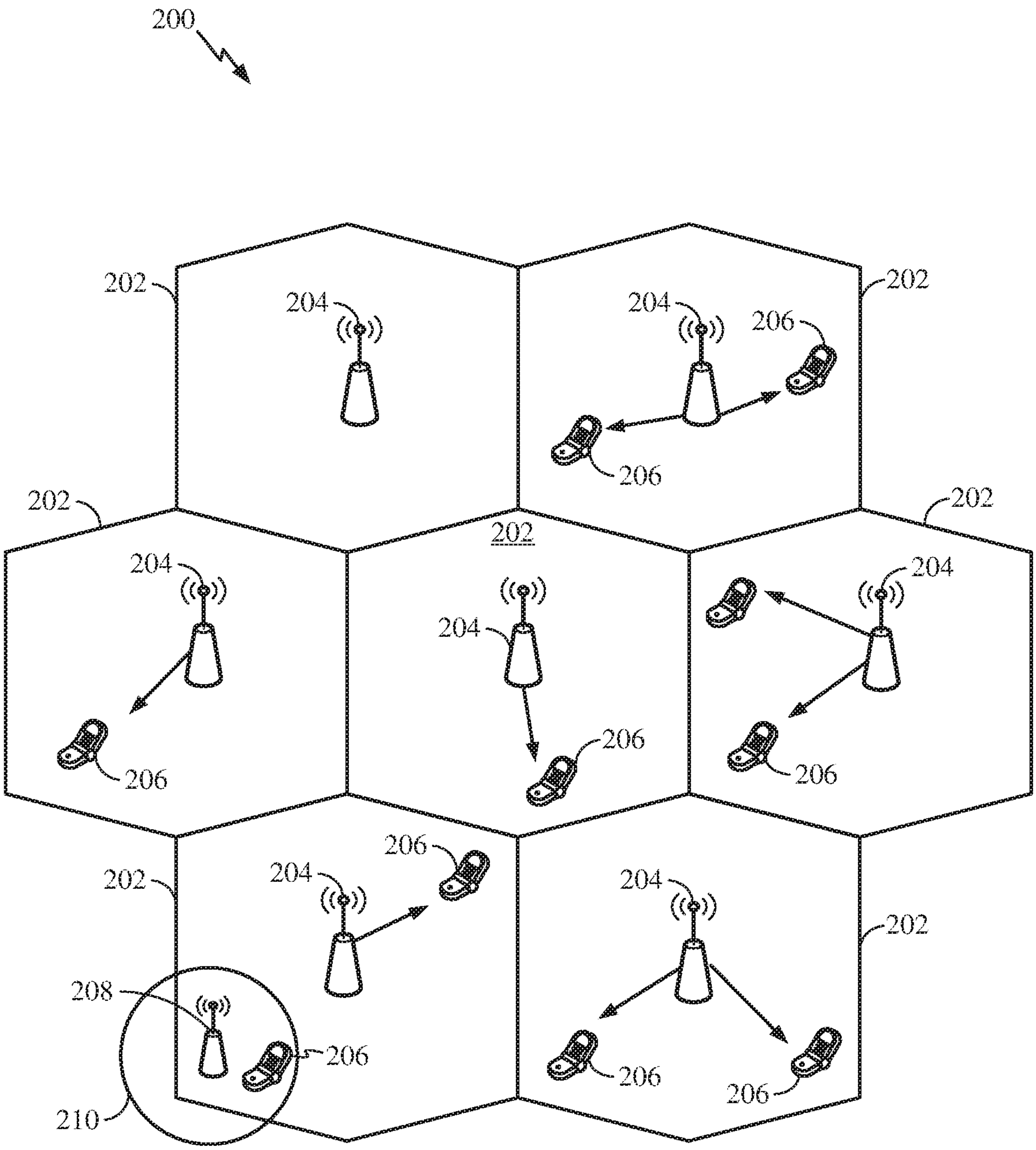
200
202
204
206
202
204
202
204
206
204
206
202
204
206
202
204
206
208
206
210
202
204
206
206

FIG. 2

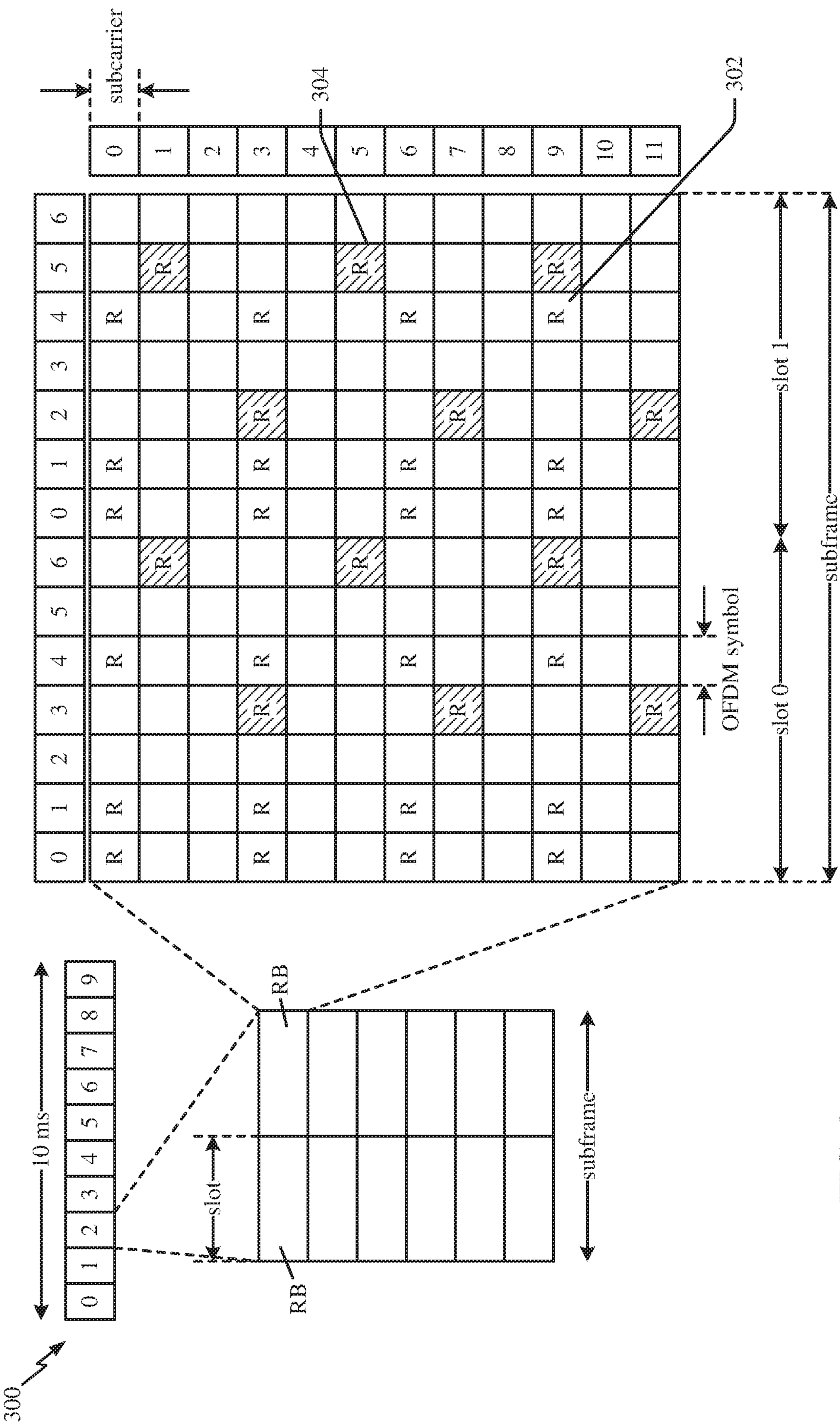
300
10 ms
0 1 2 3 4 5 6 7 8 9
slot
subframe
RB
RB
0 1 2 3 4 5 6 0 1 2 3 4 5 6
subcarrier
0 1 2 3 4 5 6 7 8 9 10 11
304
302
R
OFDM symbol
slot 0
slot 1
subframe

FIG. 3

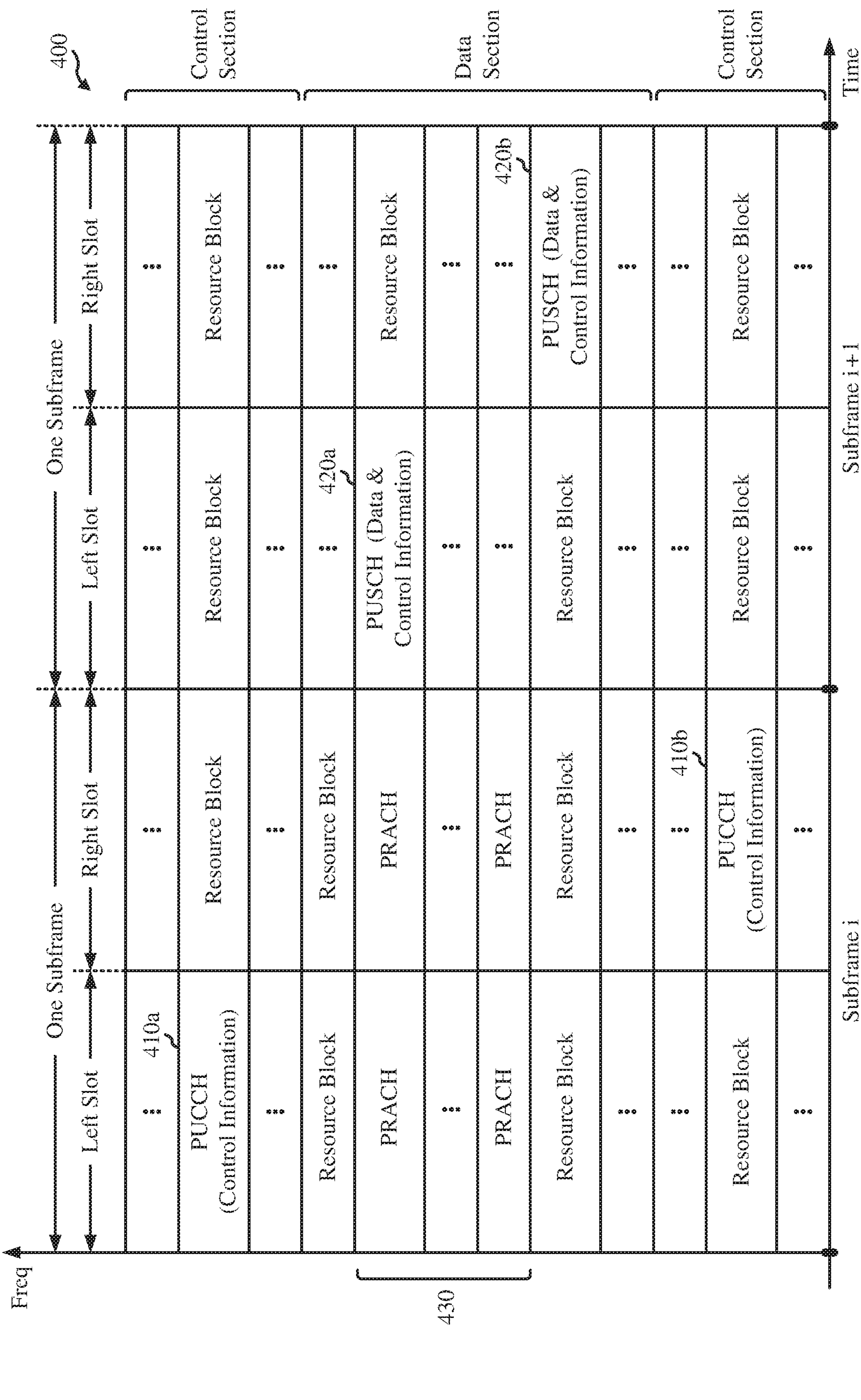
400
Freq
Time
Control Section
Data Section
Control Section
One Subframe
One Subframe
Left Slot
Right Slot
Left Slot
Right Slot
PUCCH (Control Information)
410a
Resource Block
PRACH
PRACH
Resource Block
Resource Block
430
Resource Block
Resource Block
PRACH
PRACH
Resource Block
PUCCH (Control Information)
410b
Resource Block
PUSCH (Data & Control Information)
420a
Resource Block
Resource Block
Resource Block
Resource Block
PUSCH (Data & Control Information)
420b
Resource Block
Subframe i
Subframe i + 1

FIG. 4

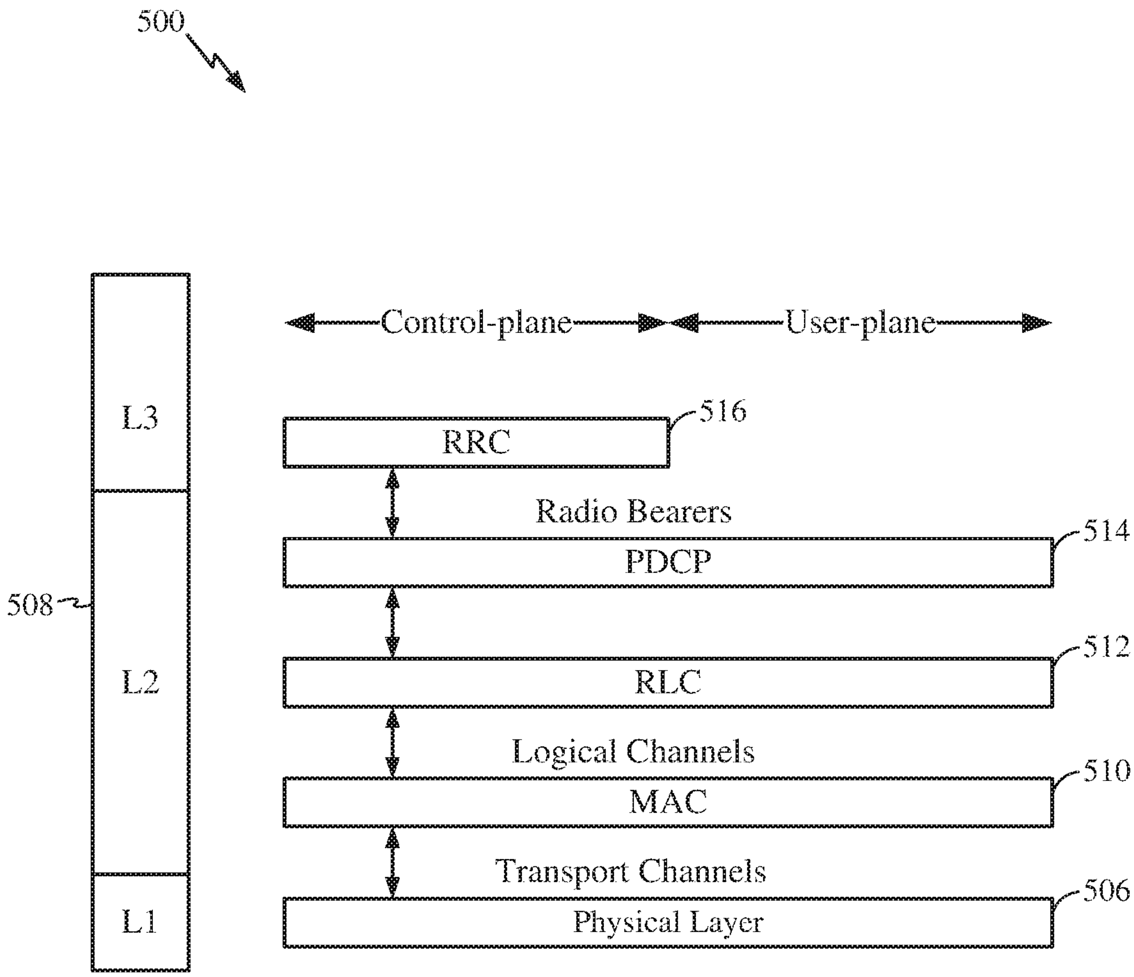
500
Control-plane
User-plane
L3
L2
L1
508
RRC
516
Radio Bearers
PDCP
514
RLC
512
Logical Channels
MAC
510
Transport Channels
Physical Layer
506

FIG. 5

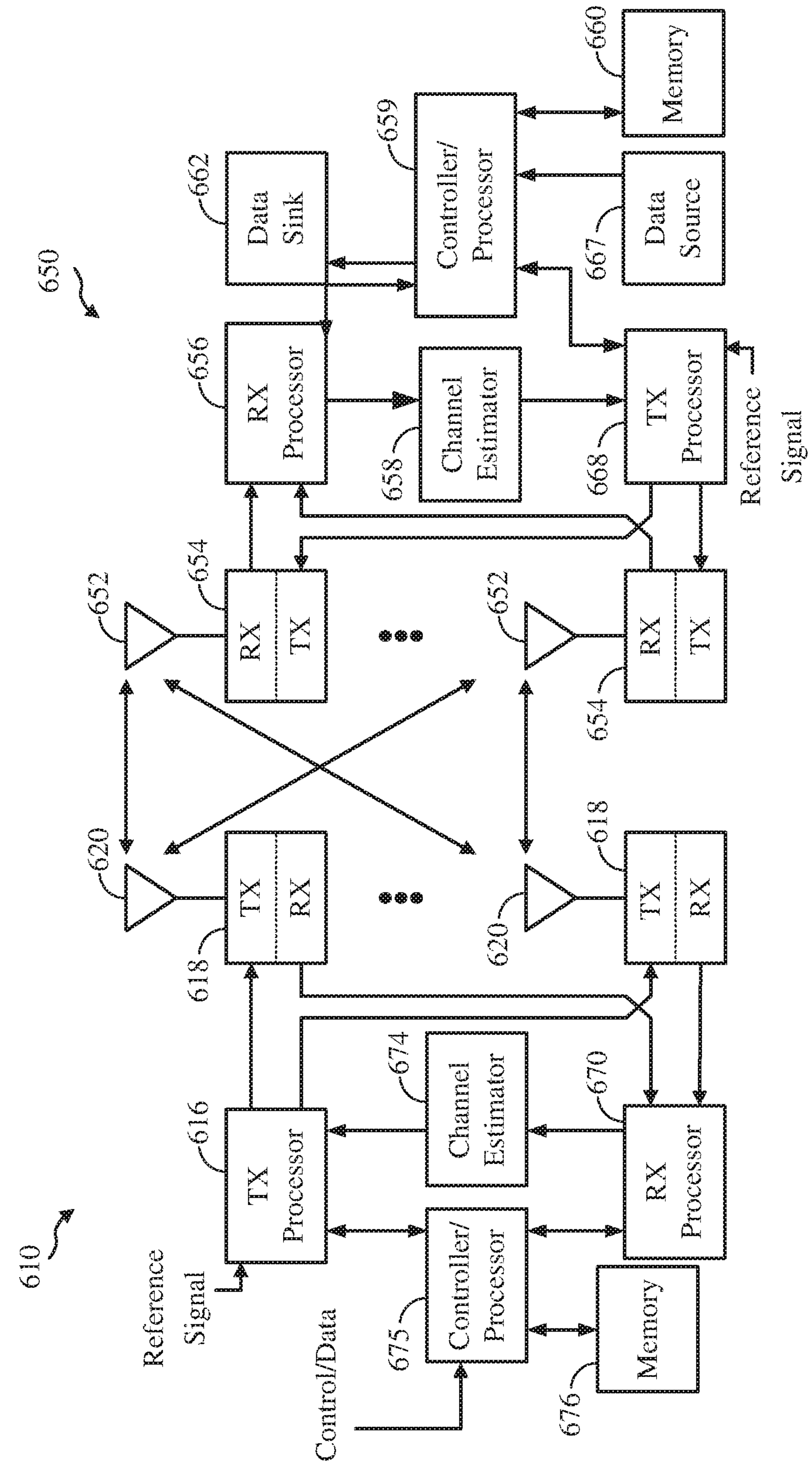
610
Reference Signal
616
TX Processor
675
Controller/ Processor
Control/Data
676
Memory
674
Channel Estimator
670
RX Processor
618
TX
RX
620
650
656
RX Processor
658
Channel Estimator
668
TX Processor
Reference Signal
662
Data Sink
659
Controller/ Processor
667
Data Source
660
Memory
654
RX
TX
652

FIG. 6

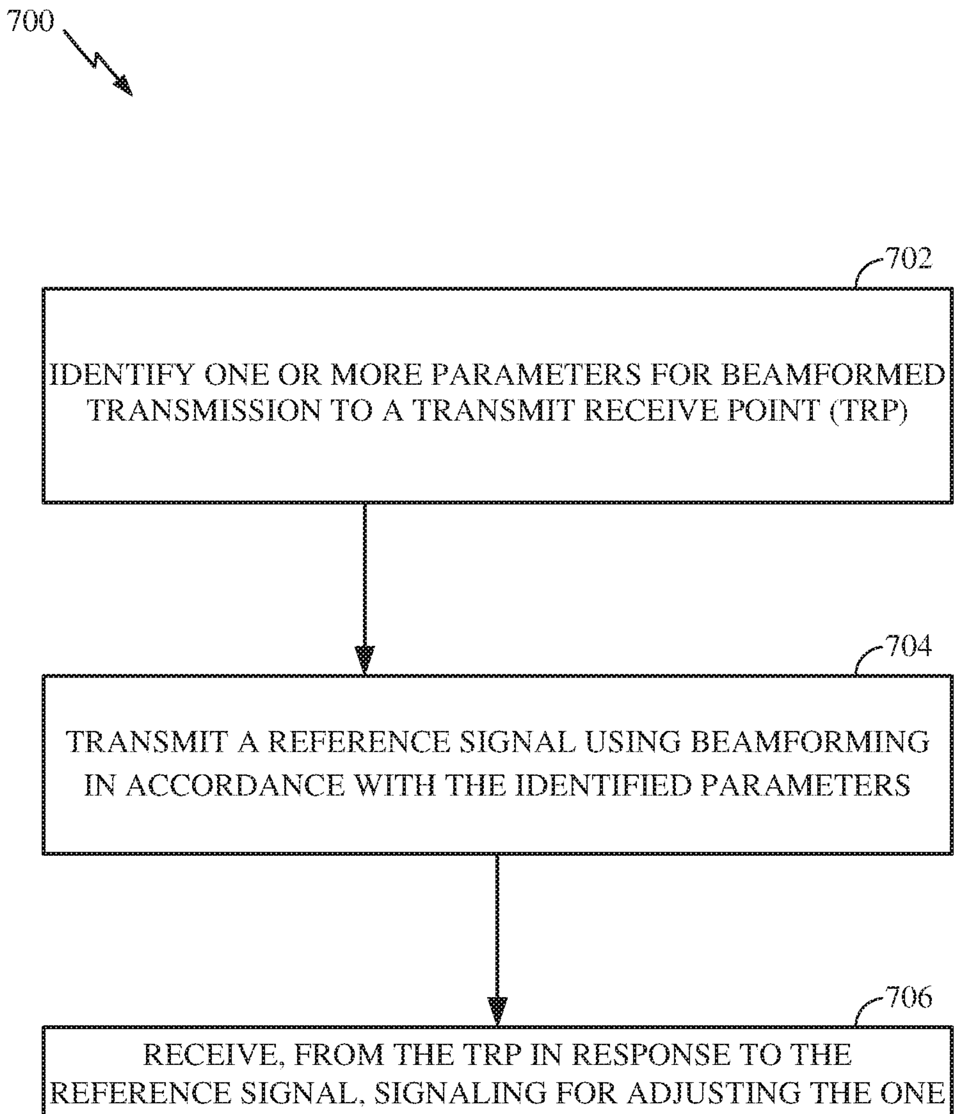
700
702
IDENTIFY ONE OR MORE PARAMETERS FOR BEAMFORMED TRANSMISSION TO A TRANSMIT RECEIVE POINT (TRP)
704
TRANSMIT A REFERENCE SIGNAL USING BEAMFORMING IN ACCORDANCE WITH THE IDENTIFIED PARAMETERS
706
RECEIVE, FROM THE TRP IN RESPONSE TO THE REFERENCE SIGNAL, SIGNALING FOR ADJUSTING THE ONE OR MORE PARAMETERS FOR ONE OR MORE SUBSEQUENT BEAMFORMED TRANSMISSIONS

FIG. 7

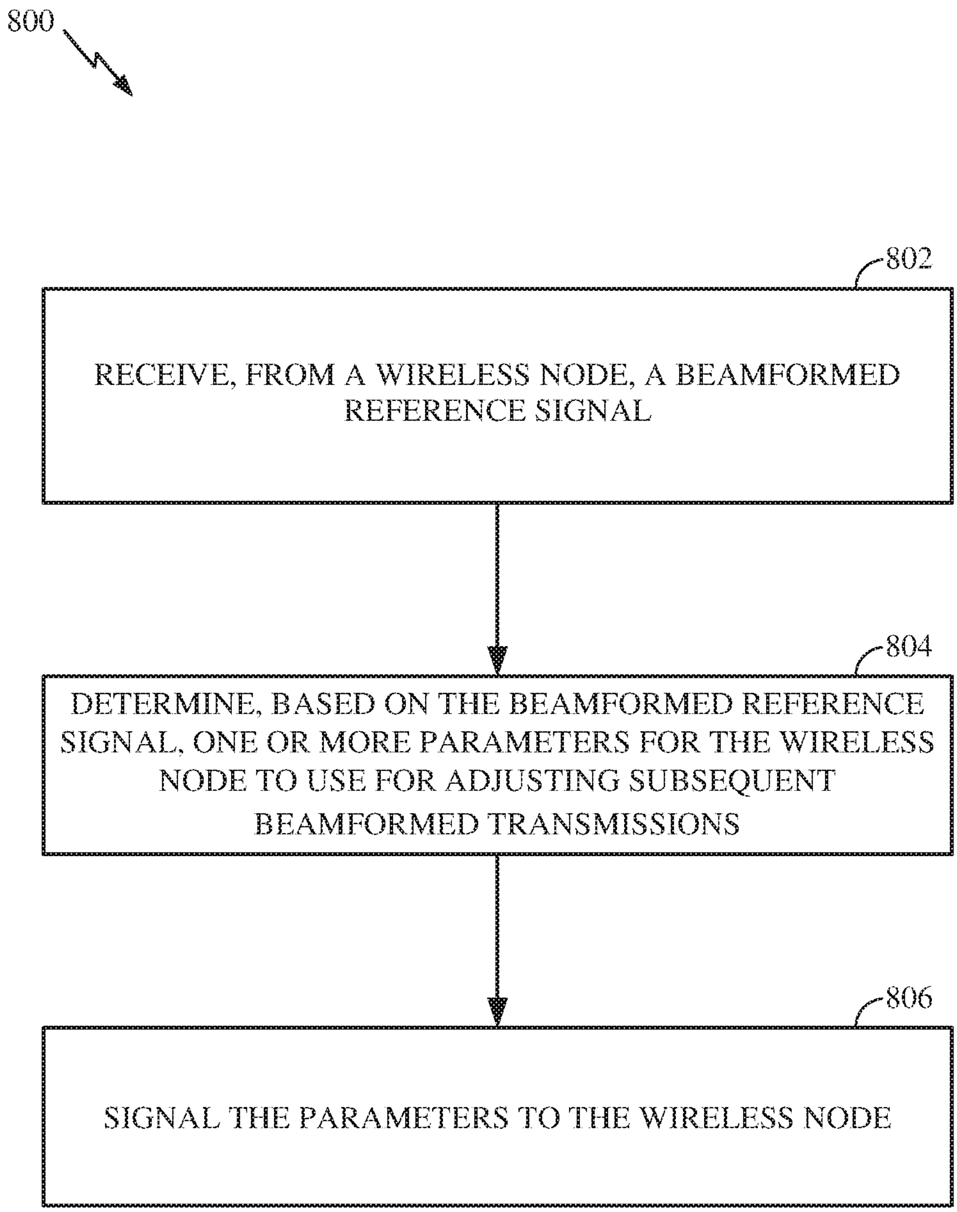
800
802
RECEIVE, FROM A WIRELESS NODE, A BEAMFORMED REFERENCE SIGNAL
804
DETERMINE, BASED ON THE BEAMFORMED REFERENCE SIGNAL, ONE OR MORE PARAMETERS FOR THE WIRELESS NODE TO USE FOR ADJUSTING SUBSEQUENT BEAMFORMED TRANSMISSIONS
806
SIGNAL THE PARAMETERS TO THE WIRELESS NODE

FIG. 8

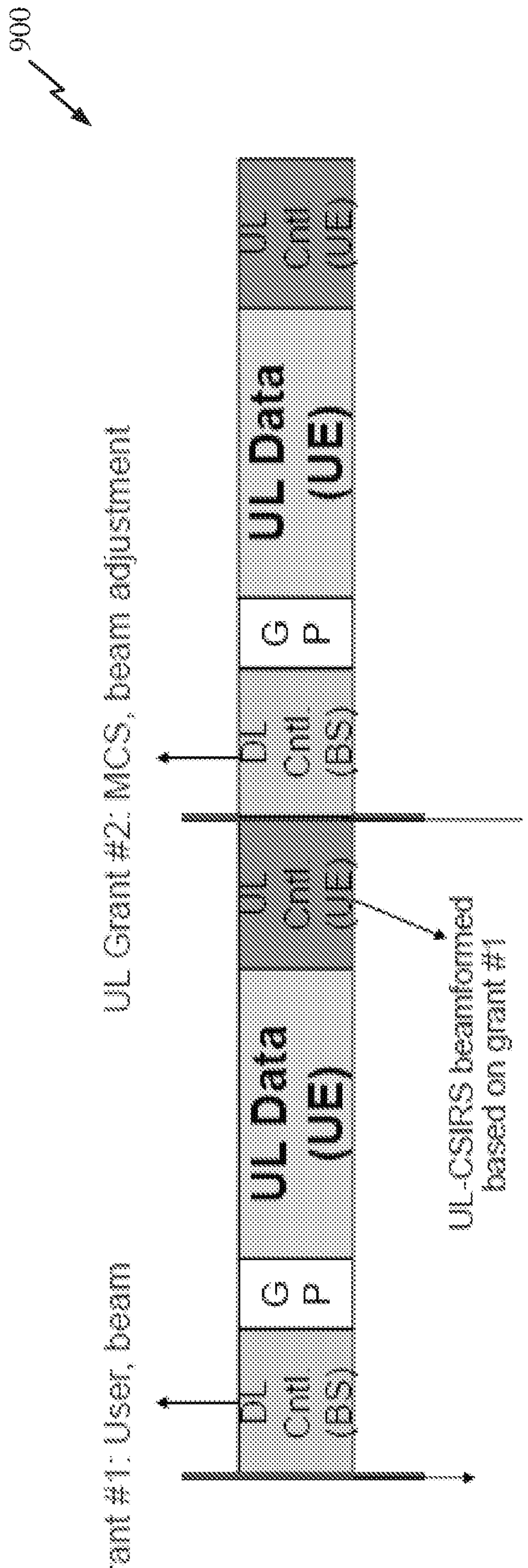
900
UL Grant #1: User, beam
DL Cntl (BS)
G P
UL Data (UE)
UL Cntl (UE)
UL-CSIRS beamformed based on grant #1
UL Grant #2: MCS, beam adjustment
DL Cntl (BS)
G P
UL Data (UE)
UL Cntl (UE)

FIG. 9

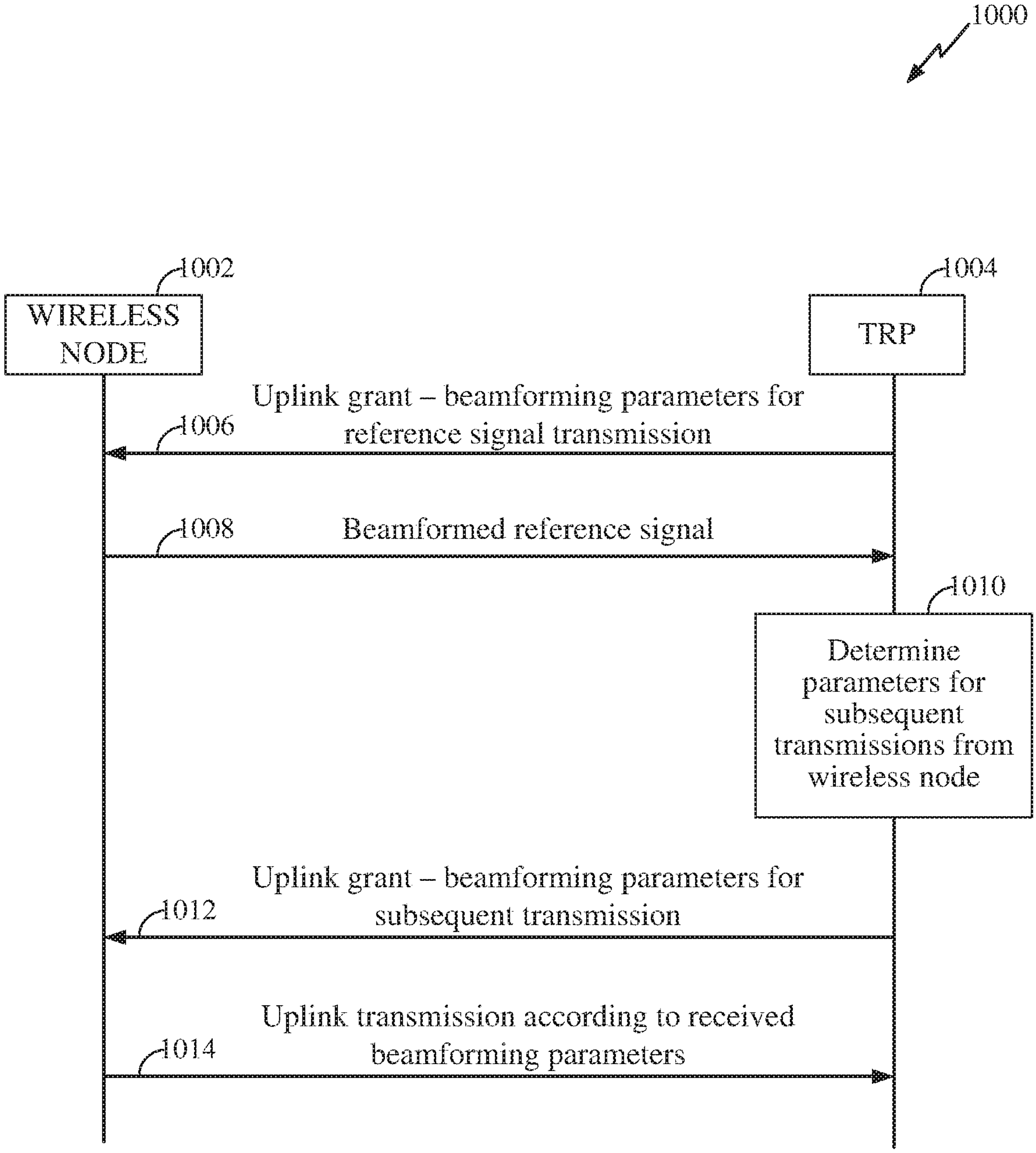
1000
1002
WIRELESS NODE
1004
TRP
Uplink grant – beamforming parameters for reference signal transmission
1006
1008
Beamformed reference signal
1010
Determine parameters for subsequent transmissions from wireless node
Uplink grant – beamforming parameters for subsequent transmission
1012
Uplink transmission according to received beamforming parameters
1014

FIG. 10

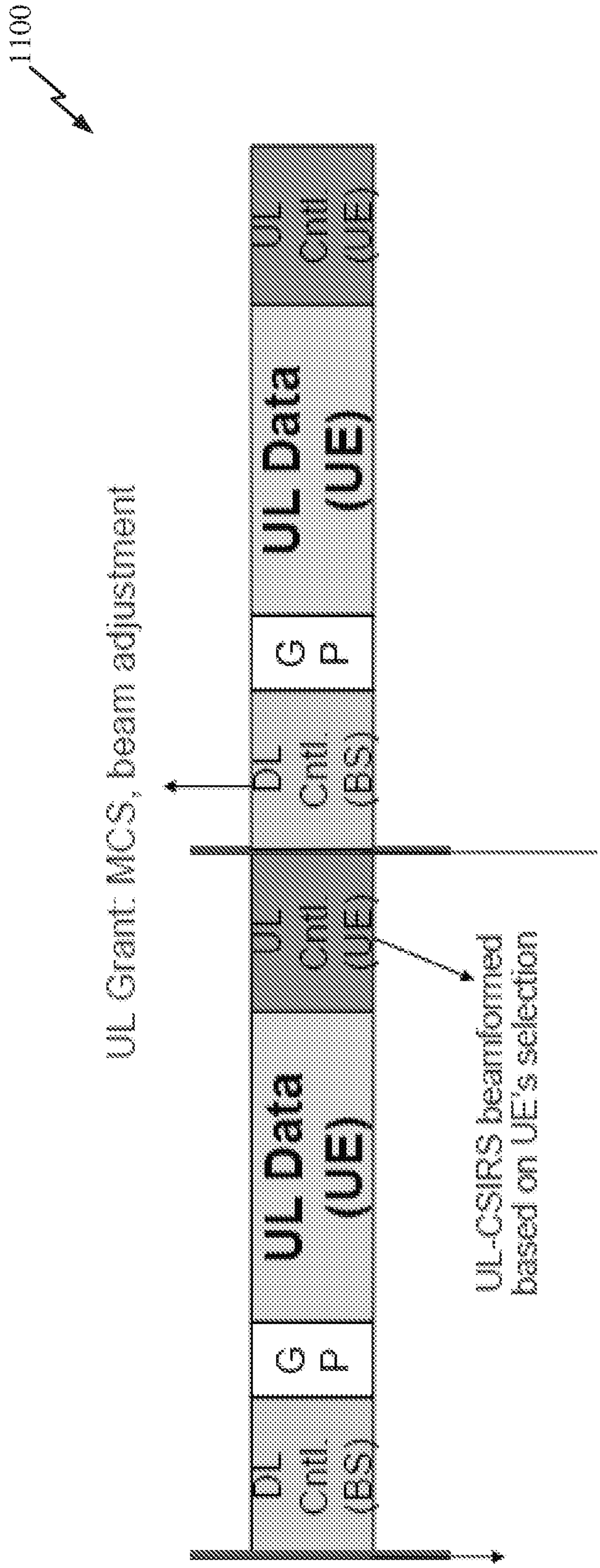
1100
UL Grant: MCS, beam adjustment
DL Cntl (BS)
G P
UL Data (UE)
UL Cntl (UE)
DL Cntl (BS)
G P
UL Data (UE)
UL Cntl (UE)
UL-CSIRS beamformed based on UE's selection

FIG. 11

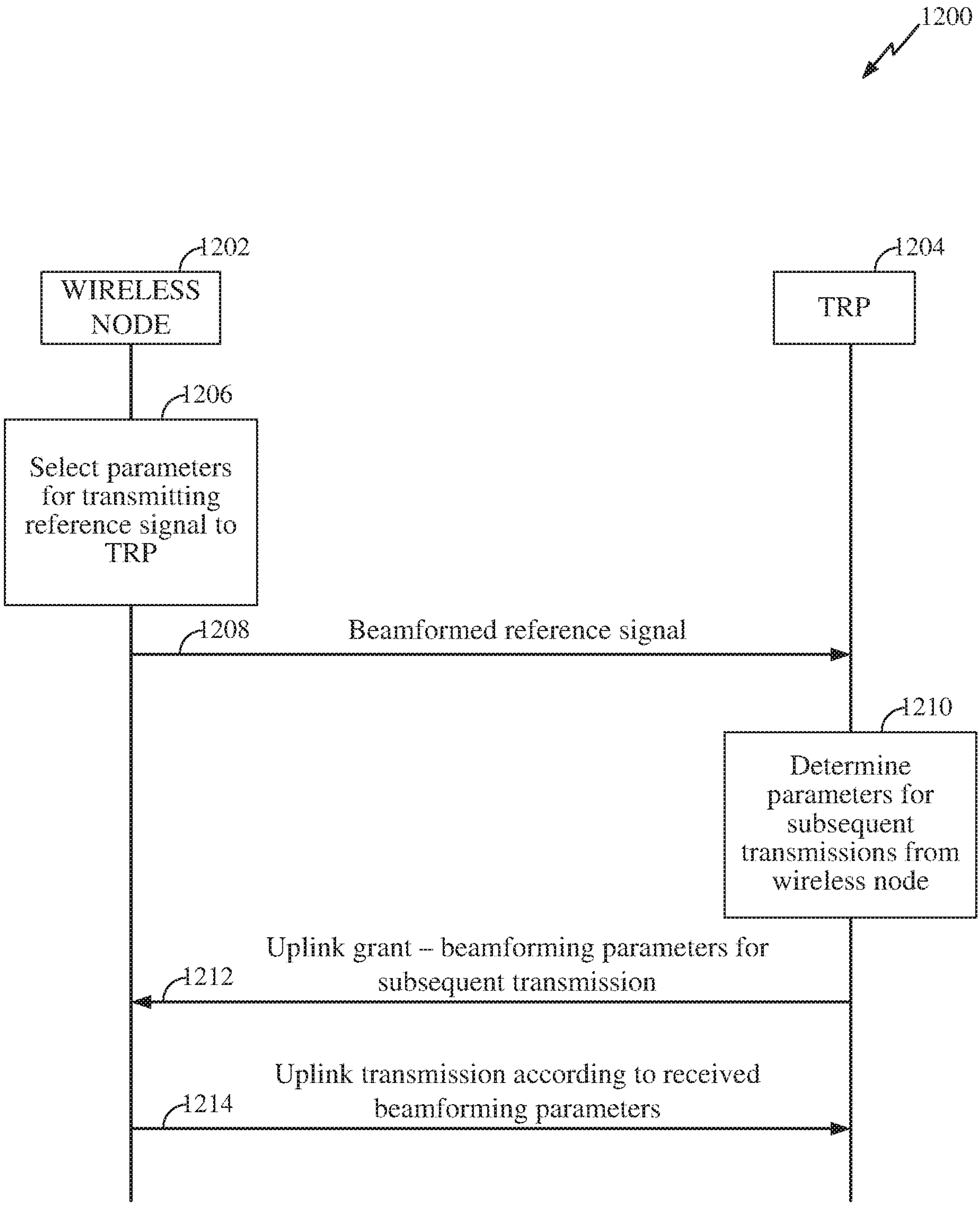
1200
1202
WIRELESS NODE
1204
TRP
1206
Select parameters for transmitting reference signal to TRP
1208
Beamformed reference signal
1210
Determine parameters for subsequent transmissions from wireless node
Uplink grant – beamforming parameters for subsequent transmission
1212
Uplink transmission according to received beamforming parameters
1214

FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2016/094956

A. CLASSIFICATION OF SUBJECT MATTER

H04B 7/06(2006.01)i；H04B 7/08(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; H04W

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

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

CNABS, CNTXT, CNKI, VEN: identify, determine, parameter, beamform, reference signal, response, feed back, adjust

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013258972 A1 (SAMSUNG ELECTRONICS CO.，LTD.) 03 October 2013 (2013-10-03) description，paragraphs [0105]-[0116]	1-23
X	CN 105007126 A (CHINA ACAD TELECOM TECHNOLOGY MII) 28 October 2015 (2015-10-28) description，paragraphs [0068]-[0106]	1-23
A	CN 101610104 A (DATANG MOBILE COMMUNICATION EQUIP CO.，LTD.) 23 December 2009 (2009-12-23) the whole document	1-23

☐ Further documents are listed in the continuation of Box C.　　☑ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 April 2017	**12 May 2017**

Name and mailing address of the ISA/CN	Authorized officer
STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China**	**ZHANG,Zhen**
Facsimile No. **(86-10)62019451**	Telephone No. **(86-10)62089133**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2016/094956

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☑ Claims Nos.: **24**
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

[1] The present written opinion is according to the rational expectation that the claims are numbered consecutively using Arabic numbers 1-24. Claim 24 sets forth a method, apparatus, system, computer program product, non-transitory computer-readable medium, user equipment, and wireless communication device as described with reference to and as illustrated by the accompanying drawings. The claim cites the accompanying drawings, therefore, the claim does not satisfy the criteria set out in PCT Rule 6.2(a). Moreover, the claim sets forth more than one subject and does not satisfy the criteria set out in PCT Articl 6. The above two reasons make the claim so unclear that no meaningful opinion could be formed.

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2016/094956

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
US 2013258972 A1	03 October 2013	US 9125070 B2	01 September 2015
		EP 2832010 A1	04 February 2015
		KR 20130110396 A	10 October 2013
		WO 2013147551 A1	03 October 2013
		EP 2832010 A4	16 December 2015
		US 2015372794 A1	24 December 2015
		US 9531517 B2	27 December 2016
CN 105007126 A	28 October 2015	KR 20160136431 A	29 November 2016
		TW 201541891 A	01 November 2015
		WO 2015161795 A1	29 October 2015
		EP 3136616 A1	01 March 2017
		US 2017033856 A1	02 February 2017
		IN 201627038896 A	09 December 2016
CN 101610104 A	23 December 2009	WO 2009152694 A1	23 December 2009
		CN 101610104 B	13 March 2013